Productivity Measurement and Analysis

Schweizerische Eidgenossenschaft
Confédération suisse
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Swiss Confederation

Federal Department of Home Affairs FDHA
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OECD

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Foreword

These Proceedings were jointly produced by the OECD Statistics Directorate and the Swiss Federal Office of Statistics (FSO). Julien Dupont (OECD) and Pierre Sollberger (FSO) are the main editors of this volume.

Special thanks are due to Ruth Meier (FSO), Philippe Stauffer (FSO) and Gregory Rais (FSO) who supported the project and mobilized the necessary resources in the FSO for the editing process. On the side of the OECD, Paul Schreyer, Eileen Capponi and Laurence Gerrer contributed to the successful completion of the volume.

And of course we thank the authors for their substantive contributions.

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Introduction

There are many different productivity measures for different purposes and policy makers and other users are not always aware of the conceptual and empirical reasons for differences between them. Productivity is a key indicator in the assessment of economic performance and a growing number of statistical offices in the OECD area have recently become engaged in the measurement of productivity. This work is raising many new questions for measurement, including the possible approaches to developing measures of aggregate productivity performance, as well as issues related to productivity measurement in specific sectors of the economy. Some of these measurement issues, especially those related to the measure of capital services, have been taking into account in the current process of revision of the System of National Accounts (SNA)[1].

Productivity measurement and analysis are the main topics addressed in this book, which is the result of the contributions presented and discussed in two international workshops[2] organized by the Statistics Directorate and the Directorate for Science, Technology and Industry of the OECD. The first workshop was organized jointly by the OECD and Fundaccion BBVA and Instituto Valenciano de Investigaciones Economicas (IVIE) and held in Madrid in October 2005. The second workshop was organized jointly by the OECD and the Swiss Federal Statistical Office and the State Secretary for Economic Affairs of Switzerland and held in Bern in October 2006. The two workshops brought together about seventy representatives of statistical offices, central banks and other branches of government in OECD countries that are engaged in the analysis and the measurement of productivity developments at aggregate and industry levels.

In the following pages, we overview twenty three studies that all provide a different perspective on productivity measurement and/or analysis around five topics. The present volume is organised as follows. It starts out with conclusions and future directions from the Bern workshop presented by **Erwin Diewert** (University of British Columbia, Canada). The first Part provides an overview of productivity growth and innovation illustrated by an analysis for Spain and Switzerland. The first measurement issue addressed in the book, notably in Parts two and three, concerns the measure of labour input. Despite significant progress and effort in this area, the measurement of hours actually worked still suffers from a number of statistical problems. In particular, different concepts and basic statistical sources used in different countries leave open many questions of international comparability, as described in Part two. Furthermore, labour input contributions to economic growth may

1 See OECD Measuring Capital (forthcoming).

2 More information on the workshops is available at the following address: http://www.oecd.org/statistics/productivity

be underestimated when labour input measures do not take into account changes in labour composition over time. Part three presents different labour input measures adjusted for changes in skills, educational attainment and labour market experience. The results underline the influence of changes in human capital on the contribution of labour input to economic growth. The fourth Part deals with different perspectives on capital input measurement and Part five presents a selection of country experiences in the measurement of industry-level multi-factor productivity.

Part 1: Productivity growth and innovation: the case of Spain and Switzerland

The part of economic growth that cannot be explained by increased utilisation of capital and labour is measured by multi-factor productivity (MFP)[3]. Among the sources of MFP growth, innovation is one of the most important. **Dominique Guellec** and **Dirk Pilat** (OECD) provide an international comparative perspective on productivity growth and innovation in OECD countries and show the influences of favourable conditions in the capacity to benefit from emerging technical fields such as information, communication and technology (ICT), biotechnology and nanotechnology. **Matilde Mas** and **Javier Quesada's** paper (University of Valencia and IVIE) provides detailed measures of the influence of ICT on MFP growth in Spain, at the aggregate and at the industry level. **Gregory Rais** and **Pierre Sollberger** (Swiss National Statistical Office - FSO) present the methodology adopted by the Swiss National Statistical Office - FSO for MFP measurement. **Jan-Egbert Sturm** (Swiss Institute for Business Cycle Research) examines to what extent different types of firm level innovations affect labour productivity of firms in Switzerland.

Part 2: The measurement of labour input

In Part two, a detailed comparative study between the USA and Canada on hours worked is presented by **Jean-Pierre Maynard** (Statistics Canada) and can serve as an excellent guide to the many statistical considerations that enter international comparisons of this kind. **Henrik Sejerbo Sørensen** and **Kamilla Heurlén** (Statistics Denmark) use Danish data to assess the influence of the choice of different statistical sources for working hours on labour productivity measures and on their international comparability. **Lucy Eldridge** and **Sabrina Pabilonia**'s paper (U.S. Bureau of Labour Statistics) addresses the question whether, due to ICT, persons actually work more outside their work place so that hours worked are underestimated. The result of their survey shows that, for the period under consideration, the impact was modest.

Part 3: The measurement of the composition of labour input

A number of countries have started to develop labour input measures adjusted for labour quality and in some cases (e.g. Italy, Spain, the European Central Bank…) there are important

3 The terms Multifactor productivity (MFP) and Total factor productivity (TFP) are used interchangeably in the present text.

differences between unadjusted and adjusted time profiles of labour input. Papers presented in this Part raise the issue of international comparability of such adjustments. **Wim Haine** and **Andrew Karutin** (European Central Bank), as well as **Lucy Eldridge, Marilyn Manser** and **Phyllis Otto** (U.S. Bureau of Labour Statistics) remark that un-weighted hours worked is an incomplete measure of labour input because it does not account for differences in educational attainment, skills and experience between workers. **Antonella Baldassarini** and **Nadia Di Veroli** (ISTAT) present both a detailed description of the method for estimating hours actually worked and evidence of changes in labour quality. **Guido Schwerdt** (Ifo Institute) and **Jarkko Turunen** (European Central Bank) observe that the increase of labour quality in the 1990's was driven by an increase in the share of workers with tertiary education and workers in prime age. As a result, a longer part of output growth is explained by labour input, reducing the contribution of total factor productivity to euro area growth.

Part 4: The measurement of capital input

This Part examines a range of important methodological questions in the measure of capital input, including the comparison of levels of capital productivity, the scope of assets, and different assumptions in the estimate of user costs and depreciation.

Paul Schreyer (OECD) aims to compare levels of capital input, levels of capital productivity and capital intensity. Not all assets are recognised in capital measurement, and full coverage is unlikely to occur in the near future. However, including assets as stocks of research and development (R&D) raise some methodological and practical issues. **Emma Edworthy**'s paper (Office for National Statistics) presents a first empirical estimate for the R&D capital stock which sheds light on the main practical issues associated with implementation (composition of R&D expenditures, construction of appropriate deflators, estimation of depreciation rates); and then proposes a first estimate of the impact of R&D in productivity growth. **Dean Parham**'s paper (Australian Productivity Commission) questions whether the planned national accounts treatment of R&D as 'just another type of asset' has any implications about how R&D assets would be treated in productivity measurement. This provides an interesting link with paper by **Matilde Mas** (University of Valencia and IVIE) on infrastructure capital given that there are a number of common characteristics between physical infrastructure capital and 'knowledge infrastructure'. In addition, Mas contribution comes with a clear definition of infrastructure assets and shows how their growth contribution can be measured.

Service lives of assets that feed into measures of capital services tend to vary significantly across countries, and it is not always clear whether such differences reflect economic reality or differences in statisticians' assumptions. **Massimiliano Iommi** and **Cecilia Jona-Lasinio's** (ISTAT) contribution presents the methodology adopted by ISTAT to calculate capital services focusing on an assessment of the impact of the different assumptions on depreciation rates and rates of return in the estimate of the user cost of capital and on age-efficiency profiles in the calculation of productive capital stock.

Part 5: The Measurement of industry level multi-factor productivity

A growing number of OECD member countries are involved in MFP measurement and Part five presents experimental results on industry-level MFP measures which show that they are feasible but fraught with measurement issues. Recurring issues are the output measurement in service industries, the availability of capital data by type of asset and by industry and the choice of the rate of return for capital services by industry. **Dirk van den Bergen, Myriam van Rooijen-Horsten, Mark de Haan** and **Bert Balk**'s paper (Statistics Netherlands) presents the experience of Statistics Netherlands in industry-level MFP measures. **Eric Bartelsmann, Carol Corrado and Paul Lengermann** (Free University of Amsterdam and U.S. Federal Reserve Board) address the question whether information on recent industry productivity developments can be used to compute estimates of the trend in aggregate multi-factor productivity growth. **Paul Roberts**'paper (Australian Bureau of Statistics) discusses the present work on the measurement of multifactor productivity at the industry level in Australia and provides a detailed summary of measurement issues related to this topic. **Harold Creusen, Björn Vroomen, Henry van der Wiel** and **Fred Kuypers** (CPB Netherlands Bureau for Economic Policy Analysis) analyse the productivity performance of the Dutch retail trade for the period 1993–2002 and focus on competition and innovation as important drivers of productivity growth. The study of Swedish economic growth by **Hans-Olof Hagen** and **Thomas Skyttesvall** (Statistics Sweden) describes the implementation of capital services and MFP measures following a KLEMS decomposition of the business sector. **Hak K., Pyo, Keun Hee, Rhee** and **Bongchan Ha** 's paper (Seoul National University, Korea Productivity Center, Pukyong National University) aims to identify the source of economic growth by industry in Korea, where the catch-up process with industrial nations in its late industrialisation has been predominantly driven by the manufacturing sector and by increasing inputs without an increase in efficiency with which this inputs are used.

During the workshops, panel discussions raised a number of suggestions regarding work that could be undertaken by the OECD in relation to productivity measurement. Suggestions included the following:

– *Build a general framework or guidelines for best practices on labour input measures:* a set of guidelines or recommendations on how to implement labour input measures would be very valuable for the national accounts and for productivity measurement. While conceptual work on labour is being carried out by the Paris Group[4], this is not necessarily done for purposes of productivity measurement (i.e. with a concept of labour input in mind) nor with a view to ensuring consistency with output measures. At a practical level, OECD started looking at national practices for estimating hours worked by industry for National Accounts and determining practices and target definitions.

– *Measures of labour composition:* hours worked constitutes an incomplete measure as input for productivity and several countries already started to develop adjusted labour input

4 The Paris Group is an informal exchange group of labour statisticians belonging to national statistical agencies and international organizations (OECD, ILO, Eurostat) created under the auspices of the United Nations at the beginning of 1997 to address selected problems in statistical methods in the area of "labour and compensation" statistics.

measures. OECD should develop measures of labour composition to harmonize adjustments across countries and to improve international comparability of hours worked.

– *Build a general framework or guidelines for best practices on capital input measures:* OECD should provide guidance on standard use of user costs in the computation of capital services. Greater harmonisation of approaches and international comparisons of the assumptions underlying measures of depreciation and capital are important and OECD should also derive standard measures of depreciation and net capital stock.

– *Innovation and productivity:* the planned capitalization of Research and Development (R&D) in the national accounts raises a number of practical issues about their measurement, in particular their deflation and their depreciation. International guidance will be needed to maximise comparability across countries. It was also noted that investment in innovation was in all probability much larger than investment in R&D and that capitalising and measuring all such expenditure is a long-term challenge for analysts.

– *Microdata:* several papers in the book employ microdata for analysis and it is generally felt that this constitutes an important avenue for work. Productivity measures and analyses based on microdata may need more attention. Microdata analysis complements industry-level and macro-economic productivity analysis in a very useful way and the OECD is encouraged to continue its efforts to pull together national work on microdata and to enhance international comparability of such analyses.

– *The measure of industry-level productivity:* a growing number of statistical offices are involved in the compilation of estimates of multi-factor productivity (MFP) by industry replying to the increased demand for analyses of market structure. This work also raises methodological questions and the OECD is encouraged to provide internationally comparable MFP estimates which also should be consistent with MFP data for the whole economy.

– *Definition of business sector:* several notions of 'business sector' exist that are not necessarily compatible with each other. A better common understanding about the definition and calculation of business sector productivity would be helpful. OECD should draft a Working Paper discussing an activity based definition of the business sector, analysing it in the context of productivity measurement and make recommendations.

– *Infrastructure capital:* this area is attracting a good deal of policy attention but remains ill-defined and ill-measured. A common understanding of what constitutes infrastructure assets and how they can be brought out in existing capital measures would be helpful as would some international data on their size and evolution.

– *Comparisons of productivity levels across countries:* this remains a highly policy-relevant indicator. Extension of labour productivity comparisons to MFP comparisons is desirable. At the same time, many statistical problems remain and productivity level comparisons are often of unknown quality. It is therefore important to accompany level comparisons with some indications of statistical confidence so as to avoid an impression of precision that is not warranted by the underlying data. The OECD is encouraged to continue its work in this direction, including the development and improvement of Purchasing Power Parities (PPP) for international productivity comparisons.

– *Communication:* communication at the national and international level is therefore important so as to be clear what measures mean and why national and international measures may differ.

– *Productivity of non-market producers:* many countries attach high priority to better measurement of the productivity, outputs and inputs of non-market producers. This responds directly to analytical and policy requirements as well as to a forthcoming EU Regulation. The OECD Statistics Committee has also endorsed work in this area and the OECD National Accounts and Financial Statistics Division and the OECD Structural Economic Statistics Division are advancing the subject matter, in particular with regard to health and education output.

– *Environment and productivity:* conventional productivity measures are sometimes criticised for not taking negative effects on the environment into account, thereby overstating productivity and economic growth. Conceptual and empirical work to link productivity measures with the use of natural resources and emissions would be welcome.

– *Firm dynamics and productivity growth:* there is growing empirical evidence suggesting that firm demography impacts on growth in aggregate productivity, even if this impact may vary across countries. Size of firm, entry and exit of firms and survival appear to be important dimensions in productivity analysis as firm turnover accounts increasingly in the process of reallocation of resources. The OECD should be involved in the assessment of the influence of firm dynamics and business environment conditions on productivity growth.

1. OECD WORKSHOPS ON PRODUCTIVITY ANALYSIS AND MEASUREMENT
Conclusions and Future Directions

By Erwin Diewert,[5],
The University of British Columbia.

Introduction

In the section below, we discuss the role of economic theory in providing solutions to some of the difficult problems that arise in the measurement of productivity.[6]

In the third section, we list some 12 measurement problems where further research is required in order to form a consensus on how to "best" solve these problems.

The last section concludes with 5 recommendations for the OECD on the way forward.

Is there a Role for Economic Theory in the Measurement of Productivity?

When Bert Balk presented an overview of Statistics Netherlands' progress in measuring productivity for the Dutch economy,[7] he was somewhat negative on the standard economic approach or growth accounting approach to productivity measurement and he suggested a preference for the statistical or axiomatic approach to productivity measurement:

"For the calculation of aggregate quantity or volume change of inputs and outputs, an index formula must be selected. In the standard growth accounting approach the index formula corresponds to a certain specification of the production function and TFP change represents technological change. However, such an approach depends on strong (neo-classical) assumptions, for instance that production processes are subject to constant returns to scale and that there is perfect competition. We don't wish to make such strong assumptions, and

5 This note is an extended written version of my Panel Discussion at the final session of the OECD Workshop on Productivity Analysis and Measurement organized jointly with the Swiss Federal Statistical Office and the State Secretary for Economic Affairs of Switzerland held in Bern, October 16–18, 2006. The financial assistance of the OECD and the SSHRC of Canada is gratefully acknowledged. My thanks to Bert Balk, Ulrich Kohli, Dean Parham and Paul Schreyer for helpful comments. None of the above individuals or organizations are responsible for any opinions expressed in this note.

6 By the term "productivity", I mean "Total Factor Productivity" or "Multifactor Productivity" and not "Labour Productivity". TFP growth is an index of the growth of outputs divided by an index of the growth in all primary inputs whereas Labour Productivity growth is an index of value added growth divided by the growth in labour hours. The problem with the Labour Productivity concept is that it neglects the contributions of nonlabour inputs and hence can give a very misleading picture of a country's actual productivity performance.

7 See van den Bergen, van Rooijen-Horsten, de Haan and Balk (2006).

prefer to select an index formula on the basis of its properties." Dirk van den Bergen, Myriam van Rooijen-Horsten, Mark de Haan and Bert M. Balk (2006; 3).

Balk is quite correct to criticize the standard growth accounting methodology, since as he pointed out several years ago[8], this methodology attributes all productivity growth to (disembodied) technical change and neglects the roles of improvements in technical and allocative efficiency, nonconstant returns to scale and R&D investments that lead to monopolistic behavior on the part of producers. However, I think it would be incorrect to jump to the conclusion that the economic approach to productivity measurement is irrelevant and useless.[9] It seems to me that the economic approach to productivity measurement should be the primary approach and that rather than totally discarding it in the face of the above criticisms, it would be preferable to try and remedy some of the shortcomings of the standard growth accounting methodology. However, this is easier said than done. For example, many authors have attempted to relax the assumption of constant returns to scale in a growth accounting framework but these approaches rely on econometric estimation in order to determine the degree of returns to scale and hence tend to be rather fragile and nonreproducible.[10]

It may appear at first glance that economics is not really required when setting up an axiomatic framework for productivity measurement. In the axiomatic approach, all we need to do is decide on the value aggregates for output and input, pick our favorite functional form for the index number formula and calculate the ratio of the output index to the input index. Thus it seems that there is no real need for economic theory in implementing this approach. However, when we bring capital services into the picture as an input, then it is no longer clear what the corresponding value aggregate should be. For example, present System of National Accounts conventions suggest that general government capital services should be measured by only the depreciation applicable to the government capital in service during the reference period. However, if a government department decides to sell its office buildings and then rent or lease building services from the private sector, then the rents that the government will pay for office services will surely include a return to capital component and hence GDP will go up with this change in ownership. Thus economic theory suggests that the imputed rental for government owned buildings that have an alternative use in the private sector should have an interest rate component in the imputed rental price in addition to the depreciation component.[11] The point is that we will have to rely on economic theory to at least some extent to determine what the appropriate value aggregate is for capital services.[12]

8 See Balk (1998) (2003).

9 It should be noted that Balk did not jump to this conclusion in his presentation!

10 For example, see Diewert and Fox (2004), Diewert and Lawrence (2005a) (2005b) and Fox (2006). Nonreproducibility here is interpreted in a broad sense; i.e., different econometricians, using the same data set, will generally make different aggregation and functional form assumptions and different stochastic specifications, leading to different estimates for the key parameters in the model.

11 Mas (2006) also discusses these issues.

12 In fact, van den Bergen, van Rooijen-Horsten, de Haan and Balk (2006) rely on a considerable amount of economic theory in order to derive their user costs for capital. This theory was developed in Balk and van den Bergen (2006), which in turn drew on Diewert (2005a) and others.

In the following section, we turn to a list of some of the economic measurement problems that were discussed at this conference (or that perhaps that should have been discussed). Economic theory will generally be useful in providing some guidance on how to resolve these measurement problems.[13]

Theoretical Issues in the Measurement of Productivity

We will list some 12 important measurement issues that arise in measuring the productivity growth of a production unit (i.e., of a firm, industry or entire economy) in sections 3.1–3.12 below.

How to Treat R&D Expenditures in a Growth Accounting Framework?

The Canberra Group on Capital Measurement has recommended that the next international version of the SNA should capitalize R&D expenditures.[14] The capitalization of R&D expenditures provides some new challenges for the standard growth accounting methodology as will be explained below. There were two excellent papers on R&D and productivity measurement presented at this workshop: the papers by Parham (2006) and by Edworthy and Wallis (2006). The second paper follows what has become the "standard" methodology for the treatment of R&D investments: namely assume a plausible depreciation rate for these investments and use the Perpetual Inventory method for forming capital stocks to form stock estimates for R&D capital. These stocks would be depreciated over time using the assumed depreciation rates and user costs for inventory stocks could also be formed using the same methods as are used for conventional reproducible capital stock components.[15] However, Pitzer (2004), Diewert (2005b) and Parham (2006)[16] suggested that the treatment of R&D assets is not quite so straightforward as the standard methodology suggests since these R&D assets do not behave in the same manner as ordinary reproducible capital inputs where an increase in the number of "machine" or structures" inputs will generally lead to a positive increment in production. R&D investments create new technologies and once the new technology has been created, the investment has the nature of a fixed cost rather than a contribution factor to normal production of goods and services. Diewert explained these differences between R&D assets and reproducible capital assets as follows:

"R&D is not like other depreciable assets which gradually wear out through use; rather R&D can be viewed as the creation of new technologies. These new technologies may just reduce the cost of producing an existing commodity or they may create entirely new goods

13 Jack Triplett has made this point repeatedly over the years.

14 Another important recommendation of the Canberra Group is that Gross Operating Surplus be decomposed into price and quantity (or volume) components where the price would be a user cost of capital, along the lines pioneered by Jorgenson and Griliches (1967) (1972). This user cost should approximate a market rental price for the same asset.

15 Perhaps the most complete and up to date version of "standard" growth accounting methodology for capitalizing R&D can be found in Corrado, Hulten and Sichel (2005).

16 In addition to questioning whether the "standard" model for R&D accounts is really appropriate, Parham provides a very nice summary of the very extensive econometric work by Shanks and Zheng (2006) on estimating the effects of R&D on Australia's productivity growth.

and services (process versus product innovation). In either case, the R&D "asset" is not like a "normal" reproducible capital asset that depreciates with use. The expenditures incurred in creating the R&D asset are sunk costs and they have no resale value as is the case with a purchase of a reproducible asset. However, a successful private sector R&D venture has created a new product or process that will give rise to a stream of profits in future periods. In many cases, the new technology can be licensed and the rights to use the new technology can be sold. Thus in the case of successful private R&D ventures, a new asset has been created: the rights to a (monopoly) stream of future incremental revenues. However, once a new successful technology has been created, expiry of patents, diffusion of knowledge about the innovation, even newer innovations by competitors and changing tastes all combine to reduce the stream of monopoly profits over time. Note that the effects of these factors, which reduce the value of the R&D asset over time, are difficult to forecast.[17]"

"To summarize the above discussion: a private sector R&D asset is much more complicated than a typical reproducible capital asset (like a structure or machine). There are actually two "assets" associated with an R&D venture:

- The first *cost asset* is the cumulated costs of the R&D project and
- The second *revenue asset* is the discounted value of the incremental profits that the R&D project is expected to generate.

For any individual R&D project, it is unlikely that the R&D cost "asset" is equal to the R&D incremental revenue asset but, over a large population of R&D projects, we could expect to see the value of the cost assets to be approximately equal to the value of the revenue assets.[18]"

"As defined above, the cost and revenue assets are defined in terms of nominal dollars. It is relatively straightforward to obtain a constant dollar counterpart to the nominal cost asset, provided that deflators are available for the important components of nominal expenditures on R&D projects, such as scientific and engineering personnel, structures, materials and instruments. However, it is not straightforward to obtain constant dollar estimates for the revenue asset. Since the discounted incremental revenues that the project is expected to yield are in units of today's dollar, the simplest approach to obtaining a constant dollar estimate for the revenue asset would be to deflate the current expected discounted profits estimate by a current general index of inflation.[19]"

"As was mentioned above, the cost asset is not really an asset: it is a sunk cost. In the present system of national accounts, SNA 1993, privately funded R&D expenditures are

17 Many of these points (and more) were made in Bernstein (2002).

18 Adjusting for the risk inherent in R&D projects, we would expect that the value of the cost assets be less than the value of the revenue assets. Thus it is completely reasonable that R&D assets earn higher rates of return on average than reproducible capital assets.

19 A producer price index over the gross outputs produced by the economy could be used but I would recommend the use of a consumer price index as the general deflator. The GDP deflator should not be used since imports enter this index with negative weights and so a large increase in the price of imports relative to other prices can lead to a counterintuitive fall in the GDP deflator; see Kohli (1982; 211) (1983; 142) and Diewert (2002; 556) on this point.

regarded as intermediate business expenses and are written off as they occur. This point of view is defensible, particularly for unsuccessful R&D ventures. However, for successful R&D ventures, it could be argued that it is "unfair" to write down current period income by these expenditures since these expenditures will eventually be recovered in future periods as the project's incremental revenues pour in to the firm. Hence, from this point of view, it makes sense to capitalize these R&D expenditures into an "asset" and depreciate this "asset" in a proportional manner to the future period incremental revenues. From this point of view, the problem is to determine how to *allocate* the cumulated cost of an R&D project over future periods. This accounting problem has a different character than the usual problems involved in depreciating reproducible capital stock investments, where information on used assets can be used if an opportunity cost approach to depreciation is used. For an R&D cost "asset", the problem is one of *matching* current costs with future expected revenues,[20] which is a rather daunting task!" Erwin Diewert (2005b; 6–8).

In addition to the problems outlined above, there are some additional challenges to the conventional growth accounting paradigm:

- Publicly funded R&D that generates new technologies or products that are made freely available to the public may not generate any identifiable revenue streams; rather they may simply lead to valuable new products that are manufactured and sold at cost. Thus the benefits of some R&D expenditures may simply show up as increases in utility (which are extremely difficult to measure) rather than as a stream of monopoly profits.
- The standard growth accounting model, adapted to the R&D context, does not explicitly recognize any monopoly profits.
- The problem of spillovers also needs to be addressed.

The point of the above rather lengthy discussion is this: the standard Solow, Jorgenson and Griliches growth accounting methodology assumes that technical progress is exogenous and any R&D expenditures are treated as current expenditures. This standard model does not really capture the intertemporal aspects of R&D expenditures but just treating R&D expenditures as another type of reproducible capital does not capture the fact that these expenditures partially endogenize technical progress. Thus at present, we do not really have a satisfactory growth accounting methodology that can deal with the complications that arise when we capitalize R&D expenditures.[21]

To sum up: there is a great deal of theoretical work that remains to be done in adapting the standard growth accounting methodology to deal with the complexities that are inherent in the treatment of R&D investments.

20 Paton and Littleton (1940; 123) argued that the primary purpose of accounting is to match costs and revenues but other points of view are possible. For an excellent early discussion on the importance of matching costs to future revenues, see Church (1917; 193). For a more recent discussion on the problems involved in matching R&D costs to future expected incremental revenues, see Diewert (2005a; 533–537).

21 Parham (2006; 18–19) also makes this point.

Should the Output Aggregate be Gross Output, Value Added or Net Product?

One topic that came up in several papers presented at the conference was the question of what is the theoretically best measure of productivity; i.e., should we use a *gross output formulation* where gross output growth is in the numerator of the productivity measure and an aggregate of intermediate input plus labour input plus capital services input is in the denominator of the productivity measure or should we use a *value added formulation* where the output in the numerator is an aggregate of gross output less intermediate inputs used and the denominator is an aggregate of labour and capital services? Diewert and Lawrence (2006) favored a third productivity concept for their particular purpose; namely a *net product formulation* where the output in the numerator is an aggregate of gross output less intermediate inputs used less depreciation[22] and the denominator is an aggregate of labour and waiting services, so that depreciation was taken out of the primary input category and treated as an intermediate input in this last formulation.[23]

There is a general feeling that economic theory favors the gross output definition of productivity growth because nobody has seen a value added production function in the real world whereas it is natural to regard output as being produced by a traditional production function that has capital, labour, energy, materials and services as inputs.[24] However, if we use the approach to productivity measurement suggested by Diewert and Morrison (1986) and Kohli (1990)[25], it turns out that the assumptions required to justify the translog gross output, the translog (gross) value added and the translog net value added approaches to productivity measurement are all *equally* restrictive[26] and in particular, *no separability assumptions are*

22 This leaves open the question of what to do with the (anticipated) revaluation term; i.e., should it be subtracted from gross investment as well as depreciation? Diewert and Lawrence avoided making a decision on this point because they assumed that the anticipated rate of asset inflation was equal to the CPI inflation rate and hence all they used balancing real interest rates in place of balancing nominal rates less the anticipated revaluation terms. My current advice on this difficult topic is that the Diewert and Lawrence treatment is reasonably satisfactory except for a few assets where "everybody" anticipates either a real devaluation (e.g., any class of assets that uses computer chips intensively) or a real appreciation (e.g., land in economies with growing populations). In these latter cases, I would treat the negative real revaluation terms as depreciation and hence the absolute value of these terms would be treated as an addition to traditional wear and tear depreciation. In the case of a positive real revaluation term, I would add these terms to gross investment, since we are taking an asset from the beginning of the period when it is less valuable to the end of the period when it will be more highly valued. These issues are discussed at more length in Diewert and Wykoff (2006) and Diewert (2006a).

23 These three alternative approaches to measuring productivity were discussed in Schreyer (2001). See also Balk (2003b) on these issues.

24 Strictly speaking, in the context of technologies that produce multiple outputs, we would require a separability restriction which would allow us to aggregate all of the outputs into an output aggregate in order to justify the traditional production function approach.

25 This approach is explained in the paper by Diewert and Lawrence (2006) which was presented at this conference.

26 There is one caveat to this statement that must be mentioned: when we calculate the value added aggregate (net or gross) for the production unit under consideration for the two periods being compared, the two value added aggregates must have the same sign in order to obtain meaningful results using the translog approach,

required for any of these three approaches. All three approaches rely on duality theory, which states that under price taking behavior and constant returns to scale convex technology, the primal technology sets S^t can be equally well described by dual (net) revenue functions $g^t(p,x)$, where p is a gross or net output price vector and x is an input quantity vector.[27] However, the (positive) fact that all three of these translog approaches to productivity measurement do not make any separability assumptions is balanced by a bit of a negative factor and that is the fact that only the geometric mean of two very particular productivity indexes can be identified empirically using this approach.[28] I do not find this limitation to be particularly troublesome but others may disagree.

Given that all three approaches to productivity measurement do not differ in the restrictiveness of their assumptions, which approach should be used in practice? This question is discussed at some length in Schreyer (2001) but I would like to make the following observations:

If we are studying the productivity performance of a particular firm or industry, then perhaps the gross output formulation is most suitable since it will be easier to explain to users.[29]

If we are attempting to analyze the productivity performance of an entire economy or an aggregate of industries, then the gross or net value added approaches seem preferable since economy wide growth in TFP will be approximately equal to a share weighted average of the industry growth rates in value added TFP. Thus the contribution of each industry's TFP growth to over all TFP growth is a bit easier to explain to users if we use the gross or net value added approaches.[30]

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since index number theory breaks down when the value aggregate passes through zero. If we use the gross output approach to productivity measurement, this caveat does not apply because both the input and output value aggregates will definitely be positive for the two periods being compared.

27 See Gorman (1968), McFadden (1978), Diewert (1973) (1974; 133–141) and Balk (1998) for various versions of these duality theory results.

28 Referring to Diewert and Lawrence (2006; 6), the two particular productivity indexes, $\tau_L{}^t$ and $\tau_P{}^t$ that are singled out are the Laspeyres type measure that uses the (gross or net) output prices of period t–1, p^{t-1}, and the input vector of period t–1, x^{t-1}, as reference vectors, $\tau_L{}^t \equiv g^t(p^{t-1},x^{t-1})/g^{t-1}(p^{t-1},x^{t-1})$, and the Paasche type measure that uses the (gross or net) output prices of period t, p^t, and the input vector of period t, x^t, as reference vectors, $\tau_P{}^t \equiv g^t(p^t,x^t)/g^{t-1}(p^t,x^t)$. The Diewert-Morrison-Kohli translog approach to productivity measurement can only empirically estimate (using index numbers) the geometric mean $\tau^t \equiv [\tau_L{}^t\tau_P{}^t]^{1/2}$ of these two theoretical productivity indexes. The definition of productivity change used by these authors, which relies on the (net) revenue function, originally appeared in Diewert (1983; 1063–1064) but he did not develop it in any great detail. The other main theoretical approach to productivity measurement relies on the Malmquist productivity index, which was introduced by Caves, Christensen and Diewert (1982). However, this approach does require that the output aggregate be gross output (rather than value added).

29 However, the other two approaches are equally valid from the viewpoint of theoretical restrictiveness.

30 The value added framework for productivity measurement has some additional advantages. For example, productivity growth will be invariant to the degree of domestic outsourcing of business services and will be invariant to the absolute size of the foreign trade sector. For example, the gross output productivity growth of the Netherlands compared to the U.S. will look very poor compared to its value added productivity growth simply because exports and imports in the Netherlands are a very high fraction of GDP compared to the situation in the U.S. Calculating value added productivity growth rates for both countries will make the growth rates comparable across countries.

What about the choice between the usual *(gross) value added approach* to TFP where we use gross domestic product as the output aggregate versus the *net value added approach* to TFP where we treat depreciation as an intermediate input and hence the output aggregate is gross output less traditional intermediate inputs less depreciation? Diewert and Lawrence (2006) clearly preferred the net value added approach because their purpose was to explain the contribution of TFP improvements to the growth in living standards; i.e., they followed Rymes (1968) (1983) in treating depreciation as an offset to gross investment so that depreciation charges no longer appeared as "income" to households. Thus the depreciation term was moved from the primary input category (where it appears as part of user cost in the traditional approach) and placed in the intermediate input category in the empirical work of Diewert and Lawrence. The remaining part of user cost was treated as a primary input and was labeled the "reward for waiting" following Rymes (1968) (1983).[31] Households cannot consume depreciation and so if we want to explain increases in household real income, this net value added approach to TFP measurement seems to be clearly preferable.

It seems to me that the main theoretical issues in this area of gross versus net have been more or less settled but as can be seen from the discussion above, there are many points that are quite subtle and other observers could well argue that more work remains to be done in this area.

Adjusting Productivity Measures for Changes in the Terms of Trade

There is an extensive national income accounting literature on how to measure the effects of changes in the terms of trade (the price of exports over the price of imports) on national welfare.[32] Much of the early literature took a household point of view but Diewert and Morrison (1986), following the example of Kohli (1978) (1991)[33], who observed that most international trade flows through the production sector of the economy, took a producer point of view to modeling the effects of changes in the terms of trade:

"Our alternative approach to the measurement of the impact of terms of trade changes is to consider the problem from the point of view of the producer. In this alternative approach, our objective function becomes real output rather than welfare. We assume that exports and imports flow through the production sector and we show that an increase in the price of exports relative to imports has an effect that is similar to an increase in total factor productivity." W. Erwin Diewert and Catherine J. Morrison (1986; 659).

Thus some 20 years ago, a connection between productivity measures and changes in the terms of trade was made. For many years, there was not a lot of interest in this topic, but the recent increases in the price of oil and other raw materials has again stimulated interest in modeling the effects of changes in the terms of trade in a productivity framework. In addition

31 Diewert and Lawrence's (2006) approach to the construction of user costs was somewhat simplified and did not deal adequately with the issue of obsolescence. For more thorough discussions of the obsolescence problem in the user cost context, see Ahmad, Aspden and Schreyer (2004), Diewert (2006a) and Diewert and Wykoff (2006).

32 See Diewert and Morrison (1986) for references to this early literature.

33 See also Woodland (1982) and Feenstra (2004; 64–98) who used this approach extensively.

to the paper by Diewert and Lawrence (2006) presented at this conference on this topic (and the paper by Diewert, Mizobuchi and Nomura (2005) who took a similar approach using Japanese data rather than Australian data), see Morrison and Diewert (1990), Kohli (1990) (2003) (2004a) (2004b) (2006a) (2006b) and Fox and Kohli (1998). The approaches suggested in these papers, while being broadly comparable, differ somewhat in their details.[34] Since most of the papers in this area are relatively recent, a consensus on which approach is "best" has not yet emerged. It may be useful to have a review paper on this topic that would list the advantages and disadvantages of each approach.

The Effects of Public Infrastructure Investments on Productivity

The paper by Mas (2006) presented at this conference raises some of the issues surrounding the treatment of public infrastructure investments and their effects on private market sector productivity. The issue I would like to raise here is the following one. The public sector makes investments in infrastructure (primarily roads and other transportation facilities), which are surely very useful in facilitating production in the private sector but the public sector in general does not charge for the use of these valuable transportation services. Following Aschauer (1989), we could take a production function perspective and try to directly estimate a private sector production function (or a transportation sector production function) which had road services as an input. This is fine as far as it goes but econometric estimates tend to be rather fragile so it would be useful to also determine the effects of publicly funded infrastructure investments on private sector productivity in a growth accounting framework and Mas (2006) provides such a framework for the economy as a whole. However, since the infrastructure services are provided free of charge to the private sector, economic theory suggests that these free resources should be used so intensively such that the marginal value to the private sector of an extra unit of infrastructure services is close to zero.[35] This observation implies that the shadow price of infrastructure services to the private sector should be close to zero in all periods and hence changes in infrastructure services would have little or no effect on private sector productivity growth in the usual growth accounting framework. This result seems to be intuitively incorrect[36] but we need some additional

[34] In particular, when Diewert and Lawrence speak of modeling the effects of changes in the terms of trade, a closer examination of their methodology shows that what they are actually modeling are the effects of changes in the price of exports relative to the price of consumption and changes in the price of imports relative to the price of consumption. The main difference between the Diewert and Lawrence (2006) approach and the recent work of Kohli (2004b) (2006a) (2006b) is that Kohli divides prices by the price of domestic absorption (an aggregate of C+G+I) whereas Diewert and Lawrence (and Diewert, Mizobuchi and Nomura (2005)) divide prices by the price of domestic household consumption C.

[35] Diewert (1980; 484–485) made this argument many years ago.

[36] Dean Parham noted that Australia imposes a tax on diesel fuel that is meant to be a user fee for the use of its "free" network of roads. Other countries impose similar commodity taxes on fuel inputs and this may be a way to get positive prices for the use of roads into the productivity growth framework. Kohli suggested another way out of this "paradox": "If the public infrastructure is supplied free of charge congestion will set in at some stage (Pigou's wide road might become narrow at certain times of the day). The time wasted by the users will represent the marginal cost to them. The marginal value to the private sector of an extra unit of the infrastructure will therefore not be zero." Ulrich Kohli, private communication.

research on this topic in order to pin down more precisely what the contribution of public infrastructure investments is to private sector productivity growth in a growth accounting framework.

Pricing Concepts for Outputs and the Treatment of Indirect Taxes

The growth accounting framework for the private sector originally developed by Solow (1957) and Jorgenson and Griliches (1967) (1972) relied on the assumption of competitive price taking behavior on the part of producers. In Solow (1957) and Jorgenson and Griliches (1967), outputs were priced at final demand prices, which include indirect taxes. However, Jorgenson and Griliches (1972) noted that this treatment was not quite consistent with competitive price taking behavior on the producers, since producers do not derive any benefit from indirect taxes that fall on their outputs:

"In our original estimates, we used gross product at market prices; we now employ gross product from the producers' point of view, which includes indirect taxes levied on factor outlay, but excludes indirect taxes levied on output." Dale W. Jorgenson and Zvi Griliches (1972; 85).

Thus at the level of the individual firm, indirect taxes that fall on the outputs of the firm should be excluded from the output prices facing the firm, since the firm derives no revenue from these indirect tax wedges.[37] However, indirect taxes that fall on the intermediate (and primary) inputs used by the firm are actual costs to the firm and hence should be included in the corresponding prices of the intermediate inputs. Thus when we apply the growth accounting framework to an individual firm, the pricing concept that is consistent with the underlying theory excludes indirect taxes that fall on outputs but includes these taxes that fall on inputs. Thus at the level of the individual firm, the treatment of indirect taxes is relatively straightforward in the growth accounting framework. However, some problems emerge when we aggregate over firms and we apply the growth accounting framework to the entire private sector. When we aggregate over firms or sectors of the economy in the growth accounting framework in order to form national estimates of final demand output, intermediate input transactions cancel out, *except for the indirect taxes that fall on intermediate inputs*; i.e., a firm producing an intermediate input gets only the before tax revenue for the output but the using firm has to pay this price plus the indirect tax and so aggregating over the entire private sector, we end up with net deliveries to final demand at producer prices (which excludes the final demand indirect tax wedges) *less* indirect taxes on intermediate inputs paid by private sector producers. These taxes on intermediate inputs cause problems when we calculate aggregate market sector output and productivity and attempt to decompose say market sector output into contributions from each industry since these industry contributions will not sum up to the national total.[38] The details of how the industry output aggregates are related to the national aggregate if Laspeyres, Paasche or Fisher indexes are used may be found in Diewert

37 Obviously, per unit of output subsidies that the firm gathers from governments should be added to the prices of the subsidized outputs. I have neglected this complication in the discussion which follows.

38 Diewert (2001; 97–98), following Debreu (1951), noted that these indirect tax wedges on intermediate inputs lead to an economy wide loss of output; i.e., taxes on intermediates generally lead to some deadweight loss for the economy as a whole even though each sector can be efficient.

(2006b). However, the issue of how to interpret the indirect taxes on intermediate inputs "contribution" to national output growth has not been resolved and requires further research.[39] It would also be useful to develop a growth accounting framework that allowed us to relate industry contributions to national private sector productivity growth at final demand prices (rather than at producer prices as in the present theoretical growth accounting framework).

What is the Exact Form of the User Cost Formula?

Since the pioneering work of Jorgenson and Griliches (1967) and Hall and Jorgenson (1967), it is well known that the formula for the user cost of capital consists of roughly four terms:

- An interest rate or opportunity cost of capital term;
- A depreciation term;
- A revaluation or capital gain or loss term and
- Adjustments for income and other taxes on capital.

Although there is general agreement that the above four terms belong in the user cost of capital, there is still no agreement on the precise form for each term. Some of the important issues are:

- Should user costs take an ex ante or an ex post point of view?
- Should user costs be discounted to the beginning, end or middle of the period?
- Should interest rates be in real or nominal terms?
- Should the tax adjustments reflect average or marginal considerations?
- What is the exact form of depreciation that should be used?
- Should the interest rate be an exogenous market rate or a balancing internal rate of return that will make the value of input equal to the value of output?

I have been writing about the above issues for over 25 years[40] but unfortunately, we still do not have a consensus on many of the above issues. As more and more countries embark on official productivity programs, there is a need to achieve a consensus on the above issues so that the productivity estimates will be at least roughly comparable between countries.

39 A practical difficulty should be mentioned at this point. A theoretically "correct" treatment of indirect tax wedges will require detailed information by commodity and industry on where these taxes occur and this information is typically not available in the input output accounts of most countries.

40 See Diewert (1980; 475–485), (2001; 88–96), (2005a) (2006a), Diewert and Lawrence (2000), (2002) (2005a) (2006) and Diewert and Schreyer (2006). See also Schreyer (2001) (2004) and Schreyer, Diewert and Harrison (2005).

Should Depreciation Rates, Interest Rates and Wage Rates be Constant Across Industries?

In some national productivity programs, wage rates are standardized for demographic factors (age, sex, educational attainment and so on) but they are held constant across industries. Similarly, depreciation rates for different asset classes are often estimated on a national level and thus are held constant across industries. Finally, endogenous balancing rates of return on assets could be calculated on an industry basis or on a national level. The question is: which procedure is "best"?

We know that wage rates and rates of return vary greatly across firms and industries. Productivity growth for developing countries is fueled by the migration of labour from the agricultural sector to the modern industrial sector and under these conditions, it is appropriate to allow for industry wage rates to differ, holding constant demographic characteristics. Similarly, it is known that ex post rates of return differ considerably across industries.[41] Thus if possible, sectoral productivity estimates should allow for differences in wage rates and the return to capital.[42]

The situation with respect to depreciation rates is less clear cut. It is quite possible that different industries use various forms of capital more or less intensively and thus depreciation rates should be allowed to be different across industries. However, it is difficult to obtain scientific information on depreciation rates. Historically, a few countries[43] have had periodic capital stock surveys, which allow depreciation rates to be estimated, but they are very expensive and hence have been discontinued. Another scientific method for obtaining depreciation rates was developed by Hulten and Wykoff (1981a) (1981b) (1996) and relies on observations on the sales of used assets. A final possible method for obtaining depreciation rates is for national statistical agencies to add questions on capital stock retirements and resales in their ongoing investment surveys. Canada,[44] the Netherlands[45] and New Zealand

41 See for example Diewert and Lawrence (2005b).

42 Note that these differences in wage rates and user costs for the same type of input can be a source of economy wide productivity growth if the differentials are narrowed over time. "Individual firms or establishments could be operating efficiently (i.e., could be on the frontiers of their production possibilities sets) yet the economy as a whole may not be operating efficiently. How can this be? The explanation for this phenomenon was given by Gerard Debreu (1951): there is a loss of system wide output (or waste to use Debreu's term) due to the imperfection of economic organization; that is, different production units, although technically efficient, face different prices for the same input or output, which causes net outputs aggregated across production units to fall below what is attainable if the economic system as a whole were efficient. In other words, a condition for system wide efficiency is that all production units face the same price for each separate input or output that is produced by the economy as a whole. Thus if producers face different prices for the same commodity and if production functions exhibit some substitutability, then producers will be induced to supply jointly an inefficient , economy wide joint output vector." W. Erwin Diewert (2001; 97).

43 The Netherlands, Japan and Korea come to mind.

44 For a description and further references to the Canadian program on estimating depreciation rates, see Baldwin, Gellatly, Tanguay and Patry (2005).

45 Actually, since 1991, the Dutch have a separate (mail) survey for enterprises with more than 100 employees to collect information on discards and retirements: The Survey on Discards; see Bergen, Haan, Heij and Horsten (2005; 8) for a description of the Dutch methods.

ask such questions on retirements in their investment surveys and Japan is about to follow suit.[46] Diewert and Wykoff (2006) indicate how this type of survey can be used to obtain estimates for depreciation rates and it would be feasible theoretically to obtain these estimates on an industry basis. However, sample sizes are likely to be small if one attempts to use this survey information to form estimates of depreciation rates by asset class and industry and hence the resulting estimates may be very inaccurate. Thus one may be better off by estimating depreciation rates at a national level rather than at the industry level.

The Problem of Imputing Wage Rates for the Self Employed and Unpaid Family Workers

In the present System of National Accounts, the contributions to production of the self employed and of unpaid family workers are buried in Gross Operating Surplus. However, when constructing productivity accounts, it is necessary to decompose this value aggregate into a capital services aggregate plus the value of self employment labour and unpaid family worker labour. Note that for many advanced economies, the self employed can make up 20 percent of the labour force and for developing economies, unpaid family workers can also be a substantial fraction of the labour force. Thus the problem of imputing wage rates for the self employed and family workers is not an empirically unimportant one.

There are three methods that the Bureau of Labor Statistics has suggested to accomplish this imputation for the self employed:[47]

- Approach 1 to this allocation problem imputes a wage to the self employed that is equal to the wage of comparable employees in the industry and the resulting measure of labour earnings is subtracted from Gross Operating Surplus, leaving what is left over as the return to the capital used by the self employed.
- Approach 2 allocates an industry rate of return to the capital used by the self employed and allocates what is left of net operating surplus as the wages earned by the self employed.
- Approach 3 takes an average of the allocations to labour and capital that are generated by the first two approaches.

The problem with Approaches 1 and 2 is that these allocation methods can give rise to negative compensation for either labor or capital. The BLS uses Approach 3 in its productivity program; i.e., it averages the first two methods of allocation to ensure a positive compensation for both factors of production. However, this procedure is not entirely satisfactory since it ensures that “incorrect” estimates are made if Approaches 1 and 2 differ and one of these two approaches is actually the “correct” one.[48]

46 The Economic and Social Research Institute (ESRI), Cabinet Office of Japan, with the help of Koji Nomura is preparing a new survey to be implemented as of the end of 2006.

47 For a description of the BLS productivity program and an extensive list of references, see Dean and Harper (2001).

48 The BLS procedure also leads to some inconsistencies if an endogenous rate of return to capital is used in constructing user costs.

Which approach is likely to the "correct" one?[49] I would vote for Approach 2 over Approach 1 since workers often become self employed because they *prefer* this type of employment over paid work; i.e., self employed work is not really equivalent to employee work, even after standardizing for the type of job.[50] On the other hand, the user cost of capital should be the same whether workers are employees, self employed or family workers.

In any case, it can be seen that there are still some major unresolved measurement issues surrounding the imputation of wage rates for the self employed and family workers.

The Treatment of Inventory Change in the SNA

In the current System of National Accounts, the treatment of inventory change in real terms is very confusing to users since when nominal inventory change is divided by the corresponding real change, negative implicit prices frequently occur. The meaning of these negative prices is problematical. Diewert (2005c) suggested that this problem is due to the failure of normal index number theory when the value aggregate being deflated can be of either sign in the two periods under consideration. His solution to this problem was straightforward: the value aggregate should be written as the difference between two positive value aggregates and each of the two aggregates should be separately deflated. This is analogous to the treatment of the trade balance which is rarely deflated directly; rather exports and imports are separately deflated and shown as two separate real aggregates in the SNA. Diewert (2005c) also showed how inventory change and the user cost of inventories can be jointly derived in a consistent economic framework due to Hicks (1961) and Edwards and Bell (1961).[51]

The problem of obtaining a more theoretically consistent treatment of inventory change may seem rather minor but inventory fluctuations often drive changes in GDP so a transparent treatment of this part of inventories is important in productivity analysis.

The Measurement of Financial Services Outputs and Inputs

The problems involved in defining the outputs and inputs of banking services (and other financial institutions more generally) have been with us for a long time and there is still no general consensus on what are the "correct" measures. Excellent recent discussions of the issues involved may be found in Schreyer and Stauffer (2003), Fixler, Reinsdorf and

49 In practice, our choices may be constrained by the availability of data. For approach 1, it is necessary to know the number of workers who are self employed and their hours of work. For approach 2, one needs data on the capital stock that is being used by the self employed.

50 This preference for Approach 2 over Approach 1 does not solve our measurement problems since if there are say both self employed and family workers in a firm, Approach 2 only gives us an aggregate imputation for the two types of labour rather than a separate imputation for each type of labour. We may have to resort to econometric methods and production function estimation in order to obtain direct estimates for the shadow prices of self employed and family labour.

51 Diewert's analysis also draws on Diewert and Smith (1994).

Smith (2003) and in Chapter 7 of Triplett and Bosworth (2004).[52] I lean towards the "user cost" school of thought that has been developed by Hancock (1985) (1991) and Fixler and Zieschang (1991) (1999) but a consensus on the "best" theoretical approach to measuring financial service industry outputs and inputs has not yet emerged.

The Effects on Productivity Growth of the Entry and Exit of Firms

How does the entry and exit of firms contribute to productivity growth?[53] This is an exciting new area of research in productivity analysis that is only a bit over 10 years old; see the pioneering contributions of Baldwin and Gorecki (1991) and Baily, Hulten and Campbell (1992). Not only is this area of research of interest from a theoretical point of view, it appears to be extremely important empirically; see Haltiwanger (1997) (2000) , Ahn (2001), Bartelsman (2004) and Bartelsman, Haltiwanger and Scarpetta (2004).

An unresolved issue in this literature on the contributions to productivity growth of entering and exiting firms is *how exactly should we measure these contributions*. Various answers to this question have been proposed by Baldwin and Gorecki (1991), Baily, Hulten and Campbell (1992), Griliches and Regev (1995), Olley and Pakes (1996), Bartelsman and Doms (2000), Foster, Haltiwanger and Krizan (2001), Fox (2002), Balk (2003a; 25–31), Baldwin and Gu (2003) and Diewert and Fox (2006). Again, there is a need for a consensus to form on what is the "best" treatment of this subject.

The Consistency of Quarterly Estimates of Productivity Growth with Annual Estimates

The final measurement problem associated with productivity measurement that has not been definitively resolved is the following one: how can quarterly estimates of productivity growth be made consistent with annual estimates?

The answer to this question is not simple because of three factors:

- The existence of seasonal commodities; i.e., it is difficult (or impossible!) to form estimates of real output growth if some outputs are not available in all quarters and
- The possible existence of moderate or high inflation within the year.
- There are mathematical problems in reconciling sums and ratios which defy easy solutions.[54]

If there is high inflation within the year, then when annual unit value prices are computed (to correspond to total annual production of the commodities under consideration), "too

52 A summary and comments on Triplett and Bosworth may be found in Diewert (2005d), which is an extended version of a shorter review which appeared in the International Productivity Monitor, Volume 11, Center for the Study of Living Standards, Fall 2005, pp. 57–69.

53 See Bartelsman, Haltiwanger and Scarpetta (2004) for a review of the evidence on the productivity effects of entry and exit over 24 countries using micro data sets over the past decade. Other reviews of the literature on this topic can be found in Haltiwanger (1997) (2000), Ahn (2001) and Balk (2003; 25–31).

54 See Balk (2005) on this point in particular.

much" weight will be given to the prices of the fourth quarter compared to the prices in the first quarter.[55] There are possible solutions to this problem but they are rather complex and as usual, there is no consensus on what the appropriate solution should be.

For possible solutions to the above problems, the reader is referred to Hill (1996), Diewert (1998) (1999), Bloem, Dippelsman and Maehle (2001), Armknecht and Diewert (2004) and Balk (2005).

It can be seen that there is a fairly large number of outstanding *theoretical* problems associated with the measurement of productivity growth. Hopefully, in the future, we will make some progress in coming to a consensus on what the "best" solution is to each of these problems.

In the following section, I conclude with some recommendations to the OECD which could help facilitate productivity comparisons between countries.

Recommendations for the OECD

The OECD is my favorite international statistical organization since they provide products that I find most useful in my own teaching and research. Some of the most useful products from my perspective are the following ones:

- The OECD tries to provide standardized national accounts data for its member countries back to 1960.[56]
- The OECD is *the* source for tax data on a harmonized basis.[57] Thus when international comparisons of taxation are made, the OECD data base on taxation is always the first source that researchers turn to.
- The OECD provides very useful advice to its member countries in its annual country reports.
- The OECD has specialized in providing R&D data for its member countries and in examining the role of R&D in productivity growth.

55 See Hill (1996) and Diewert (1998) for a discussion of these problems.

56 In my applied economics course that I teach to MA students, each student has to pick an OECD country and develop a set of productivity accounts for his or her country back to 1960. They find the OECD national accounts and tax data invaluable.

57 However, Kohli points out that these taxation data must be used with some care to ensure that like is compared to like: "The OECD always ranks Switzerland among the low tax countries, but by the time you have added up the premia for unemployment insurance, disability insurance, accident insurance, medical insurance, and pension funds (all of which are compulsory, but not financed by general government revenues), the picture is quite different." Ulrich Kohli, private communication.

Thus the OECD is already in the business of providing standardized data on its member countries. My recommendations below suggest that this role should be expanded in the following ways:

- The OECD should provide some guidance on "standard" assumptions for the construction of user costs and provide these standardized user costs for its member countries. Also the OECD should fix the inventory change problem mentioned in section 3.9 above and provide "standard" user costs of inventory in a theoretically consistent framework.
- The OECD should provide "standard" depreciation rates for capital stocks and provide "standard" estimates of the flow of capital services for member countries.[58]
- The OECD should provide "standard" estimates for the imputed labour income of the self employed and unpaid family workers. The methods used to do this will not be exactly right, but someone has to make a start on this difficult problem.
- The OECD should continue to cooperate with the EU KLEMS project.[59] As a start, it would be very useful for the OECD to provide data on the price and quantity of inputs and outputs for the market sector in each member country; i.e., once we have the sectoral data on the market and nonmarket sectors from the KLEMS project, it would be straightforward to calculate productivity levels for the market sector of each OECD economy and compare these levels across countries.[60] In short, an expansion of the EU KLEMS project to cover all OECD countries would allow us to make international comparisons of productivity for the *market sector* in each member country's economy.
- The OECD should continue to sponsor these meetings on productivity so that member countries can continue to report on their practical experience in setting up productivity accounts and so that interested researchers can interact with the practitioners and hopefully provide solutions to some of the difficult measurement problems mentioned above.

58 Once the standardized depreciation estimates are in hand, it would also be useful to the OECD to publish net value added productivity growth rates for member countries along the lines recommended by Diewert and Lawrence (2006).

59 See the papers by van Ark, Timmer and Pilat (2006), van Ark, Timmer and Ypma (2006) and Timmer and Inklaar (2006) that were presented at this conference.

60 The general government sector in each economy cannot be expected to behave in an optimizing manner so that the usual assumptions underlining the growth accounting methodology will generally not hold for the nonmarket sectors in each economy.

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Part 1:

Productivity Growth in Spain and in Switzerland

2. PRODUCTIVITY GROWTH AND INNOVATION IN OECD

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Introduction[61]

There has been renewed divergence of GDP per capita among OECD countries over the past decade: Whereas the relatively less advanced countries tended to catch up with the leader, the US, from the late 1940s to the late 1980s, the situation has reversed since the mid-1990s. While GDP growth was accelerating in the US, it was just slowing down in most countries of Europe and in Japan. It tended to slow down again in the 2000s in the US, but also in Europe.

GDP depends on how many workers there are, and how efficient they are: It results as the combination of two immediate factors, utilisation of labour and productivity of labour (See OECD 2008, Compendium of Productivity Indicators). Productivity matters especially in the long run; it is the key to sustainable economic growth. Innovation in turn is a central factor of productivity growth. Assessing the innovation performance of a country, and explaining it, goes a long way to understanding the dynamics of its productivity, hence its economic growth. It is what this paper will attempt to do, starting from GDP growth, going to productivity, to R&D, to innovation performance, and to the structural and institutional factors which influence innovation.

The major OECD sources of data used for this article are as follows: the Compendium of Productivity Indicators (2008) for growth and productivity figures; the Main Science and Technology Indicators (MSTI) for R&D data; the Compendium of Patents Statistics of 2007 for patent indicators; the Science, Technology and Industry Scoreboard of 2007 for most other indicators.

From GDP to productivity growth: General trends and determinants

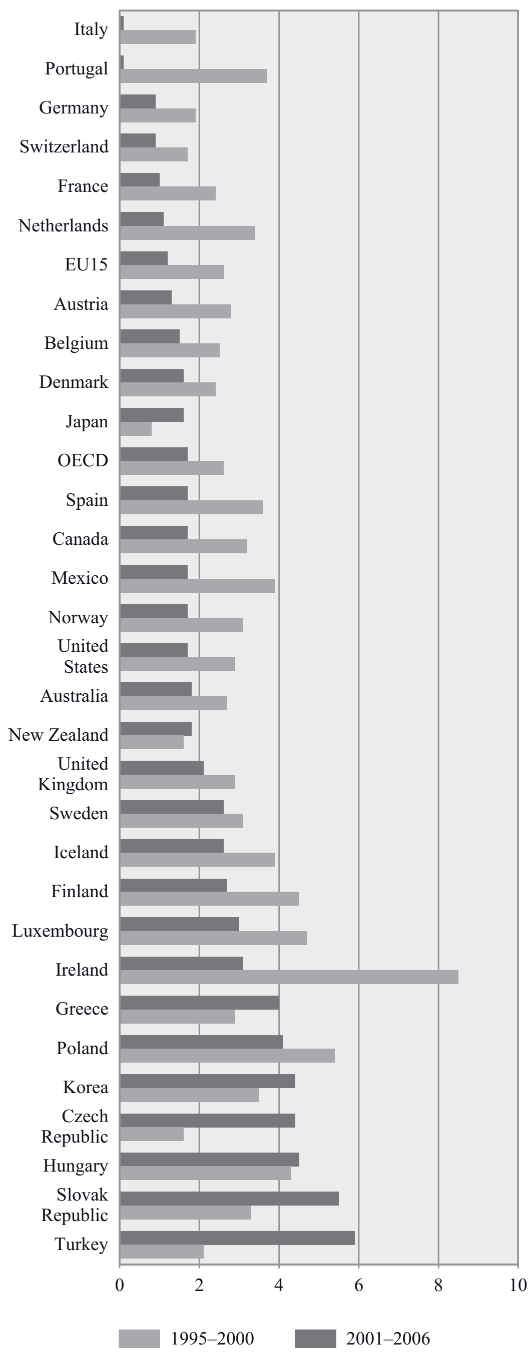
The interest of many OECD countries in economic growth over the past years was partly linked to the strong performance of the United States over the second half of the 1990s and

61 This study is based on presentations made at the OECD Productivity Conference of 2005 held in Madrid (Pilat 2005) and of 2006 held in Bern (Guellec 2006). This paper reflects the views of the authors and not necessarily the views of the OECD or its member countries. The findings of this paper draw on work of many colleagues of the OECD, notably Paul Schreyer. Productivity indicators from the Compendium of Productivity Statistics have been compiled by Agnès Cimper and Julien Dupont.

the reversal of the catch-up pattern that had characterised the OECD area over the 1950s and the 1960s. During much of the early postwar period, most OECD countries grew rapidly as they recovered from the war and applied US technology and knowledge to upgrade their economies. For most OECD countries, this catch-up period came to a halt in the 1970s; average growth rates of GDP per capita over the 1973–92 period for much of the OECD area were only half that of the preceding period, and many OECD countries no longer grew faster than the United States (Maddison, 2001).

During the 1990s, a different pattern emerged. Even though the United States already had the highest level of GDP per capita in the OECD area at the beginning of the decade, it expanded its lead on many of the other major OECD countries during the second half of the 1990s. A few other OECD countries, including Australia, Canada, Finland, Greece, Ireland, Portugal, Spain and Sweden, also registered markedly stronger growth of GDP per capita over the 1995–2006 period compared with the 1980–1995 period. Some of these countries continued to catch up with the United States in the second half of the 1990s and in the 2000s. In contrast, the increase in GDP per capita in several other OECD countries, including Japan, Germany and Italy, slowed sharply over the second half of the 1990s, leading to a divergence with the United States. Most OECD countries have experienced a slowdown in GDP per capita growth in the first half of the 2000s, Japan being a major exception. However in this context the US kept the fastest growth among G7 countries except for the UK, while the largest continental European countries experienced even further significant slowdown (graph 2–1).

Growth in GDP per capita **G 2–1**
(Compund annual growth rate, %)



Source: Compendium of Productivity Statistics 2008

Even though US growth performance is no longer considered to be as exceptional as was claimed during the "new economy" hype, its strong performance over the past decade has increased interest in the analysis of economic growth and the sources of growth differentials across countries. The OECD work suggests that the divergence in growth performance in the OECD area is not due to only one cause, but that it reflects a wide range of factors.

Differences in the measurement of growth and productivity might also be contributing to the observed variation in performance. An OECD study (Ahmad, *et al*, 2003) suggests that such differences do play a role, but that they probably only account for a small part of the variation in growth performance. To reduce the uncertainty of empirical analysis related to the choice of data, OECD has developed its Productivity Database, which is used in this paper.

GDP per capita can be broken down into two components: labour utilisation (number of hours worked per capita) and the efficiency of labour (GDP per hour worked, also labelled productivity of labour). Labour utilisation in turn results from three factors: average working time, labour force participation rate and unemployment rate.

Improving labour utilisation remains important for many EU countries

The first factor affecting growth differences concerns labour utilisation (graph 2–2). In the first half of the 1990s, most OECD countries, in particular many European countries were characterised by a combination of high labour productivity growth and declining labour utilisation. The high productivity growth of these EU countries may thus have been achieved by a greater use of capital or by dismissing (or not employing) low-productivity workers. In the second half of the 1990s, many European countries, improved their performance in terms of labour utilisation, as unemployment rates fell and labour participation increased. However, the growth in labour utilisation was accompanied by a sharp decline in labour productivity growth in many European countries, which was not necessarily the case elsewhere (e.g. Canada or Ireland).

Achieving a combination of labour productivity growth and growing labour utilisation requires well functioning labour markets that permit and enable reallocation of workers. This is particularly important during times of rapid technological change. Labour market institutions have to ensure that affected workers are given the support and the incentives they need to find new jobs and possibly to retrain. In many countries, institutions and regulations hinder the mobility of workers and prevent the rapid and efficient reallocation of labour resources. In most of the countries characterised by a combination of increased labour utilisation and labour productivity, reforms over the 1980s and 1990s improved the functioning of labour markets, effectively enabling more rapid growth.

Much progress in enhancing labour utilisation has been made in many OECD countries over the 1990s, but the 2000s have experienced a stagnation of labour utilisation OECD-wide, with a decline in all G7 countries except Canada. In terms of levels, for several OECD countries, notably many European countries, there is still a large scope for improvement in labour utilisation, as it accounts for the bulk of the gap in GDP per capita with the United States (The OECD Compendium of Productivity 2008 provides more data on labour utilisation and productivity *levels* across countries). The gap in labour utilisation is particularly large for Belgium and France, but also affects many other European countries.

Labour productivity growth improved only in some OECD countries

Together with labour utilisation, labour productivity is the other key component of GDP per capita. It is also the main determinant of the gap in income levels between the United States and most other OECD countries. After its acceleration in the second half of the 1990s in a number of countries (including Australia, Canada, Greece, Ireland and the United States), labour productivity slowed down in most countries in the 2000s, the United States and some European countries such as the United Kingdom and Sweden being the main exceptions (graph 2–3).

The impact of human capital

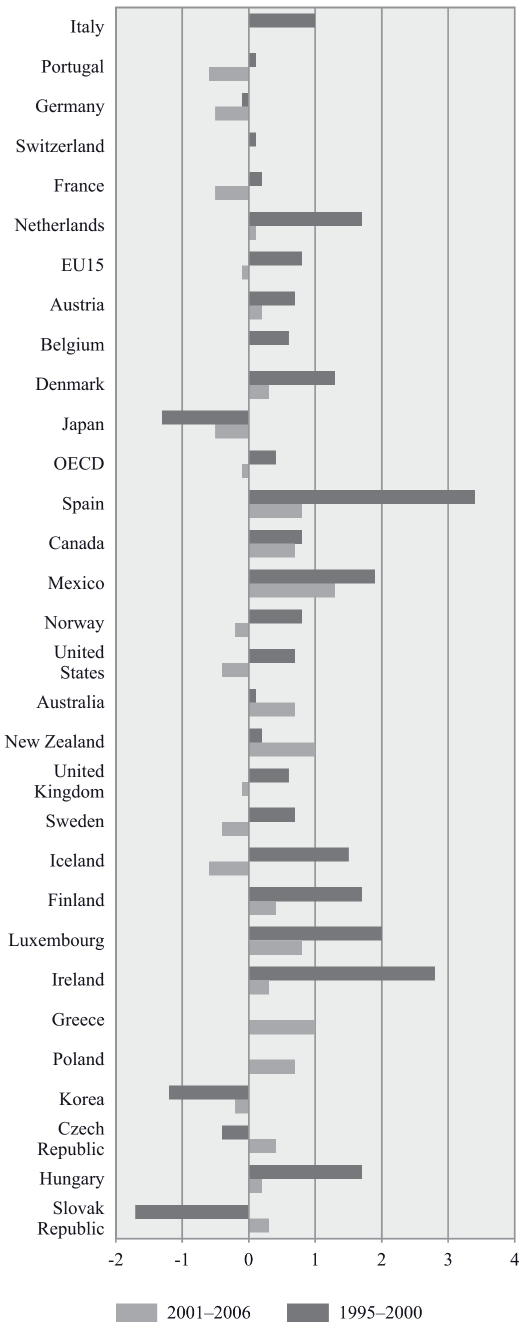
Labour productivity growth can be increased in several ways: by improving the composition of labour used in the production process, increasing the use of capital and improving its quality, and attaining higher multi factor productivity (MFP). The composition of the labour force is the first of these, and plays a key role in labour productivity growth. This is partly because in all OECD countries, educational policies have ensured that young entrants on the jobs market are better educated and trained on average than those who are retiring from it. For example, in most OECD countries, more 25–34 year olds have attained tertiary education than 45 to 54 year olds.

The available empirical evidence suggests that improvements in the composition of labour have directly contributed to labour productivity growth in virtually all OECD countries (Bassanini and Scarpetta, 2001; Jorgenson, 2003). Jorgenson (2003) points to contributions of 0.2–0.4% of labour composition to GDP growth for the G7 countries. These estimates also suggest that the contribution of labour composition to labour productivity growth has slowed in most G7 countries over the second half of the 1990s, Italy being the only exception. This is typically attributed to the large number of low-skilled workers that were integrated in the labour force in many OECD countries over the second half of the 1990s. Moreover, the contribution of labour composition may also decline over time if the gap in education levels between cohorts of new and retiring workers becomes smaller over time. Growth accounting estimates typically only take account of changes in educational attainment, however; increases in the level of post-educational skills are also important, but few hard measures are available.

The role of investment in fixed capital

Investment in physical capital is the second factor that plays an important role in labour productivity growth. Capital deepening expands and renews the existing capital stock and enables new technologies to enter the production process. While some countries have experienced an overall increase in the contribution of capital to growth over the past decade, ICT has typically been the most dynamic area of investment. This reflects rapid technological

Labour utilisation and productivity of labour
Labour utilisation **G 2–2**



Source: Compendium of Productivity Statistics 2008

Productivity of labour
(GDP per hour worked) **G 2–3**

Source: Compendium of Productivity Statistics 2008

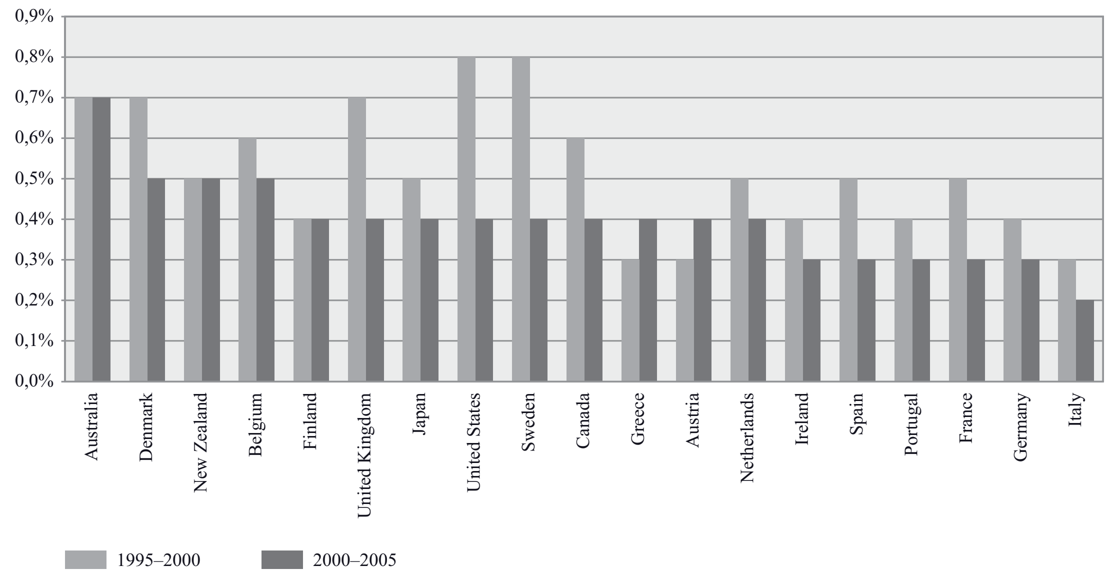
progress and strong competitive pressure in the production of ICT goods and services and a consequent steep decline in prices. This fall, together with the growing scope for application of ICT, has encouraged investment in ICT, at times shifting investment away from other assets (Pilat and Wölfl 2004).

While ICT investment accelerated in most OECD countries, the pace of that investment and its impact on growth differed widely across countries. For G7 countries, the use of ICT capital accounted for between 0.2 and 0.7 percentage points of growth in GDP per capita over the 2000–2005 period, with most countries around 0.4 (graph 2–4). This is significantly less than the contribution of ICT capital to growth in the 1995–2000 period. Among the G7, the US, the UK and Japan are the countries with the highest contribution of ICT, while the large continental European countries have the lowest.

The question that follows concerns the reason why the diffusion of ICT is so different across OECD countries. A number of reasons can be noted. In the first place, firms in countries with higher levels of income and productivity typically have greater incentives to invest in efficiency enhancing technologies than countries at lower levels of income, since they are typically faced with higher labour costs. Moreover, the structure of economies may affect overall investment in ICT; countries with a larger service sector or with a large average firm size are likely to have greater investment in ICT.

More specifically, the decision of a firm to adopt ICT depends on the balance of costs and benefits that may be associated with the technology. There is a large range of factors that affect this decision (OECD, 2004*a*). This includes the direct costs of ICT, *e.g.* the costs of ICT

Contribution of ICT to GDP growth **G 2–4**



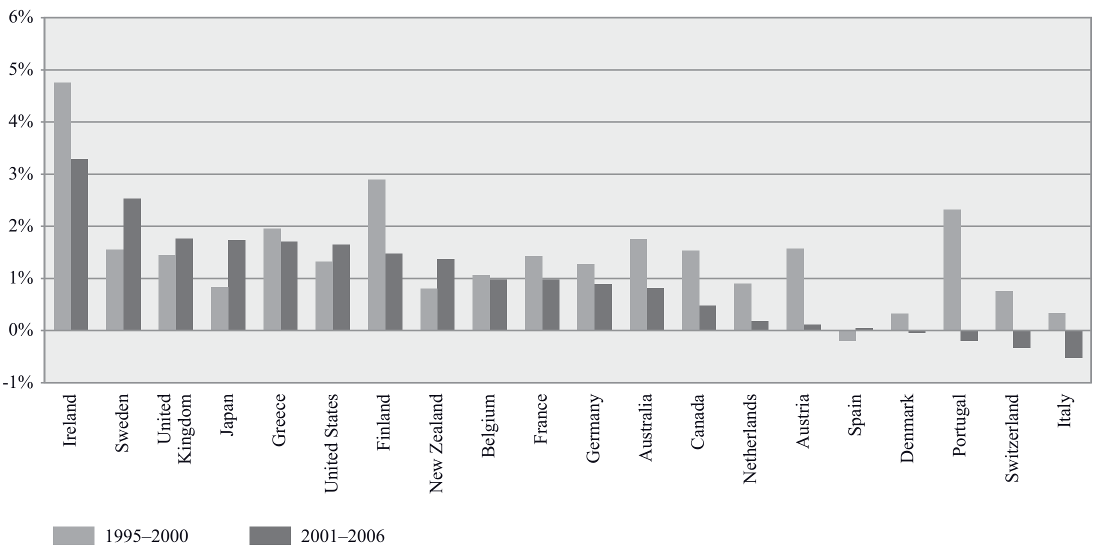
Source: Compendium of Productivity Statistics 2008

equipment, telecommunications or the installation of an e-commerce system. Considerable differences in the costs of ICT persist across OECD countries, despite strong international trade and the liberalisation of the telecommunications industry in OECD countries. Moreover, costs and implementation barriers related to the ability of the firm to absorb new technologies are also important. This includes the availability of know-how and qualified personnel, the scope for organisational change and the capability of a firm to innovate. In addition, a competitive environment is more likely to lead a firm to invest in ICT, as a way to strengthen performance and survive, than a more sheltered environment. Moreover, excessive regulation in product and labour markets may make it difficult for firms to draw benefits from investment in ICT and may thus hold back such spending.

Strengthening MFP growth

The final component that accounts for some of the pick-up in labour productivity growth in the 1990s in certain OECD countries is the acceleration in multi factor productivity (MFP) growth (graph 2–5). MFP growth rose particularly in Canada, Finland, France, Greece, Ireland, Portugal, Sweden and the United States. In other countries, including Germany, Italy, Japan, the United Kingdom, Belgium, Denmark, the Netherlands and Spain, MFP growth slowed down over the 1990s. In the United Kingdom, the United States, Sweden and Japan, MFP still accelerated in the 2000s, but in the large continental European countries it slowed down.

Multifactor productivity Growth **G 2–5**



Source: Compendium of Productivity Statistics 2008

The improvement in MFP in some countries after the mid-1990s reflected a break with slow MFP growth in the 1970s and 1980s and may be due to several sources. Better skills and better technology may have caused the blend of labour and capital to produce more efficiently, organisational and managerial changes may have helped to improve operations, and innovation may have led to more valuable output being produced with a given combination of capital and labour. MFP growth is measured as a residual, however, and it is difficult to provide evidence on such factors. Some is available, though, and is discussed below.

Innovation as a factor of productivity growth

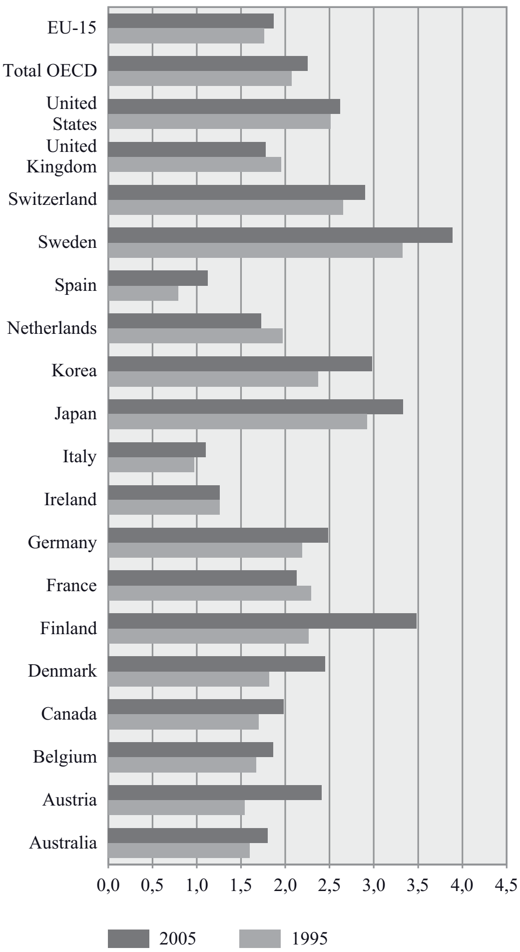
Among the sources of multifactor productivity growth, technological and non technological innovation is usually recognised as the most important one in the long run. Innovation occurs when new ideas or inventions are put into use, so as to enhance efficiency of the production process or the range or quality of goods and services (see the Oslo Manual, OECD 2005). Innovation can come from R&D, a type of investment aimed at producing new knowledge; it can also result from more applied types of activities, experimentation, on-site adaptations etc. The impact of R&D on MFP growth has been established by many quantitative studies (e.g. Guellec and van Pottelsberghe 2001). In addition, much innovation is not technological but can still exercise a strong effect on productivity (new organisational systems, new ways of delivering goods and services, new types of services etc.). Innovation not only increases directly economic efficiency, but it also creates investment opportunities which translate into further economic growth via the accumulation of capital. Such opportunities created by ICT obviously played a role in the wave of physical investment in a series of countries in the second half of the 1990s.

Innovation is of particular interest to government as it is seen as an area where policy can have a significant impact. The returns from investment in new knowledge can often be appropriated only partly by the inventing firm, as competitors can take inspiration from the new technology and create their own version, which will reduce the market power of the inventor, hence her mark up on the price. Lower return for inventors means a tendency to invest in R&D less than it would be efficient from the perspective of society. Hence the importance of government in this area: to provide monetary incentives (subsidies, tax reliefs), but also, and sometimes mostly, to provide adequate institutional conditions which will give business a sufficient return on investment and adequate incentives to invest. That includes industrial property rights, competition policy, regulation etc.

R&D performance

R&D intensity, the ratio of R&D expenditure over GDP, is the most often used measure of effort in science and technology (graph 2–6). The OECD average was 2.25% in 2005, but there is wide cross-country variation. Nordic countries, together with Japan, Switzerland, Korea, the US and Germany feature significantly above the average. These are all countries with high GDP per capita, and most of them have had high growth over the past decade. The EU15 has been around 1.9% for years. The UK, the Netherlands, Spain and Australia are well below the average. The R&D intensity of OECD increased significantly in the late 1990s,

GERD as % of GDP **G 2–6**



Source : OECD, Main Science and Technology Indicators, October 2007.

but it has not progressed since then, as the increase in Japan was compensated by the reduction in the US.

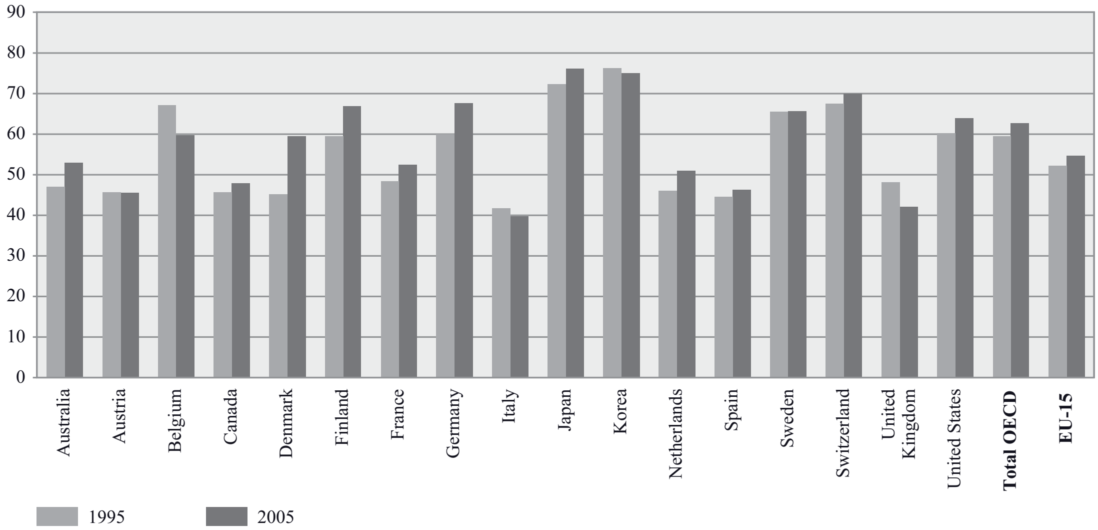
The business enterprise sector funds and performs the bulk of R&D (63% and 68% respectively OECD-wide; graph 2–7) and its share has been increasing consistently in most countries over the past two decades. Whereas government R&D is rather aimed at public policy objectives, such as expanding the knowledge base or responding to social needs (health, environment), business R&D is closely related to market applications, with a more direct impact on measured productivity. The share of business in total R&D is lower in the EU as compared with Japan and the US, although some countries (Nordic countries, Germany) feature high. Business R&D is the determinant factor in cross country variations in total R&D, because government R&D relative to GDP is much less dispersed across countries than business R&D is.

However it is noticeable that countries where government does or funds more R&D are also the ones where business does more R&D: notably Nordic countries, the US or Germany (graph 2–8). This illustrates the impact of public R&D on business R&D, shown in a more controlled way in various econometric studies (e.g. Guellec and van Pottelsberghe 2001b). Public R&D can open new avenues to knowledge, which are then followed by the more applied, business R&D. Public R&D also trains researchers (e.g. PhDs) which find then jobs in the business sector.

Technological output

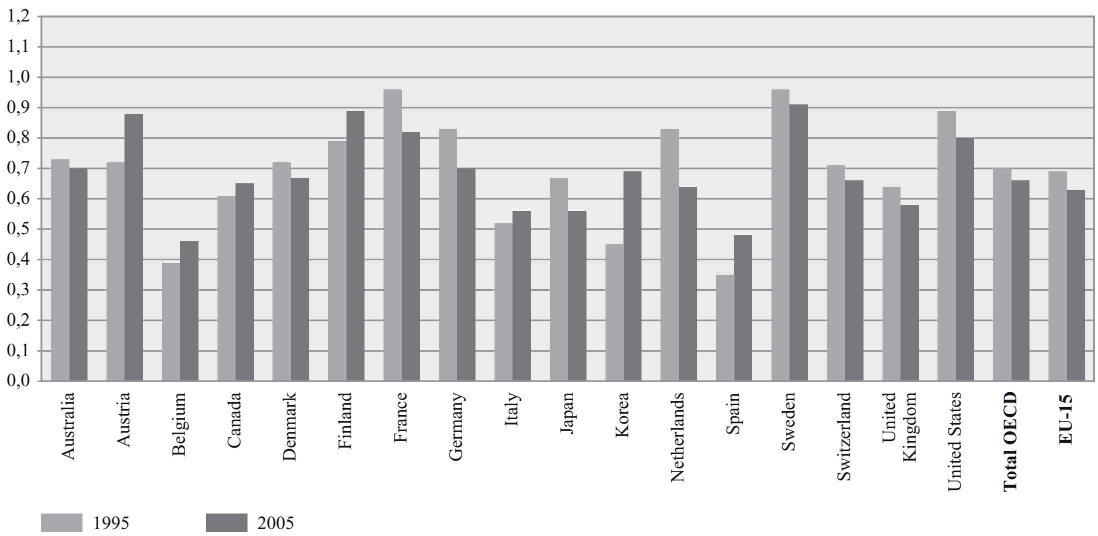
What does this considerable investment on R&D result in? The most often used indicator of the output of R&D investment is patents. The statistical properties of patents as indicators of technical change have been extensively studied (OECD 2007, Compendium of Patent Statistics). The indicator used here is "triadic patent families", which are inventions protected altogether in Europe, the US and Japan. They are not subject to the "home bias" which affects all national patent data, and they leave aside inventions with low economic value which are

Percentage of GERD financed by industry **G 2–7**



Source: Main Science and Technology Indicators (MSTI), OECD 2007

Government funded R&D as % of GDP **G 2–8**



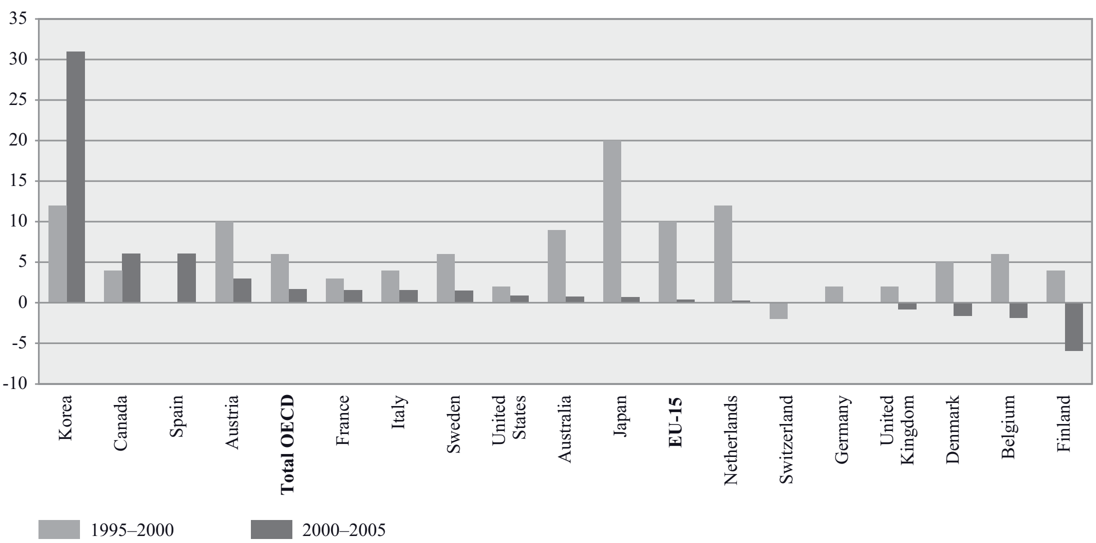
Source: Main Science and Technology Indicators (MSTI), OECD 2007 patented in one country only. The country of reference is the one where the inventor (not necessarily the owner, usually a company) resides. (graph 2–9).

About 53 000 triadic patent families were filed worldwide in 2005, a sharp increase from less than 35 000 in 1995. Growth during the second half of the 1990s was at a steady 7% a year on average until 2000. The beginning of the 21st century was marked by a slowdown, with patent families increasing by 2% a year on average. The United States, the European Union and Japan show similar trends, with a stronger deceleration in Japan after 2000. Between 2000 and 2005, the number of triadic patent families remained stable in Australia, Germany, France, Sweden and Switzerland, while those originating from Denmark, Finland and the United Kingdom decreased respectively by 2%, 6% and 1% on average (but Finland had had a sharp increase in 1995–2000). Overall the output of technological activities evolved quite in parallel with the main input of these activities, R&D, with an acceleration in the mid-1990s and a slowdown after 2000. Not only the number of patents matter, but also the technological composition is important, and in that regard some countries have been more successful than others in developing emergent technologies rather than digging deeper in older fields (see next section below).

Openness

Inventions made in a particular country rely not only on R&D performed in that country, but also on knowledge inputs from other countries, or "knowledge transfers". Openness to the rest of the world is extremely important to the economic growth of any one country, due to

Triadic patent families, compound annual growth rates **G 2–9**

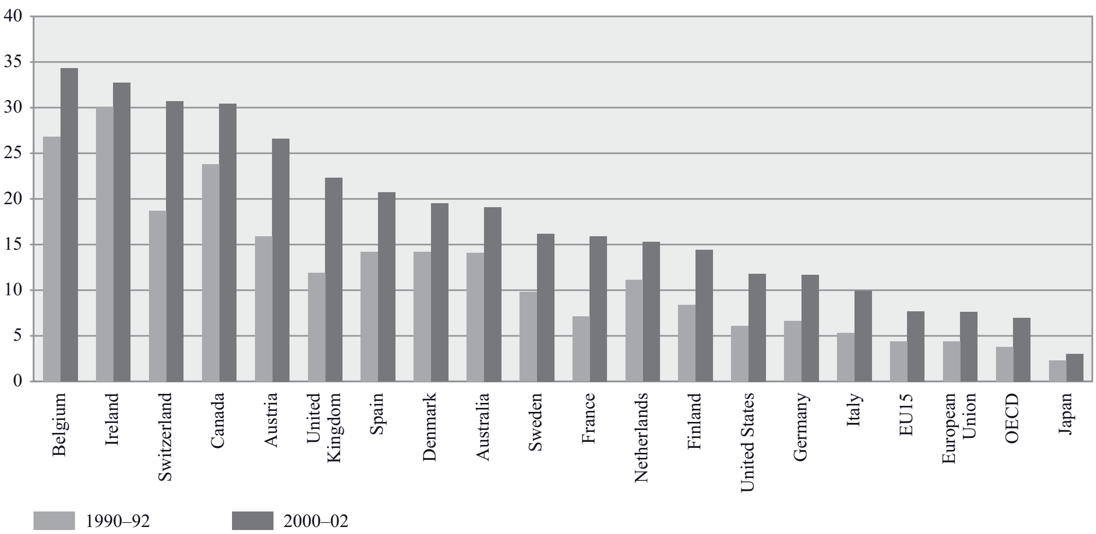


Source: OECD Patent Database

several mechanisms such as increased competition (on the domestic market and on foreign markets), or the ability to specialise so as to develop comparative advantages and benefit from economies of scale, but it is all the more important in the field of technology. For all countries foreign sources of knowledge have a major impact on MFP growth. This is all the more true for smaller countries, which could not invent everything by themselves. In addition, the impact of foreign R&D on domestic productivity is higher in countries which do themselves much R&D, as own capabilities facilitate the assimilation of others' technology. International technology transfers can be facilitated in different ways, such as research co-operation (i.e. research projects involving both domestic and foreign researchers), the creation of foreign research facilities by domestic multinational firms, or of domestic laboratories by foreign multinational firms.

International linkages can be measured with patent information, as patent filings include the address of all co-inventors of any particular invention. The world share of patents involving international co-invention among all patents increased from 4% in 1991–93 to 7% in 2001–03 (graph 2–10). This reflects the enhanced impact of globalisation on technological change (OECD 2008b). The extent of international co-operation differs significantly between small and large countries. Small and less developed economies engage more actively in international collaboration. Co-invention is particularly high in Belgium, Ireland, Switzerland and Canada. Larger countries, such as France, Germany, the United Kingdom and the United States, report international co-operation of between 12 and 23% in 2001–03. In view of its size, the UK is more opened than other comparable countries, while Japan and Korea look more insulated.

International co-inventions
(Share of patents with co-inventors residing in a different country) **G 2–10**

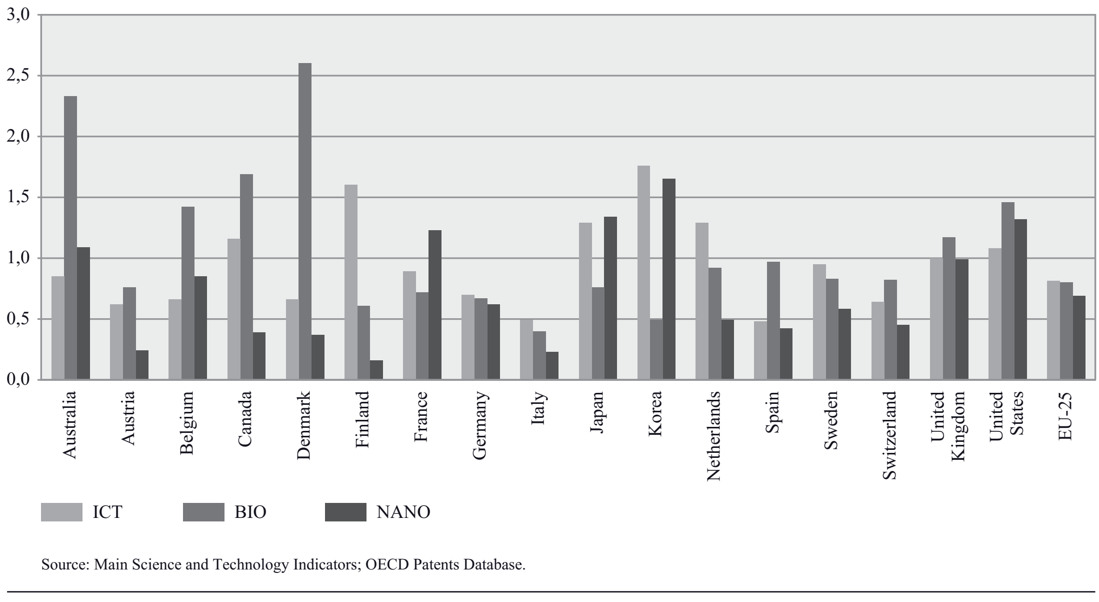


Source: Compendium of Patent Statistics, OECD 2006

The development of new activities

For countries which are at the technological frontier –the case of most OECD countries and a few others- their ability to nurture new technical fields is an important component of growth performance. Not only such fields are growing more rapidly and are at the root of tomorrow's industries, but they generate spillovers which benefit to other fields. Three technical fields are of particular interest in that regard nowadays: ICT, biotechnology and nanotechnology. In terms of the impact on productivity, we've seen how important ICT use has been, and it is expected that biotechnology and nanotechnology, as they are getting more mature and are applied at a large scale, will have significant impact on productivity in the future. In terms of economic conditions, all these technologies are initially developed mainly by new firms, start-ups, created just for developing and implementing such inventions. Many of these start-ups were born out of research conducted in universities. Hence, the performance of a country in new, emerging technical fields is a reflection of its ability to encourage entrepreneurship and to generate high quality academic research with industrial applications. A country's relative focus on these fields can be measured by the share of these fields in total patents taken on inventions coming from the country, relative to the same share in other countries – this is an indicator of comparative advantage (graph 2–11). In that regard, the US seems to have a significant comparative advantage in biotechnology and in nanotechnology, whereas it is in the average for ICT. Japan has an advantage in ICT and nano, but is weak in biotechnology. As for the EU as a whole, it is weak in all three fields, in accordance with a tendency to keep to established technical fields. The latter statement does not apply to all countries, as the UK, Denmark and Belgium have an advantage in biotechnology,

Comparative advantage of countries in emerging technology fields (share of patents in the field in the country divided by the share of the field in total OECD patents)
EPO patent applications; Priority Year 2003 **G 2–11**



Source: Main Science and Technology Indicators; OECD Patents Database.

France in nanotechnology, Finland and the Netherlands have an advantage in ICT; the strong advantage of Australia and Canada in biotechnology is also noticeable.

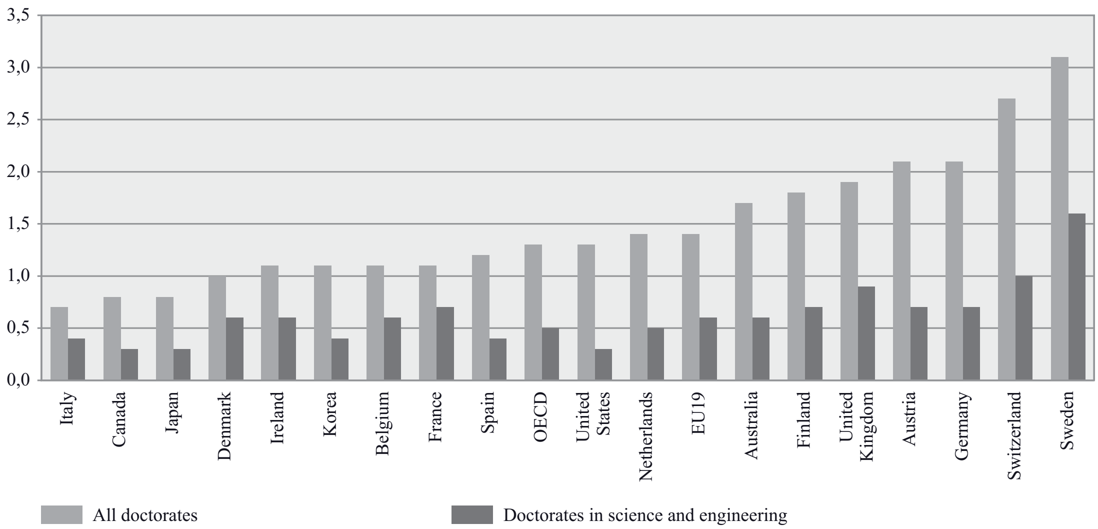
The emergence and expansion of new industries depends notably on:

1) The availability of the needed factors, mainly skilled labour, knowledge (science), and capital;
2) The incentives and institutions that will drive these factors into new industries rather than keeping them into established activities. That includes competition and openness of product markets and of the labour market, as well as adequate incentives for capital to go into risky areas and incentives for universities to transfer new knowledge to industry.

The availability of human capital

Innovation in general requires skilled labour, both for its generation and for its diffusion. In addition, emerging fields usually require new skills, which are brought by new graduates rather than older cohorts. Hence the ability of a country to nurture emerging fields should be related to the flow rather than the stock of human capital, provided that new fields would have a higher share in current flows than in older ones. The number of new university graduates is an indicator of this flow (graph 2–12). In 2004, OECD universities awarded about 6.7 million degrees, of which 179 000 doctorates. At the typical age of graduation, 35% of the population completed a university degree and 1.3% a doctoral degree. Nordic countries, with Switzerland, the United Kingdom, Germany and Austria have the highest graduation rates at doctoral level in science and engineering.

Graduation rates at doctoral level, 2004
(% of doctorates in the relevant age cohort) **G 2–12**



Source: STI Scoreboard, OECD 2007

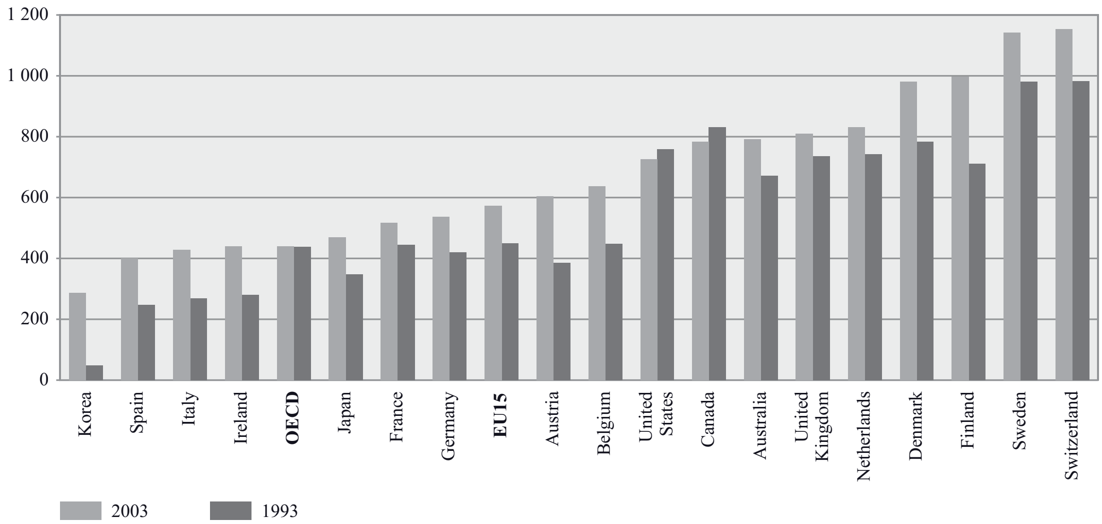
The availability of basic knowledge

Technological innovation, especially in emerging fields, is very close to science. New artefacts are invented in connection with new discoveries, more than it is the case in mature technical fields. It is not by accident that clusters of innovative start-ups usually blossom in the neighbourhood of the most advanced research universities. Hence a country willing to nurture emerging technical fields should make particular efforts in basic scientific research. Counts of scientific journals articles are used as indicators of the performance of scientists, scientific institutions and of countries.

In 2003, some 699 000 new articles in science and engineering (S&E) were reported worldwide, most of which resulted from research carried out by the academic sector. They remain highly concentrated in a few countries. In 2003, almost 84% of world scientific articles were from the OECD area, nearly two-thirds of them in G7 countries. The United States leads with over 210 000.

In order to assess the performance of countries, the number of articles has to be standardised by the population (graph 2–13). The geographical distribution of publications is very similar to that of R&D expenditure, with more S&E articles produced in countries with higher R&D intensity. For instance, in Switzerland and Sweden, output exceeded 1100 articles per million population in 2003. The level of scientific publications is low in Korea and Japan, compared to their R&D efforts, but a statistical bias in publication counts towards English-speaking countries may be part of the reason.

Scientific publications per million population, 2003 and 1993 **G 2–13**

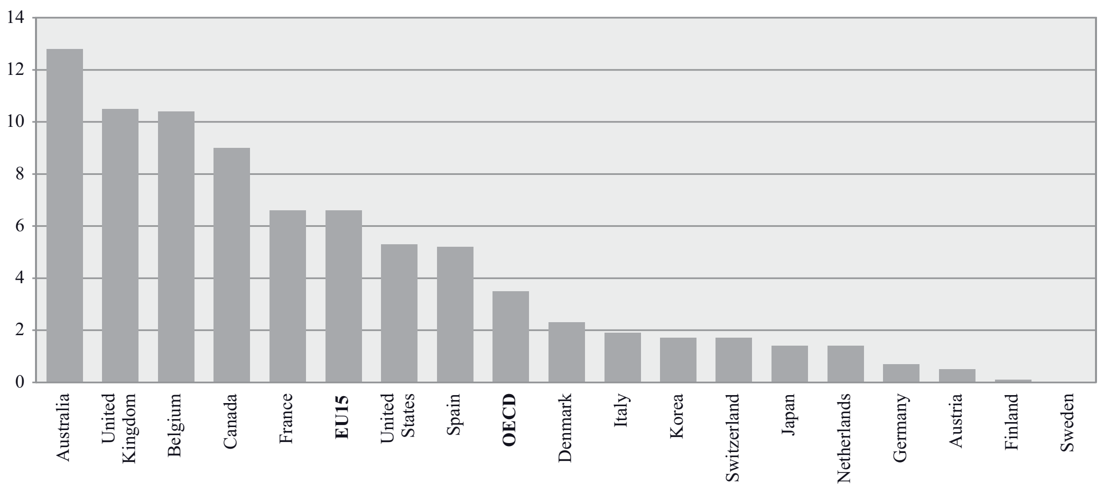


Source: STI Scoreboard, OECD 2007

Universities and government laboratories (public research organisations: PROs), are a unique source of knowledge for industry: To what extent does this potentially essential role materialise across countries? Knowledge transfers from PROs to industry can take several channels. Over the past 25 years, starting in the US and then coming to other OECD countries, PROs have patented more and more of their inventions, with the objective to encouraging their downstream exploitation, notably by the creation of spin-offs and licensing out to start-up companies. The justification is that most enterprises will not engage in costly downstream investment if they are not guaranteed some exclusive rights on the product they are developing on the basis of fundamental knowledge provided by universities. It is then interesting to look at the number of patents taken by PROs across countries (graph 2–14). It shows notably that the EU (led by Belgium, the UK and France) is ahead of the US in that regard, while Nordic countries are far behind Nordic countries are putting more emphasis on other mechanisms of technology transfer.

This is not the whole story however, as another channel for knowledge transfers between PROs (notably universities) and industry is to conduct joint research projects, where the business part provides often the funding while the research is done by university staff. This mechanism is reflected in the share of public research funded by business (graph 2–15). From that perspective, the ranking of countries is quite different: If Canada and Belgium are highly ranked in both indicators, we see Germany, Switzerland or the Netherlands (and Finland and Sweden to a lesser extent) featuring better for funding than for patenting, while the UK and France lag behind. This could show that PROs follow different models across countries in their

Patent applications filed by Public Research Organisations as % of total patents
(EPO, priority year 2001–2003) **G 2–14**



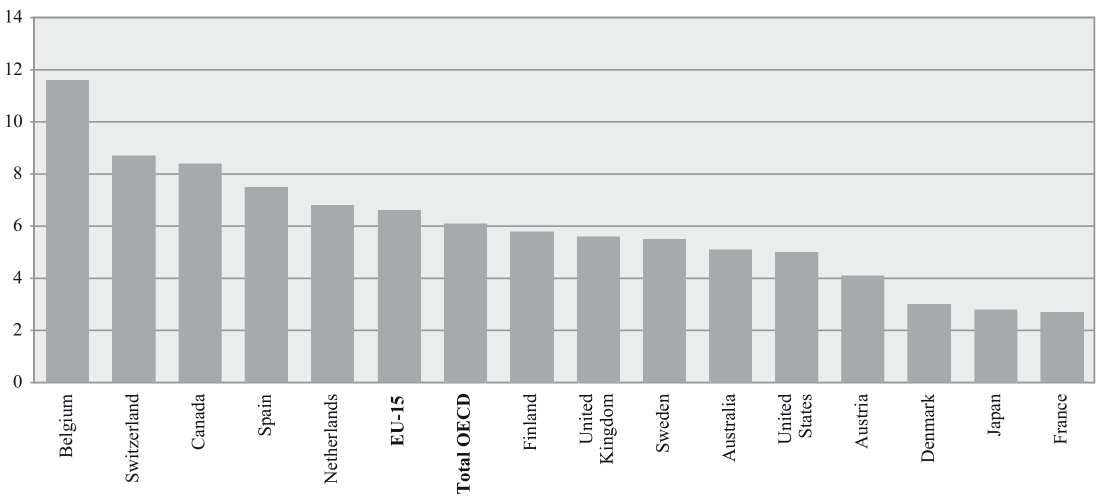
Source: Patent Statistics Compendium 2007, OECD Patents database.

attempt to transfer technology to industry. For instance, in Sweden and in Germany (until a law passed in 2003) patents from collaborative research could be taken by the researchers themselves or by the industry partner, rarely by the university itself. However, the upward time trends in both indicators indicate clearly that in all countries technology transfers are getting more significant.

Venture capital

The standard mechanisms for allocating capital across economic activities, within company planning, capital markets and banks, are not well equipped to address emerging technologies and in particular start-ups. Large, established firms will tend to fund new activities which are in line with their current business, not those which might disrupt it or cannibalise it. Banks are ill-equipped for managing the specific risk patterns of emerging industries, and they are limited by strict prudential regulations. Capital markets are characterised by arm-length relationships between investors and the firms, which limit the quantity of information that can be passed to investors. It is therefore not expected that entirely new activities are started by large, established firms or funded by markets or banks. In fact, capital is allocated to emerging activities mainly through venture capital (VC). Emerging activities are typically developed by new firms, with high risk and high reward. VC has permitted the creation of nearly all successful companies in new industries since World War 2, including Intel, Microsoft, Chiron etc. All prominent internet or biotech start ups have started with VC funding. Biotechnology was developed, starting in the 1980s, by start ups, which would then

Share of university research funded by the business sector (2004) **G 2–15**



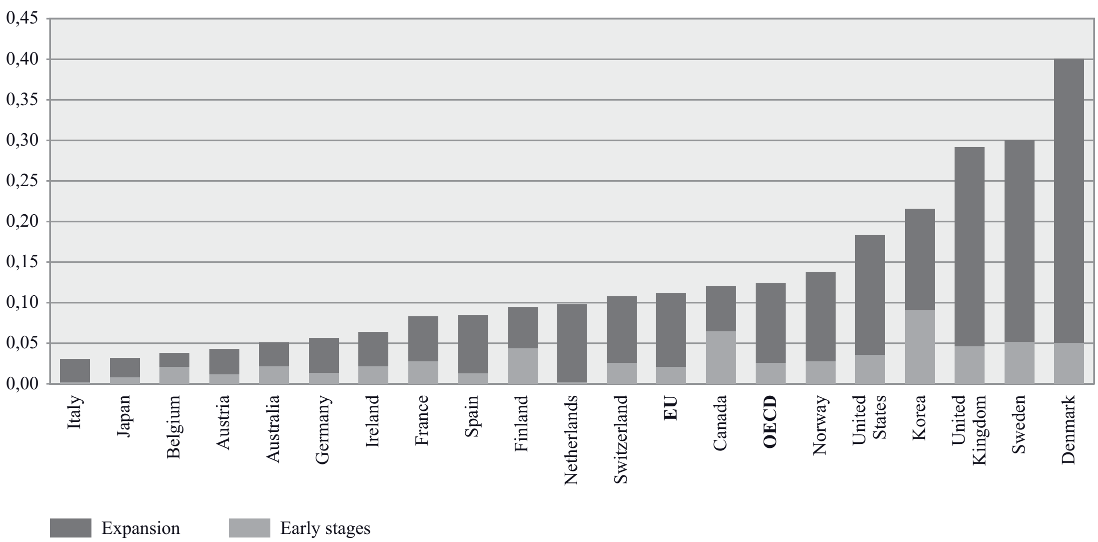
Source: MSTI

(when being successful) possibly be acquired by big pharmaceutical companies as a way for these companies to access biotech knowledge and implement it in their mainstream activities (developing new drugs, tests etc.).

The share of investment allocated by VC funds in proportion of GDP varies significantly across countries (graph 2–16). It is higher in Nordic countries, the UK, Korea, and the US, while continental Europe and Japan lag behind. Actually the correlation between the share of nanotechnology and biotechnology in total patents and the ratio of VC over GDP across OECD (as reported in graphs 2–11 and 2–16 respectively), is higher than 0.5, showing the close association of emerging technologies and venture capital.

The weak development of VC in certain countries is probably one factor which explains the difficulty of nurturing new industrial activities. The degree of development of venture capital in a particular country is related to both supply side and demand side factors. On the supply side are financial regulations (e.g. easiness for institutional investors to channel capital into VC funds; easiness to free the capital back when the investment has succeeded, by an Initial Public Offering). Demand for VC depends on entrepreneurship, and it is affected by the broader conditions of entrepreneurship, such as bankruptcy laws (which influence the distribution of risk between entrepreneurs and fund providers), market openness to new entrants (competition law, public procurement etc.), and by labour market regulation (which command the possibility and cost for new firms to attract and lay off staff). Nordic countries, the UK, Korea and the US seem better positioned in that regard.

Venture Capital investment as a percentage of GDP, 2005 **G 2–16**



Source: OECD Venture capital database. STI Scoreboard 2007

Conclusion

Starting from an analysis of productivity growth across OECD countries, we've seen the contribution of technical change and focused on the key role of emerging technical fields, based on the ability of countries to generate new scientific knowledge and to encourage venture capital and entrepreneurship. Although the complete picture is of course ore complex (notably with a catching up component for certain countries like Ireland or Korea), countries with the highest growth performance, including the US and Nordic countries, are the ones which displayed the highest ability to nurture emerging technical fields –ICT, biotechnology and nanotechnology. It is the countries were conditions for entrepreneurship are the most favourable, allowing them to capture the gains generated by emerging fields. The quality of the higher education system, of the public research system, of the financial regulation, the adequate regulation of product and labour market has encouraged, in various ways, the reallocation of resources to new fields, generating productivity gains which are at the core of economic growth.

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3. THE ROLE OF ICT ON THE SPANISH PRODUCTIVITY SLOWDOWN

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Introduction

Spain and most of the rest of the European Union (EU) countries have experienced a productivity slowdown since the middle of the nineties. During the same period, the United States (US) showed an upsurge of productivity that lasted until now. Information and Communication Technologies (ICT) were soon identified as a major force in the reversal of the productivity slowdown in the US[63]. In contrast, no strong evidence in this direction is still available for most of the EU countries. Many studies concentrate on the aggregate behaviour –referring either to total output or to business sector output. However, it became soon evident that at least a distinction should be drawn between ICT producing sectors and the rest of the economy. Particularly, for those countries without a strong ICT production sector, the classification of the different industries according to the intensity of their ICT use was a great step forward.

We follow this latter approach using a database recently released by the FBBVA Foundation (Mas, Pérez and Uriel, 2005), which provides capital services estimates for thirty three industries and eighteen assets, three of which are ICT assets (software, hardware and communications). We concentrate on the business (non-primary) sectors of the economy. Most likely, this set of industries is the best sample to analyze the productivity performance of a country for two reasons: 1. productivity measurement problems in the non-market sectors and 2. the continuous and intensive increase in productivity observed in the primary sectors as a result of an accelerated process of jobs destruction.

The current absence of information on the ICT producing sectors forced us to concentrate on the impact on productivity of using rather than producing ICT. Accordingly, we partitioned the business sector into two subgroups based on their intensity of ICT use. The evolutions of these two clusters –as well as the individual industries that make up the groups- are analyzed in detail for the period 1985–2004. Then, we follow the well established growth accounting

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63 Bailey (2003), Bailey and Gordon (1988), Colechia and Schreyer (2001), Gordon (1999), Jorgenson and Stiroh (2000), Oliner and Sichel (2000), O'Mahony and Van Ark (2003), Pilat (2003), Stiroh (2002), Van Ark and Timmer (2004) and Timmer and van Ark (2005).

framework to obtain the sources of growth decomposition. This exercise allows us to identify and quantify the contribution to productivity growth -with its corresponding slowdown- made by i) capital deepening –distinguishing ICT from non-ICT capital- ii) improvements in labour qualification, and iii) Total Factor Productivity (TFP).

The structure of the paper is as follows. The first section describes the data. The second section presents the aggregate behaviour, proposes a taxonomy of industries based on the intensity of ICT use and explains their dynamics over the 1985–2004 period. The third section details the time pattern as well as the observed changes in quality experience by labour and capital. The fourth section reports the results of the growth accounting exercise, emphasizing the 2000–2004 recovery of productivity, while the last section presents some concluding remarks.

Data

Output data come from the Spanish National Accounts. Since residential capital is not considered part of the definition of productive capital, we exclude two items from gross value added: namely, rents from dwellings and incomes from private households with employed persons. We measure labour in hours worked. The employment figures come also from National Accounts. The number of hours worked per employed person has been taken from OECD and was available at the Groningen Growth Development Centre, *60 Industry Database*. They assume that the number of yearly working hours by employee is the same in all branches but different throughout time. The labour quality index considers seven types of qualification according to the level of studies. Information on the number of employed workers comes from the *Labour Force Survey (INE, Instituto Nacional de Estadística)* and the corresponding wages from the *Wage Structure Survey*, also compiled by INE for the years 1995 and 2002. The data for capital services come from Mas, Pérez and Uriel (2005). They provide detail for 18 different types of assets, three of which are ICT assets (software, hardware and communications).

Aggregate behaviour and industries dynamics

Table 1 shows the evolution of output, employment (in hours) and labour productivity over the whole period 1985–2004 and also for five different sub-periods. Panel a) refers to the total economy while panel b) concentrates on the business non-primary sectors of the economy (that is, excluding agriculture and fishing as well as all non-market sectors). Graph 3–1 plots the series for the latter aggregate.

First thing to notice is the remarkable influence of the primary and the non-market sectors on the performance of productivity in Spain. Labour productivity grows faster in the total economy than in the business non-primary sector. This is mainly due to different rates of employment growth. Essentially, this effect is brought about by the destruction of employment in the agricultural sector.

T3–1 Real Gross Value Added, Employment (hours worked) and Labor Productivity
annual rates of growth (%)

a) Total economy

	1985–2004	1985–1990	1990–1995	1995–2004	1995–2000	2000–2004
Real GDP	3.21	4.75	0.98	3.57	4.05	3.00
Employment (hours worked)	2.25	3.11	-0.56	3.39	4.05	2.55
Labor productivity per hour worked	0.96	1.64	1.54	0.19	0.00	0.45

b) Total Market (non-primary) Economy

	1985–2004	1985–1990	1990–1995	1995–2004	1995–2000	2000–2004
Real GDP	3.21	4.75	0.98	3.57	4.05	3.00
Employment (hours worked)	2.25	3.11	-0.56	3.39	4.05	2.55
Labor productivity per hour worked	0.96	1.64	1.54	0.19	0.00	0.45

Source: INE and own calculations.

If we concentrate on the business (non-primary) sectors, panel b) informs us that, for the entire period the three variables show a positive trend, but with very different intensities. The average annual growth rate of real output for 1985–2004 was 3.23% and that of employment 2.93%, so productivity grew at a very modest rate of only 0.30%. It is interesting to note that labour productivity growth had different drivers. In the first sub-period (1985–1990) the slight increase in productivity was due to the rapid increase of output (4.78%) over an also significant positive rate of employment creation (4.16%). In the second period (1990–1995) productivity growth was the result of a very modest output growth (0.82%) and a reduction of employment (-0.15%). The combination of both forces made this second period the fastest labour productivity growing sub-period of all. During the period 1995–2000 real GDP grew at a very fast rate (4.12%) but employment creation was even stronger (4.81%). As a consequence, labour productivity growth was negative (-0.69%). Finally, over the last sub-period (2000–2004) both, output (3.18%) and employment (2.94%) slowed down from their previous fast growth rates, allowing a very modest labour productivity recovery of only 0.23% per year.

The aggregate behaviour might hide from view potential differences among the distinct sectors. In fact, the very sharp reduction of agricultural employment over the period –and its corresponding extremely fast productivity growth- recommended the removal of the primary sector (agriculture, cattle farming and fishing) from the analysis. On its part, measurement problems –together with difficulties on how to interpret properly labour productivity improvements- in the public sector recommended to concentrate on the private non-primary branches of the economy.

After these modifications, we were left with information for twenty six industries. The next step was to classify these branches according to their intensity in the use of ICT assets. We have used one basic criterion: the relation between the value of ICT capital and total capital services in each industry over the period 1995–2004. If the ratio of a particular industry is above the average we include it in the Intensive ICT users group. Otherwise, it is considered part of the Non-Intensive ICT users group. Additionally, we use a second indicator: the ratio of ICT capital services over employment (hours worked). The proposed taxonomy of the twenty six industries is shown in table 3–2.

T3–2 Industries taxonomy

I	Intensive ICT users	II	Non-Intensive ICT users
1	Electricity, gas and water supply	9	Food, drink and tobacco
2	Pulp, paper, printing & publishing	10	Textiles, clothing, leather and footwear
3	Electric, electronic & optic equipment	11	Chemicals
4	Transport and communications	12	Rubber & plastics
5	Financial intermediation	13	Other non-metallic mineral products
6	Business services	14	Fabricated metal products
7	Private health & social services	15	Machinery & mechanical equipment
8	Other community, social & personal services	16	Transport equipment manufacturing
		17	Wood & products of wood & cork; Miscellaneous manufacturing
		18	Wholesale & retail trade; Repairs
		19	Hotels & catering
		20	Real estate activities
		21	Private education
		24	Mining and quarrying
		25	Mineral oil refining, coke & nuclear fuel
		26	Construction

Source: INE and own calculations

Table 3–3 shows the weight that each industry –as well as the two clusters- have in the aggregate private non-agricultural sector. The following comments are in order. First, the weight of the Intensive ICT cluster on total gross value added and employment is lower than that of the Non-Intensive. However, the former group has won some weight over the period. More specifically, in 2004 the gross value added generated by the ICT Intensive cluster represented 38.40% of total value, two percentage points more than in 1985 (36.54%). It is interesting to note that not all the industries included in this cluster have experienced an increase in their weight. In fact, only three out of eight had a higher weight in 2004 than in 1985, being Business Services the one experiencing the highest increase, four percentages points (from 5.88% in 1985 to 9.85 in 2004). Only the Construction industry experienced an even higher increase: over five percentage points (from 8.56% in 1985 to 13.97% in 2004).

T3–3 Share of each industry on total market economy. Gross Value Added and Employment (hours worked). Total Market (non-primary) Economy

Percentages

Total	Gross Value Added			Employment (hours worked)		
	1985	1995	2004	1985	1995	2004
TOTAL MARKET (non-primary)	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Intensive ICT users	**36.54**	**38.33**	**38.40**	**30.75**	**32.29**	**32.06**
Electricity, gas and water supply	3.76	3.42	2.40	1.02	0.81	0.54
Pulp, paper, printing & publishing	2.20	2.11	1.93	1.74	1.77	1.67
Electric, electronic & optic equipment	2.42	1.76	1.27	2.10	1.63	1.21
Transport and communications	9.56	9.79	9.59	9.12	7.89	7.31
Financial intermediation	6.70	6.62	6.01	4.60	3.59	2.62
Business services	5.88	7.72	9.85	5.57	8.57	10.16
Private health & social services	1.45	2.32	2.63	1.95	2.63	2.99
Other community, social & personal services	4.58	4.60	4.74	4.67	5.40	5.57
Non-Intensive ICT user	**63.46**	**61.67**	**61.60**	**69.25**	**67.71**	**67.94**
Food, drink and tobacco	5.45	3.98	2.84	4.73	4.12	2.96
Textiles, clothing, leather and footwear	3.45	1.91	1.21	4.78	3.15	2.17
Chemicals	3.06	2.44	2.05	1.81	1.46	1.11
Rubber & plastics	1.08	1.02	0.94	0.87	0.90	0.86
Other non-metallic mineral products	2.32	1.89	1.60	1.92	1.71	1.44
Fabricated metal products	5.05	3.76	3.68	4.13	3.40	3.48
Machinery & mechanical equipment	2.11	1.56	1.53	1.79	1.53	1.42
Transport equipment manufacturing	2.07	2.70	2.30	2.92	2.42	2.07
Wood & products of wood & cork; Miscellaneous manufacturing	2.30	1.72	1.47	3.18	2.82	2.44
Wholesale & retail trade; Repairs	15.46	15.51	14.27	20.51	21.32	19.99
Hotels & catering	6.40	9.51	9.93	7.45	8.51	8.77
Real estate activities	2.29	2.58	3.08	0.91	0.75	1.19
Private education	1.80	1.92	1.92	2.30	2.38	2.28
Mining and quarrying	0.97	0.55	0.36	1.02	0.50	0.26
Mineral oil refining, coke & nuclear fuel	1.08	0.57	0.43	0.11	0.08	0.06
Construction	8.56	10.05	13.97	10.82	12.65	17.43

Source: INE and own calculations

Secondly, notice that employment followed a similar time pattern in the ICT Intensive cluster, but with a lower weight in total employment than in value added. In 2004, employment in this cluster represented 32.06% of the total versus 38.40% in terms of value added. As a consequence, labour productivity was higher in this cluster. Table 3–4 provides the figures. Taken together, labour productivity was almost 30% higher in the ICT Intensive cluster in 2004. However, the behaviour of the eight branches included in this group is not homogenous.

In fact, three of them presented in 2004 lower than average productivity levels. Table 3–4 shows also the sectors with the lowest productivity levels in that year, namely, Textiles, clothing, leather and footwear; Wood & products of wood & cork; and the Construction industry, the three of them belonging to the Non-ICT intensive cluster.

T3–4 Labour productivity

Total market (non-primary) = 100

	1985	1995	2004
TOTAL MARKET (non-primary)	**100.00**	**100.00**	**100.00**
Intensive ICT users	**122.46**	**118.71**	**129.73**
Electricity, gas and water supply	347.90	424.29	698.32
Pulp, paper, printing & publishing	141.67	119.28	130.45
Electric, electronic & optic equipment	61.98	108.13	129.23
Transport and communications	97.17	124.11	144.82
Financial intermediation	188.20	184.23	243.69
Business services	110.12	90.08	97.54
Private health & social services	106.44	87.99	82.08
Other community, social & personal services	99.42	85.09	85.87
Non-Intensive ICT user	**90.02**	**91.08**	**85.97**
Food, drink and tobacco	98.42	96.64	109.70
Textiles, clothing, leather and footwear	54.16	60.68	62.61
Chemicals	141.98	167.17	199.56
Rubber & plastics	113.38	114.34	133.37
Other non-metallic mineral products	90.87	110.30	127.61
Fabricated metal products	104.47	110.60	113.51
Machinery & mechanical equipment	78.77	102.06	122.17
Transport equipment manufacturing	74.80	111.35	118.87
Wood & products of wood & cork; Miscellaneous manufacturing	59.85	61.04	66.82
Wholesale & retail trade; Repairs	80.90	72.73	70.39
Hotels & catering	121.20	111.76	94.41
Real estate activities	259.89	341.31	216.35
Private education	72.19	80.48	77.01
Mining and quarrying	67.79	110.15	126.17
Mineral oil refining, coke & nuclear fuel	522.36	719.45	653.96
Construction	83.74	79.44	65.53

Source: INE and own calculations

Table 3–5 presents the dynamics of the 26 industries over the analyzed period. It shows the contribution of each industry –and cluster- to aggregate GVA, employment, and labour productivity growth . As it can be seen, the ICT Intensive cluster has been the most dynamic group over the last decade, with a contribution to GVA growth ten points higher than its weight in total GVA, and with a similar contribution in terms of employment. As a result, the contribution of this cluster to labour productivity growth in the period 1995–2004 is remarkable. While the aggregate GVA presented a negative value of -0.29% the contribution of the ICT Intensive cluster was positive (0.52), thanks mainly to Transport and Communication (0.20), Financial Intermediation (0.19) and Electricity, gas and water supply (0.14). In contrast, the contributions of two of the industries of this cluster (Business Services and Other community, social and personal services) were negative. Finally, it is interesting to notice that the positive contribution to productivity of the ICT Intensive cluster is exactly compensated by the reduction (0.52) shown by the Construction industry. In fact, three industries concentrate the responsibility of the Spanish productivity decline: Construction (-0.52); Wholesale & Retail trade; Repairs (-0.28); and Hotels and Catering (-0.16). If we eliminated their negative contribution, labour productivity growth would be 0.67%, instead of the actual negative rate of -0.29% over the period 1995–2004.

The sources of growth

We have considered the two traditional factors of production, labour and capital, but we have taken into account explicitly differences in their quality.

Capital accumulation

The FBBVA/Ivie dataset allows us to distinguish among 18 different capital assets, three of which (Software, Communication and Hardware) are ICT assets. Table 3–6 presents these figures. The rate of accumulation of non-residential capital in Spain was quite strong over the 1995–2004 period, averaging an annual rate of 5.64%, almost one point higher than in the previous decade (4.85%). The ICT capital growth rates almost doubled those of total capital, reaching 9.7% in both sub-periods. Non-ICT capital accumulation was more modest and stronger in the period 1995–2004 than in the previous one. As expected, ICT capital accumulation concentrated on the ICT Intensive branches, specifically in Business Services and Financial Intermediation. In the sub-period 1995–2004 over 68% of total ICT capital growth originated in the ICT Intensive cluster.

Labour qualification

Spain has experienced a great transformation in labour qualification over the period under study. Table 3–7 shows that only 20 years ago, 61.30% of the Spanish workers had a level of education no higher than primary school, and 8.61% were illiterate or had no studies at all . In 2004 these numbers had been reduced to 18.98% and 2.51% respectively. On the opposite side of the educational range only 7.64% of the workers had a college educational level in 1985. This percentage had risen to 18.24% in 2004. However, the most radical change took place at the secondary school level (including professional training) where the rate rose from 31.04% in 1985 to 62.78% in 2004. As a result of this outstanding change, the proportion of Spanish workers with at least a secondary school level of education more than doubled, rising from 38.7% in 1985 to 81.02% in 2004.

T3–5 Industries contribution to real GVA, employment and productivity growth. Labor productivity. Total Market (non-primary) Economy

Percentages

	GVA		Employment		Productivity	
	1985–1995	1995–2004	1985–1995	1995–2004	1985–1995	1995–2004
TOTAL MARKET (non-primary)	**2.82**	**3.69**	**2.00**	**3.98**	**0.81**	**-0.29**
Intensive ICT users	**1.16**	**1.77**	**0.79**	**1.25**	**0.37**	**0.52**
Electricity, gas and water supply	0.09	0.14	0.00	0.00	0.09	0.14
Pulp, paper, printing & publishing	0.03	0.08	0.04	0.06	-0.01	0.02
Electric, electronic & optic equipment	0.12	0.04	-0.01	0.01	0.13	0.03
Transport and communications	0.37	0.44	0.05	0.24	0.32	0.20
Financial intermediation	0.01	0.21	-0.02	0.01	0.03	0.19
Business services	0.35	0.57	0.45	0.55	-0.10	0.02
Private health & social services	0.07	0.11	0.11	0.15	-0.04	-0.04
Other community, social & personal services	0.12	0.19	0.17	0.24	-0.05	-0.04
Non-Intensive ICT user	**1.66**	**1.92**	**1.21**	**2.73**	**0.44**	**-0.81**
Food, drink and tobacco	0.06	0.05	0.03	0.01	0.03	0.04
Textiles, clothing, leather and footwear	-0.01	0.00	-0.09	0.00	0.08	0.00
Chemicals	0.06	0.06	0.00	0.01	0.07	0.05
Rubber & plastics	0.03	0.05	0.02	0.03	0.01	0.02
Other non-metallic mineral products	0.08	0.06	0.02	0.03	0.06	0.03
Fabricated metal products	0.06	0.16	0.00	0.15	0.06	0.01
Machinery & mechanical equipment	0.07	0.08	0.01	0.05	0.06	0.03
Transport equipment manufacturing	0.12	0.07	0.00	0.05	0.11	0.02
Wood & products of wood & cork; Miscellaneous manufacturing	0.04	0.05	0.02	0.06	0.01	-0.01
Wholesale & retail trade; Repairs	0.33	0.39	0.50	0.67	-0.17	-0.28
Hotels & catering	0.26	0.21	0.27	0.37	0.00	-0.16
Real estate activities	0.09	0.11	0.00	0.09	0.09	0.02
Private education	0.08	0.05	0.06	0.08	0.02	-0.03
Mining and quarrying	0.00	-0.01	-0.04	-0.01	0.04	0.00
Mineral oil refining, coke & nuclear fuel	0.02	0.00	0.00	0.00	0.02	0.00
Construction	0.36	0.61	0.42	1.13	-0.06	-0.52

Source: INE and own calculations

We have constructed a synthetic index of labour qualification based on the growth rates of employment in each of the seven levels of education, weighted by their relative wages . The index improves if the high-educated workers gain weight in total employment, improving the composition of the labour force towards higher skilled workers. Table 3–8 shows the profiles of the contributions to the index made by the different educational levels. We see a continuous improvement of the index over the whole period, intensified after 1995. This is the result of two complementary elements: a higher rate of employment creation and a simultaneous improvement in education, particularly at the college level.

T3–6 Industries contribution to capital services growth. Total Market (non-primary) Economy

Percentages

	Total		ICT Capital		Non-ICT Capital	
	1985–1995	1995–2004	1985–1995	1995–2004	1985–1995	1995–2004
TOTAL MARKET (non-primary)	**4.85**	**5.64**	**9.74**	**9.70**	**3.98**	**4.66**
Intensive ICT users	**2.44**	**2.79**	**7.31**	**6.63**	**1.51**	**1.86**
Electricity, gas and water supply	0.01	0.17	0.23	0.18	-0.03	0.17
Pulp, paper, printing & publishing	0.16	0.12	0.24	0.21	0.15	0.10
Electric, electronic & optic equipment	0.14	0.16	0.38	0.39	0.10	0.10
Transport and communications	0.88	1.08	2.15	2.85	0.65	0.66
Financial intermediation	0.51	0.32	2.55	1.37	0.10	0.07
Business services	0.41	0.53	0.92	0.95	0.32	0.42
Private health & social services	0.04	0.07	0.09	0.17	0.03	0.05
Other community, social & personal services	0.29	0.34	0.74	0.50	0.21	0.30
Non-Intensive ICT user	**2.42**	**2.85**	**2.43**	**3.07**	**2.47**	**2.80**
Food, drink and tobacco	0.24	0.31	0.32	0.35	0.15	0.30
Textiles, clothing, leather and footwear	0.06	0.06	0.10	0.12	0.14	0.05
Chemicals	0.07	0.15	0.16	0.20	0.05	0.14
Rubber & plastics	0.06	0.07	0.06	0.08	0.17	0.07
Other non-metallic mineral products	0.16	0.11	0.16	0.15	0.07	0.10
Fabricated metal products	0.15	0.14	0.20	0.21	0.14	0.12
Machinery & mechanical equipment	0.06	0.06	0.10	0.09	0.05	0.05
Transport equipment manufacturing	0.16	0.25	0.14	0.23	0.17	0.25
Wood & products of wood & cork; Miscellaneous manufacturing	0.07	0.08	0.08	0.11	0.07	0.07
Wholesale & retail trade; Repairs	0.56	0.66	0.69	0.94	0.54	0.60
Hotels & catering	0.20	0.17	0.12	0.11	0.22	0.19
Real estate activities	0.43	0.41	0.10	0.17	0.50	0.47
Private education	0.02	0.04	0.02	0.05	0.02	0.03
Mining and quarrying	0.01	0.03	0.02	0.02	0.00	0.03
Mineral oil refining, coke & nuclear fuel	-0.01	0.02	0.03	0.03	-0.02	0.02
Construction	0.19	0.29	0.12	0.21	0.20	0.31

Source: INE and own calculations

It is interesting to note that over the years 1995–2004 the contribution to the labour qualification index of the ICT Intensive cluster is almost twice as large as that of the Non-Intensive group (0.89 vs. 0.46). These figures strongly contrast with the contribution of each cluster to total employment growth, 1.25 the ICT Intensive cluster vs. 2.73 the Non-ICT Intensive (see table 3–5). The main contributors to the improvement of the labour qualification index belonged to the ICT Intensive ICT group, standing out Business services (0.41); Transports & communications (0.12); and Financial intermediation (0.11). We consider these results of great relevance for the analysis of the ICT contribution to Spanish growth to which we now turn in the next section.

T3–7 Employment structure by educational levels. Total Market (non-primary) Economy
Percentages

	1985	1995	2004
TOTAL MARKET (non-primary)	**100.00**	**100.00**	**100.00**
Illiterate	8.61	5.48	2.51
Primary Education	52.69	31.13	16.47
Secondary Educ. (1st level)	18.42	27.67	30.85
Secondary Educ. (2nd level)	9.12	10.53	14.10
Professional Training	3.50	13.62	17.83
Tertiary Educ. (1st level)	3.73	5.24	7.46
Tertiary Educ. (2nd level)	3.91	6.32	10.78

Source: INE and own calculations

Growth accounting. 1995–2004

We now have the necessary ingredients to analyze the impact of ICT use on Spanish growth over the period 1985–2004. We concentrate in this period since it is when Spanish productivity slowdown took place. The impact of ICT on output and productivity growth can follow several transmission mechanisms that can be summarized in three different testing hypotheses : 1. Labour productivity gains are due to capital deepening (ICT and non ICT). 2. TFP gains should be observed mainly in the ICT producing sector, since this is the sector where most of the genuine technological progress takes place. 3. ICT using industries could show additional labour productivity gains arising from spillover effects and/or embodied technical progress. In our study, the data set does not identify the ICT producing sector of the economy so that hypothesis 2 cannot be tested yet. However we know from other indicators that the relative weight of the Spanish ICT production sector is not very large. Consequently, we turn our attention to hypotheses 1 and 3.
Suppose that the production function is given by

Qt = g (KPt, HLt, KHt, B) (1)

where Qt = real output, KPt = productive capital (a volume index of capital services), HLt= employment (hours worked), KHt, = human capital (index of labour qualification) and B = the level of efficiency in the use of productive factors. Standard growth accounting assumptions allow us to obtain

$$\Delta \ln Q_t = \overline{w}^{HL} \Delta \ln HL + \overline{w}^{ICT} \Delta \ln KP^{ICT} + w^{O} \Delta \ln KP^{O} + \Delta TFP \qquad (2)$$

$\overline{w}_t^{\chi} = 0.5\left[w_t^{\chi} + w_{t-1}^{\chi} \right]$ for χ = *HL, ICT* and *O* (= the aggregation of 14 other non-ICT non residential assets).

T3–8 Industries contribution to the labour qualification index growth. Total Market (non-primary) Economy

Percentages

	1985–1995	1995–2004
TOTAL MARKET (non-primary)	**0.96**	**1.35**
Intensive ICT users	**0.63**	**0.89**
Electricity, gas and water supply	0.02	0.02
Pulp, paper, printing & publishing	0.05	0.04
Electric, electronic & optic equipment	-0.03	0.03
Transport and communications	0.13	0.12
Financial intermediation	0.14	0.11
Business services	0.21	0.41
Private health & social services	0.13	0.09
Other community, social & personal services	-0.02	0.06
Non-Intensive ICT user	**0.33**	**0.46**
Food, drink and tobacco	-0.07	0.09
Textiles, clothing, leather and footwear	0.01	-0.05
Chemicals	-0.02	0.03
Rubber & plastics	-0.01	-0.01
Other non-metallic mineral products	-0.01	0.01
Fabricated metal products	-0.04	0.01
Machinery & mechanical equipment	0.06	0.01
Transport equipment manufacturing	0.01	0.05
Wood & products of wood & cork; Miscellaneous manufacturing	0.01	0.03
Wholesale & retail trade; Repairs	0.05	0.15
Hotels & catering	0.13	0.05
Real estate activities	0.05	0.02
Private education	0.06	0.03
Mining and quarrying	0.01	0.01
Mineral oil refining, coke & nuclear fuel	0.00	0.01
Construction	0.08	0.00

Source: INE and own calculations

In equation [2] the labour share is defined as

$$w_t^{HL} = \frac{\sum_i CE_{i,t}}{TC_t} \qquad (3)$$

where CEi is labour compensation on the ith sector and TCt is total cost defined as

$$TC_t = \sum_j \sum_i VCS_{j,i,t} + \sum_i CE_{i,t}$$

The value of capital services is defined as

$$VCS_{j,i,t} = p_{j,t-1}[r_t + d_t - f_{j,t}]KP_{j,i,t-1}$$

where, in turn, $p_{j,t}$ is the price of asset *j*, $f_{j,t}$ its rate of variation (computed as a three year centered moving average), r_t is the nominal interest rate and $d_{j,t}$ is the depreciation rate of asset *j*.

The share of ICT-capital is defined as

$$w_t^{ICT} = \sum_{j \in ICT} \sum_i \frac{VCS_{j,i,t}}{TC_t} \quad (4)$$

Similarly for the share of non-ICT, non residential capital

$$w_t^0 = \sum_{j \in 0} \sum_i \frac{VCS_{j,i,t}}{TC_t} \quad (5)$$

The growth rate of each variable in [2] is computed as a Törnqvist index. Thus, for ICT capital, its growth rate is defined as

$$\Delta \ln KP^{ICT} = \ln KP_t^{ICT} - \ln KP_{t-T}^{ICT} = \frac{1}{T}\left[\sum_{j=s,h,c} \sum_i \bar{v}_{j,t} (\ln KP_{j,i,t} - \ln KP_{j,i,t-T})\right] \quad (6)$$

where $\bar{v}_{j,t} = 0.5\left[\frac{VCS_{j,i,t}}{\sum_{j=s,h,c}\sum_i VCS_{j,i,t}} + \frac{VCS_{j,i,t-T}}{\sum_{j=s,h,c}\sum_i VCS_{j,i,t-T}}\right]$

With s = software*;* h = hardware; and c = communications. Finally, the rate of growth of labour productivity will be given by:

$$\Delta \ln Q - \Delta \ln HL = \bar{w}^{ICT}\left[\Delta \ln KP^{ICT} - \Delta \ln HL\right] + \quad (7)$$
$$w^O\left[\Delta \ln KP^O - \Delta \ln HL\right] + \Delta TFP$$

Table 3–9 shows the aggregate growth accounting results, referring to the last decade. In the upper part it contains the gross value added decomposition. In the middle part it shows the decomposition of labour productivity as given by equation [7]. Finally, the bottom part –containing the contributions of labour qualification and the estimates of *TFP*- is shared by both equations.

T3–9 Growth Accounting. Total Market (non-primary) Economy

Percentages

	1995–2004	1995–2000	2000–2004
1. Real GVA growth (=2+8+16+17)	3.69	4.12	3.18
2. Capital contribution (=3+7)	1.34	1.40	1.12
3. ICT (=4+5+6)	0.45	0.54	0.33
4. Software	0.09	0.11	0.07
5. Communications	0.13	0.16	0.10
6. Hardware	0.23	0.27	0.16
7. Non-ICT	0.89	0.86	0.79
8. Working hours contribution	3.03	3.71	2.29
9. Labor productivity growth (= 10+16+17)	-0.29	-0.69	0.23
10. Contribution of capital endowments per hour worked (=11+15)	0.39	0.30	0.46
11. ICT (=12+13+14)	0.26	0.31	0.19
12. Software	0.04	0.05	0.02
13. Communications	0.04	0.05	0.04
14. Hardware	0.18	0.21	0.13
15. Non-ICT	0.13	-0.01	0.27
16. Labor force qualification	1.03	1.06	1.18
17. TFP	-1.71	-2.05	-1.41

Source: Own calculations

Over the period 1995–2004 real GVA grew at an annual rate of 3.69%. It was mainly due to the strong impulse of employment creation (3.03%), accompanied by improvements in its qualification (1.03%), as well as in increases in capital endowments (1.34%). TFP contributed negatively (-1.71%) to output growth.

This result can be interpreted in two ways: i) as a confirmation of the incapacity of Spain to extract all the benefit from the large improvements in workers' training and educational levels and ii) as evidence that –at least apparently- the quality of capital goods has not been used up by the productive system, showing up as an inefficiency factor. Labour productivity presented a negative growth rate (-0.29%) again as a consequence of the negative TFP behaviour, while the improvements in the capital/labour ratio (0.39) and in the qualification of labour (1.03) were both positive. ICT capital deepening contribution to productivity growth (0.26) is twofold that of Non ICT capital (0.13). Hardware shows the highest contribution (0.18), higher even than total Non-ICT capital.

When distinguishing between the two sub-periods it is worth noticing that the negative sign of labour productivity growth over the whole period was originated in the first sub-period, 1995–2000. It was then when its growth rate declined sharply to -0.69%. It was the consequence of both, the worsening of the negative TFP contribution and a severe drop in Non-ICT capital deepening. Labour productivity shows a less negative pattern over the most recent sub-period, 2000–2004. This is the result of the recovery of Non ICT capital deepening and the reduction of the inefficiencies captured by the TFP term that, though still presenting a negative contribution, was reduced substantially.

Table 3–10 shows the factors lying behind the improvement experienced by the Spanish economy since 2000. The recovery is due to the positive behaviour of the ICT Intensive cluster, which experienced a labour productivity growth of 1.43%. Contrarily, the corresponding rate for the Non ICT Intensive cluster was negative, -0.52%. All sources of growth in the ICT Intensive cluster contributed positively, even TFP growth (0.09) but specially, labour qualification (0.74) and capital deepening (0.60) of both, ICT (0.30) and Non ICT capital (0.30). In contrast, the Non ICT Intensive cluster experienced a negative TFP growth rate (1.28%), together with modest increases of the remaining sources of growth.

Table 3–11 takes a closer look to the data by industry allowing us to conclude that: 1. the positive TFP contribution in the ICT Intensive cluster is originated in only two sectors: Electricity, gas & water supply and Financial Intermediation. The remaining six industries presented negative TFP contributions. In the Non ICT Intensive cluster, all branches presented negative TFP contributions with only one exception, Fabricated metal products. 2. This latter industry, together with Financial Intermediation, were the only branches showing negative contributions of the labour quality index; 3. Total capital deepening was particularly intense in two industries belonging to the ICT Intensive cluster, Electricity, gas & water supply, and Electric, Electronic and optic equipment; and it was negative in only two branches belonging to the Non-ICT intensive group, Fabricated metal products and Real Estate Activities. Finally, Financial Intermediation was, by far, the industry showing the highest contribution of ICT capital deepening to labour productivity growth.

T3–10 Growth Accounting. Total Market (non-primary) Economy. 2000–2004

Percentages

	Total	Intensive ICT users	Non-Intensive ICT users
1. Real GVA growth (=2+8+16+17)	3.18	4.43	2.40
2. Capital contribution (=3+7)	1.12	1.42	0.92
3. ICT (=4+5+6)	0.33	0.57	0.17
4. Software	0.07	0.17	0.00
5. Communications	0.10	0.19	0.04
6. Hardware	0.16	0.22	0.12
7. Non-ICT	0.79	0.85	0.76
8. Working hours contribution	2.29	2.18	2.36
9. Labor productivity growth (= 10+16+17)	0.23	1.43	-0.52
10. Contribution of capital endowments per hour worked (=11+15)	0.46	0.60	0.37
11. ICT (=12+13+14)	0.19	0.30	0.11
12. Software	0.02	0.08	-0.01
13. Communications	0.04	0.06	0.02
14. Hardware	0.13	0.17	0.11
15. Non-ICT	0.27	0.30	0.25
16. Labor force qualification	1.18	0.74	0.39
17. TFP	-1.41	0.09	-1.28

Source: Own calculations

T 3–11 Growth Accounting. 2000–2004. Labor Productivity

Percentages

	Labor productivity	Capital deepening per hour worked						Labor force qualification	TFP
		Total	ICT				Non-ICT		
			Total	Software	Communi-cations	Hardware			
TOTAL MARKET (non-primary)	**0.23**	**1.48**	**1.21**	**0.02**	**0.04**	**0.13**	**0.27**	**1.18**	**-1.41**
Intensive ICT users	**1.43**	**0.60**	**0.30**	**0.08**	**0.06**	**0.17**	**0.30**	**0.74**	**0.09**
Electricity, gas and water supply	4.34	2.38	0.19	0.07	0.03	0.09	2.20	0.66	1.29
Pulp, paper, printing & publishing	1.47	0.29	0.22	-0.05	0.09	0.17	0.07	2.88	-1.70
Electric, electronic & optic equipment	2.59	2.44	0.62	0.11	0.12	0.39	1.82	1.82	-1.68
Transport and communications	0.67	0.83	0.44	0.12	0.19	0.12	0.39	0.44	-0.59
Financial intermediation	5.06	1.40	1.21	0.86	0.01	0.34	0.19	-0.40	4.07
Business services	1.68	0.29	0.06	-0.14	0.04	0.16	0.23	3.81	-2.41
Private health & social services	-0.01	0.32	0.25	0.01	0.00	0.23	0.07	2.05	-2.38
Other community, social & personal services	0.58	0.62	0.03	-0.09	-0.03	0.16	0.58	1.30	-1.33
Non-Intensive ICT user	**-0.52**	**0.37**	**0.11**	**-0.01**	**0.02**	**0.11**	**0.25**	**0.39**	**-1.28**
Food, drink and tobacco	1.85	2.03	0.33	0.01	0.10	0.22	1.70	1.84	-2.03
Textiles, clothing, leather and footwear	-0.17	1.51	0.35	0.05	0.11	0.19	1.16	1.07	-2.75
Chemicals	3.03	1.71	0.34	0.05	0.09	0.20	1.37	2.03	-0.71
Rubber & plastics	2.34	1.17	0.25	0.00	0.08	0.17	0.92	1.65	-0.48
Other non-metallic mineral products	1.56	1.51	0.31	0.05	0.12	0.13	1.20	2.14	-2.09
Fabricated metal products	0.69	-0.19	0.11	-0.01	0.02	0.09	-0.30	-0.19	1.07
Machinery & mechanical equipment	1.77	0.66	0.16	0.01	0.05	0.10	0.50	1.29	-0.18
Transport equipment manufacturing	0.22	2.27	0.29	0.00	0.10	0.19	1.98	2.59	-4.64
Wood & products of wood & cork; Miscellaneous manufacturing	0.21	1.07	0.27	0.03	0.09	0.16	0.80	1.26	-2.13
Wholesale & retail trade; Repairs	-1.02	0.44	0.15	-0.02	0.02	0.15	0.29	0.64	-2.10
Hotels & catering	-2.27	0.03	0.00	-0.02	0.01	0.02	0.03	0.48	-2.78
Real estate activities	-3.08	-1.63	0.06	-0.10	0.02	0.13	-1.69	0.57	-2.03
Private education	-0.95	0.30	0.10	0.01	0.00	0.08	0.20	0.17	-1.42
Mining and quarrying	2.97	2.75	0.20	-0.01	0.18	0.03	2.55	0.29	-0.07
Mineral oil refining, coke & nuclear fuel	-3.66	0.78	0.43	0.10	0.29	0.04	0.35	4.39	-8.83
Construction	-0.66	0.09	0.06	0.00	0.00	0.06	0.03	0.76	-1.52

Source: own calculations

Probably the most remarkable result of the Spanish experience in recent years is the negative contribution of TFP to economic growth. A first potential answer to this fact could be associated with measurement problems, almost always present in this type of exercises. But there are some additional factors that can explain why the full benefits on TFP of using ICT are not observable as yet in Spain -as well as in some other EU countries.

A short list would contain the following items: 1. Small presence of ICT producing sectors; 2. Relative small share of ICT investment on total investment (this ratio was lower in Spain in 2000 than in the US in 1980. Additionally, while in 2000 this share was over 30% in the US, it barely reached 15% in Spain. 3. Low penetration of ICT assets (in 2004, the number of personal computers per capita was 0.27 in Spain against 0.74 in the US and 0.46 in the EU); 4. Very poor technical formation and training (in 2003, over 70% of the Spanish population declared that they could not use technological instruments/equipments and over 60% computers. For the EU, the corresponding percentages were 50% and 40% respectively); 5. Low use of ICT at schools (in 2002 only 70% of the Spanish schools used Internet for educational purposes while in the EU the percentage was 80%, and in Finland, Sweden and Denmark 100%). 6. Higher cost of ICT (the access cost to Internet in Spain doubles that of the US).

Concluding remarks

Thanks to the new series on capital services by assets we have been able to analyze the growth patterns of Spain over the 1995–2004 period, distinguishing the contributions of ICT and non ICT capital, as well as their components. The results at the macro level are derived from the aggregation of the twenty six branches belonging to the market economy - excluding primary sectors- and the two categories in which these have been grouped according to their intensity in the use of ICT assets.

The lack of data has not allowed us to analyze the direct impact of the ICT production sector. From other studies we know that this mechanism has been found very relevant in countries that have a large ICT production sector. This is not the case of Spain. Consequently, we have limited the study to the impact of ICT on aggregate growth and productivity through the numerous sectors that use, but not produce, ICT capital. In this sense, we consider Spain more an ICT user than an ICT producer country, although neither should it be regarded as a very intensive user country.

Productivity has become a major issue in Spain mainly because it has shown a negative growth rate during the period 1995–2004. However, this rate has become slightly positive over the period 2000–2004 after a sharp drop experienced in the previous five years. The driver of this upturn must be found in the ICT Intensive cluster. This group has been the most dynamic one in terms of output, employment, capital deepening –ICT in particular– and labour quality improvements. Its contribution to growth has been always higher than its share in the economy. However, there exists an important degree of heterogeneity among the different industries included in the ICT cluster. In fact, a given industry cannot be considered all the time the most dynamic one since the ranking changes from period to period.

Over the period 1995–2004 the main engines of labour productivity growth were the improvements in labour qualification and capital deepening, particularly ICT capital, whereas the contribution of TFP –computed as a residual- was negative. The severe drop in labour productivity during the years 1995–2000 was motivated by a deterioration of TFP growth, together with a negative contribution of Non ICT capital deepening. The modest upturn of labour productivity in the last sub-period, 2000–2004, had its origin in the ICT Intensive user cluster, which presented an annual growth rate of 1.43% against -0.52% for the Non ICT Intensive cluster. All the sources of growth contributed to this recovery, including TFP. However, a closer look into individual branches informed us that only two industries –Electricity, gas and water supply and Financial Intermediation- were to be acknowledged for such recovery.

The main conclusion that we reach in this study is that, in Spain, the (presumably beneficial) full effects of ICT capital on total factor productivity growth are not observable as yet. A late start –as illustrated by the evidence provided in the previous section– is probably one of the main reasons for not finding yet clear evidence of a productivity pick up induced by ICT technologies. Also some structural features –like the country's productive structure or its low starting level of labour qualification– can explain this delay in experiencing the positive effects on productivity of a strong ICT technology push. Last, but not least, the reason explaining the poor behaviour not only of Spain but also of most of the EU non ICT producing countries can most probably be found in measurement problems.

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4. MULTI-FACTOR PRODUCTIVITY MEASUREMENT from Data Pitfalls to Problem Solving – the Swiss Way

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Introduction

During the past 15 years, the Swiss economy faced sluggish growth and a rise of its unemployment rate. While still low compared to other countries the rise of unemployment triggered political discussions about the relative competitiveness of the Swiss economy. Much attention was then devoted to measurement issues of labor productivity. This focus on labor productivity partly resulted from a lack of data on capital stocks and multifactor productivity (MFP). Another factor was the lack of experience of countries like Switzerland regarding measurement issues and interpretation of results of capital stocks and MFP. In this context, the Organisation for Co-operation and Development (OECD) was a key driver when it published two manuals[64] describing the concept and measurement of capital services and their relation to the measures of gross capital stock. The Swiss Federal Statistical Office (SFSO) relied of this new conceptual framework and started work on experimental series of capital stocks, capital services and MFP. The intent was twofold:

- To have new information on the stock of capital assets which could be used in parallel to the stock of financial assets which the SFSO recently developed in cooperation with the Swiss National Bank (SNB);
- To provide a new analytical framework where contributions of capital input and labor input could be associated with the evolution of MFP.

The work of the SFSO was constrained by three factors:

- First, no additional surveys could be carried out specifically for this field of study. Swiss enterprises have a feeling that the statistical burden is already high enough, and any new analytical output thus has to rely on existing data.
- Second, a central concern was the coherence with the central data framework of the Swiss National Accounts (N.A). By sticking to the central framework of N.A, international comparability should be guaranteed to a great extent.
- Third, work carried out in Switzerland ought to integrate conceptual developments carried out since the publication of the OECD manuals in 2001. In particular, it should draw upon discussions on "best practices" for the rate of return and for the age-efficiency and age-price profiles of capital goods.

64 OECD (2001a) and OECD (2001b).

- The conceptual framework of the OECD was an invaluable help during the whole process. Work started in 2005 with the first estimate of the capital stock based on N.A inputs. The results had to be set in a more general context and some new questions like the choice of the depreciation profile became more prominent. Step by step the team in charge of the project worked its way through new concepts and measurement issues. The constraints mentioned above limited the spectrum of technical possibilities, but outcomes are sound and coherent with the central framework of N.A. Just before the OECD workshop, the SFSO published a whole data set on contributions of capital and labor inputs to growth, and rates of change of MFP with various subcomponents, for the period 1991 to 2004.

This paper provides an overview of the concepts and methods underlying capital stock measures in Switzerland (second chapter), capital services (third chapter) and MPF profiles (fourth chapter). A final chapter discusses some of the consequences of the options chosen.

Capital stock measures

Definition

The capital stock encompasses all produced assets which are included in the production process. For analytical purposes, it is useful to define various kinds of assets.

Based on the System of National Accounts (SNA 1995), the typology of assets relies on two criteria. The first criterion is the distinction between produced and non-produced fixed assets[65]. A produced fixed asset is defined as a result of a production process. Thus, it is possible to differentiate for instance a building from an oil field. The second criterion is the tangibility of the fixed asset. For example, the tangible asset category contains aircrafts whereas computer software is assigned to the category of intangible assets.

Data availability in Switzerland was cross-checked on the basis of this pattern. The result was encouraging: data was available both on tangible fixed assets and on computer software. These various categories are certainly the most dynamic for an economy like Switzerland and represent approximately two thirds of the capital accounts of partner economies. Therefore, the existing information already covers a broad range of assets. A preliminary cost-benefit analysis indicated that additional information would be associated with a heavy burden on responders. Consequently no additional surveys were carried out. The capital stock of Switzerland therefore covers both tangible fixed assets and computer software. The various categories of assets covered in Switzerland are listed in Annex 1.

Before turning to the methodology used, a point must be made here: in Switzerland, gross fixed capital formations (GFCF) is based on a product-oriented approach. It thus provides no information regarding the industry or sector which is at the origin of the purchase. In other words, figures on GFCF in software represent the overall amount of purchased software of the Swiss economy. It gives no information on the amount spent for example by the software industry itself. This characteristic tends to preclude for the time being sector measures of capital stock.

65 For further details, see SNA95, §10.6ss.

Methodology

In accordance with the OECD 2001 manual, gross capital stock (GCS) is valued at "replacement cost", that is according to current market prices for a new asset. It is then expressed at constant prices by using deflators based on year 2000.

There are several methods to calculate the GCS. The **perpetual inventory method** (PIM) was chosen for two main reasons. On the one hand, Switzerland currently has no official estimation for a capital stock. Thus, any construct has to rely on data of GFCF. In this context the PIM provides a reliable solution. On the other hand, many countries have successfully implemented this method. Its use in Switzerland would thus produce results which ought to be fully compatible from a methodological point of view with those of other OECD members.

The PIM method builds up a cumulative stock of assets from past investments. It can be expressed as follows:

$$\mathrm{GCS_t} = \sum_{\mathbf{j=0}}^{\mathbf{L}} \mathbf{GFCF_{t-j} g_j} \tag{1}$$

Where:
t is time (in year)
$GFCF_{t-j}$ is gross fixed capital formation in year t-j,
g_j is the part of gross fixed capital formation of a fixed year in activity after j years,
L is equal to 2 * lifetime (in year) of the fixed asset.

The part of gross fixed capital formation (g_j) which is still active after j years is calculated with <u>mortality</u> and <u>survival</u> functions. Various density functions can be used to estimate mortality functions. A bell-shaped distribution estimated by a log-normal density function was chosen in Switzerland, owing to the fact that this type of distribution function is commonly used in this field. Besides, only a very limited number of assumptions (in particular on the flatness of the distribution curve) have to be made to compute mortality curves. Thus, the density function reads as follows:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \frac{1}{x} \exp(-(\ln x - \mu)^2 / 2\sigma^2) \tag{2}$$

where:
x = years 1, 2, …, L
σ = standard deviation computed as:

$$\sigma = \sqrt{\ln(1 + \frac{1}{(m/s)^2})} \tag{3}$$

μ = log-normal distribution mean computed as:

$$\mu = \ln(m) - 0.5\sigma^2 \tag{4}$$

m = estimated average lifetime of the fixed asset *s* controls the flatness of the distribution curve. *s* is fixed between m/2 and m/4. Given the fact that no data was available in Switzerland in order to estimate the real curve of mortality function, a value of *s*=m/3 was arbitrarily chosen for every type of fixed assets[66].

Thus, the survival function can be expressed as:

$$g(x) = 1 - \int_{t-L}^{t} \frac{1}{\sigma\sqrt{2\pi}} \frac{1}{x} \exp(-(\ln x - \mu)^2 / 2\sigma^2) dx \qquad (5)$$

where the amount of assets still in uses for the year t-i (i<L) corresponds to the GFCF made in year t-L minus the sum of all assets which were withdrawn from the process of production during the period [t-L ; t-i].

Time series and data availability

While there are numerous advantages to use the PIM, a main drawback is the issue of the length of time series. Actually, the PIM requires historical data for a period which is twice as long as the lifetime of the various fixed assets. This is linked to the fact that all assets of a given category are not discarded at the same time. For example, cars with an estimated lifetime of 10 years do not stop to be operational at the same time during their 10th year. Some cars are discarded earlier, some later. By doubling the lifetime taken into account, one can reasonably make the assumption that all assets are then discarded in the capital account.

In Switzerland, no surveys were ever made on lifetimes of assets. Thus, National accounts made estimates based on the experiences of various partner countries. Annex 1 gives lifetimes currently used in N.A in Switzerland. Annex 2 confronts the information needs in terms of time series with the data currently available in N.A. For some activities, the information is sufficient (software, industrial crops, etc.) while for others there is a lack of data. The most important deficit is for GFCF in construction[67], where data goes back to 1948 only while data is needed up to 1890. Consequently, a back-calculation based on a log linear regression model in first difference was implemented.

To back-calculate gross fixed capital formation in construction ($GFCF^{CONSTR}$) the assumption is made that there is a relationship between the evolution of Gross Domestic Product (GDP) and $GFCF^{CONSTR}$. This relation is sufficiently strong to express the $GFCF^{CONSTR}$ evolution with the evolution of GDP, adjusted with an elasticity rate[68].
Given that:

66 The same criteria as those taken by the National Bank of Belgium (BNB, 2002) were chosen.

67 An important point must be made here. In Switzerland, “Dwellings” and “Other buildings and structure” are included into the “Construction” category. This point thus differs from the OECD practice, but it is tolerated by the OECD manual « Measuring productivity ». The fact that this distinction is not made in Switzerland is linked to the unavailability of necessary data for back-calculation.

68 In order to make this assumption, a correlation test between GFCFCONSTR and GDP (ρ=.97) was implemented. Besides, an augmented Dickey-Fuller test (ADF) was also used to verify the stationary of GDP and GFCFCONSTR time series. Results reject for both time series the time-invariant hypothesis.

$$\Delta GDP_t = \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}};$$

;

and

$$\mathbf{\Delta GFCF_t^{CONSTR} = \frac{GFCF_t^{CONSTR} - GFCF_{t-1}^{CONSTR}}{GFCF_{t-1}^{CONSTR}}} \qquad (6)$$

where:

GDP_t = Gross domestic product for the year t.

$GFCF_t^{CONSTR}$ = Gross fixed capital formation in construction for the year t.

we can express our assumption as:

$$\mathbf{\Delta GFCF_t^{CONSTR} = \varepsilon_{GFCF}^{CONSTR} \Delta GDP_t} \qquad (7)$$

where $\varepsilon_{GFCF}^{CONSTR}$ is the elasticity between GDP and $GFCF^{CONSTR}$ evolution.

$\varepsilon_{GFCF}^{CONSTR}$ can be estimated with a simple log linear regression model in first difference. Thus, the model is expressed as:

$$\log\left(\frac{GFCF_t^{CONSTR}}{GFCF_{t-1}^{CONSTR}}\right) = \hat{\beta}_0 + \hat{\beta}_1 \log\left(\frac{GDP_t}{GDP_{t-1}}\right) \qquad (8)$$

where

$$\hat{\beta}_1 = \hat{\varepsilon}_{GFCF}^{CONSTR} \qquad (9)$$

T 4 – 1 Back-calculation of construction (Regression model results)

Variable	Coefficient	Std. dev.	T-statistics	P-value
Constant	-0.022	0.008	-2.923	0.005
GDP	2.063	0.203	10.158	0.000

R^2 = 0.674 F-statistic Prob. = 0.000
Source: FSO

Model (8) is significant with a p-value < .00 and one gets $\mathbf{\hat{\varepsilon}_{GFCF}^{CONSTR} = 2.063}$

With (7), (8) and (9) one can proceed to the back-calculation with

$$GFCF_{t-1}^{CONSTR} = \frac{1}{1 + (\hat{\varepsilon}_{GFCF}^{CONSTR} * \Delta GDP_t)} * GFCF_t^{CONSTR} \qquad (10)$$

Hence with (10), the official GFCF for construction can be back-calculated by applying the average evolution rate from the oldest available data of the official time series (that is to say 1948). Then, step by step, data is computed back up to 1890[69].

Back-calculation is also needed for a number of other fixed assets, as official data series often go back only to 1971. However the situation here is better than for investment in construction. As a matter of fact, before Swiss N.A revised their figures in 1997 due to the introduction of the European System of Accounts of 1978 (ESA 78), long time series had been set up in the pre-ESA 78 system. These series went back to 1948. These long time series are the only series available in Switzerland for back-calculation and, given the fact that there were only minor methodological changes for non financial assets linked to the implementation of ESA78, these series were used to construct the capital stock. Thus, for the period 1948–1970, the average evolution rates of the various fixed assets of the old time series are assumed to be equal to the average evolution rates of the fixed assets equipment goods of the official time series.

That is to say:

$$\mathbf{GFCF_{i,t-1}^{EQUIP;OFF} = GFCF_{i,t}^{EQUIP;OFF} * \frac{1}{1+\Delta GFCF_{i,t}^{EQUIP;OLD}}} \qquad (11)$$

where:

$\mathbf{GFCF_{i,t}^{EQUIP;OFF}}$ = Total gross fixed capital formation for equipment goods i of the current official time series for year t.

$\mathbf{GFCF_{i,t}^{EQUIP;OLD}}$ = Total gross fixed capital formation for equipment goods i of the pre ESA 78 time series for year t,

and

$$\mathbf{\Delta GFCF_{i,t}^{EQUIP;OLD} = \frac{GFCF_{i,t}^{EQUIP;OLD} - GFCF_{i,t-1}^{EQUIP;OLD}}{GFCF_{i,t-1}^{EQUIP;OLD}}} \qquad (12)$$

Thus with (11), official GFCF for equipment goods can be calculated by applying the average evolution rate of every type of fixed assets from the pre-ESA 78 data to the last available time series (that is to say 1971, see Annex 2). Then, step by step, data is computed back up to 1950 for the various types of assets.

Main findings

With the help of the PIM, the various types of fixed assets were aggregated and the Swiss capital stock was calculated for the period 1991–2004.

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69 Historical GDP time series come from Andrist, Anderson and Williams (2000).

T 4 – 2 Swiss capital stock, in million CHF, at constant prices (reference year: 2000)

Years	Agricultural assets	Equipment goods	Software	Construction	Total
1990	3,803	467,322	7,815	1,073,253	1,552,193
1991	3,813	483,306	8,020	1,109,223	1,604,361
1992	3,790	492,124	8,032	1,144,350	1,648,295
1993	3,757	498,342	7,973	1,178,547	1,688,619
1994	3,762	505,503	8,231	1,215,232	1,732,727
1995	3,735	517,018	8,877	1,249,725	1,779,354
1996	3,738	528,715	9,875	1,280,822	1,823,150
1997	3,708	541,025	11,407	1,310,698	1,866,838
1998	3,705	556,122	13,985	1,340,373	1,914,186
1999	3,676	572,026	17,095	1,367,929	1,960,725
2000	3,657	589,943	19,421	1,395,931	2,008,952
2001	3,658	604,667	21,582	1,421,917	2,051,824
2002	3,647	616,339	24,343	1,448,099	2,092,429
2003	3,591	625,439	26,291	1,474,344	2,129,665
2004	3,567	635,441	28,504	1,501,591	2,169,102

Source: FSO

Table 4–2 shows that fixed assets in construction and equipment goods are by far the most dynamic part of the capital stock, construction[70] being the dominant asset (two thirds of the Swiss capital stock). Conversely agricultural assets are marginal with a relative part of 0.2% of total capital stock. Annex 3 gives more details for results by asset categories.

Capital services

Definition

The next step on the road to multi-factor productivity is the calculation of capital services. The stock cannot be used as such for the analysis of productivity. This is linked to the underlying assumptions of the stock. By construction, the stock is the sum of the flows of investments corrected by the removal of discarded capital goods. The implicit assumption is that an asset's productive capacity remains fully intact until the end of its service life (Schreyer and Pilat; 2001). In the real world, past vintages of capital goods are less efficient than new ones. Therefore, assumptions have to be made to convert the capital stock into these capital services.

Here, two options can be used. As mentioned in Schreyer, Diewert and Harrison (2005), there are two alternative ways of computing capital services. The first way is to start out with the choice of depreciation parameters and from there, to develop quantity measure of capital services by moving from age-price to age-efficiency function. The second way is to directly compute quantity of capital services with the help of an age-efficiency function.

[70] As mentioned in footnote 65, construction figures include dwellings. Thus caution is needed when Swiss findings are compared with other countries results.

In Switzerland, the second option was used with the implementation of an **age-efficiency function.** This function captures capital services of fixed assets, as it indicates the development of the productive capacity of assets over their service lives (OECD; 2005a). In other words, it captures the relative marginal productivity of two vintages of the same type of assets, and thus reflects the loss in productivity due to wear and tear and/or technical obsolescence (Schreyer, Bignon and Dupont; 2003). With the help of age-efficiency profile, assets of various vintages can be aggregated by transforming the latter into **standard efficiency units.** These concepts are further developed in the next chapter.

Methodology

Age-efficiency and age-price functions

Various kinds of age-efficiency functions are available. The SFSO chose a **double-declining truncated geometric function**[71] for three reasons: i) geometric functions are widely used by OECD member states, and Swiss results would thus be comparable to those of other countries; ii) geometric patterns are very convenient to use; iii) the geometric function takes into account the age-price profile and thus no further developments are needed to describe the relative price of different vintages of the same asset at a given point in time. In line with international recommendations, no explicit retirement function was formulated due to the fact that geometric functions capture both the effects of wear and tear and retirement.

With the help of the age-efficiency profile determining the efficiency decline, the productive stock of fixed asset i (S_i^t) can be expressed as:

$$S_t^i = \sum_{j=0}^{n} (1-\delta^i)^j \, GFCF_{t-j}^i \tag{13}$$

where δ^i is the anticipated rate of efficiency decline and $GFCF^i_{t-j}$ the quantity of investment in new assets of type i in year t-j[72].

User costs

The next issue to consider is the price of renting one unit of the productive stock for one period. If there were complete markets for capital services, rental prices could be directly observed. Some rental prices exist of course, but the most common case is that of capital goods which are owned and used by the same persons. In that case, rental prices have to be imputed. The implicit rent that capital good owners "pay" themselves gives rise to the terminology "user costs of capital". These costs are also needed to aggregate the different kinds of fixed assets. According to OECD (2001b) and Schreyer, Diewert and Harrison (2005), user costs ($u_0^{i,t}$) are estimated by:

71 Function is truncated when efficiency rate is <.10.

72 Implicitly we admit two important assumptions: 1) a perfect substitutability between different vintages, and 2) proportionality between the flow of capital services and the productive stock. Non respect of these two assumptions will not be discussed in this paper.

$$u_o^{i,t} = P_o^{i,t}\left(r^{*t} + \delta_0 - \left(\Delta p^{i,t} - \omega^t\right)\right) \qquad (14)$$

where,

$u_o^{i,t}$ = user cost for the period t, of the fixed asset i; (2000=100);

$P_o^{i,t}$ = Price index of the fixed asset i (2000 = 100);

$u_o^{i,t}$ = net rate of return;

$u_o^{i,t}$ = Depreciation rate (geometric, *double declining balance*[73]);

$u_o^{i,t}$ = price variation of the fixed asset i between periods t and t-1;

$u_o^{i,t}$ = Inflation rate of the Swiss economy for the period t;

$u_o^{i,t}$ represents a holding gain/loss.

The term in the largest bracket constitutes the gross rate of return that one franc invested in the purchase of capital good i must yield in a competitive market. The gross rate of return itself comprises three terms:

- A rate of depreciation (δ_0) which materializes the loss in market value of a capital good due to ageing.
- A revaluation term, or capital gain/loss term $\left(\Delta p^{i,t} - \omega^t\right)$. Here the price evolution of a given asset is benchmarked against the general evolution of prices as given by the Consumer price index (CPI). Because the revaluation term enters into the user cost expression with a negative sign, a fall in asset prices raises user costs, mirroring the fact that there is an opportunity cost which arises from the loss of value of a given asset. For example, rental prices for personal computers have to take into account the fall in market prices and the ensuing loss in value of the computers which are in use.
- A net rate of return which is the expected remaining remuneration for the capital owner once depreciation and asset price changes have been taken into account.
- The choice of r is a matter of importance: the value of the user cost term determines the value of capital services of asset i as well as the overall remuneration of capital. This issue is dealt with in the next chapter while the question of holding gains and losses is treated below.

73 Even if double declining balance could be debatable (see Fraumeni, 1997), this method is widely used by other members of OECD.

Interest rate

Basically there are two major options for the rate of return r.

1. Set the rate of return so that the resulting value of capital services exactly exhausts the value of non-labor income (that is gross operating surplus) which is computed in N.A. This **endogenous** rate of return is thus fully consistent with the framework of the N.A. Its drawback is that it builds on a number of assumptions underpinning the underlying model which can be questioned. For example one assumes perfect competition, rational expectations of actors and constant rates of return. The fact that these assumptions do not meet with unanimous support tends to indicate that the endogenous rate of return is not the best option.
2. Choose an external rate of return. A common option is to take market interest rates as a proxy. This **exogenous** rate of interest thus mirrors conditions on markets and has strong links with the financial framework in which firms operate. While no extra assumptions are needed here, the resulting values of capital services do not necessarily add up to gross operating surplus and this may complicate growth accounting exercises. Besides, an important drawback is the difficulty to find interest rates which incorporate a risk premium which is consistent with the rate of return approach. As a matter of fact, in Switzerland, long-time series of interest rates are available only for government bonds. These are considered as risk-free by most analysts and are thus not a good choice for the rate of return. Calculations were nevertheless carried out in Switzerland for both options. For the period 1991–2004, the endogenous rate of return is 2.4% while the exogenous rate turns out to be 4.4%. These values can be considered as being the minimum and maximum for the estimate. In this context the SFSO decided to take an **average of both rates** as a proxy for the rate of return. The latter therefore is valued at 3.4% and held constant during the whole period. This treatment means that the rate of return is an ex-ante rate, which is coherent with the conceptual framework chosen here.

Holding gains/losses

As indicated above, holding gains tend to lower the user cost while holding losses raise that cost. A holding gain appears when the price of the underlying asset rises more than the general rate of inflation, and conversely for a capital loss. For the analysis, the difficulty arises when large price changes occur which may have a significant impact on the user cost. In some cases, the holding gain could be such that it compensates totally not only the acquisition price, but also the interest rate and the rate of depreciation. In such an extreme case, given the negative sign in front of the bracket term, the user cost would be negative, which is quite a challenging result for the analyst.

The possibility of having such a negative outcome cannot be readily discarded. To cope with such a situation, the following assumption is adopted: an investor will estimate an expected holding gain/loss in accordance with results of previous years. In order to reproduce the investor behavior, a simple linear regression model is used with as dependant variable the ex post holding gain/loss $\left(\Delta p^{i,t} - \omega^{t}\right)$ observed between 1980 and 2004 and time as independent variable.

If the model shows a significant trend, fitted values are used in equation (14) to estimate the expected (*ex ante*) holding gain/loss. *A contrario*, if the result of the regression model is not significant, the mean of *ex post* holding gain/loss of the period 1980–2004 is computed and is applied for every year. In that way, this mean neutralizes the potential price volatility of asset categories. In both situations (that is, results of the linear regression model and results of the mean), the values obtained are held constant during the whole period 1991–2004. This *ex-ante* approach should avoid the possibility of having to cope with negative user costs in a specific year.

T 4 – 3 Holding gains/losses: Results of simple linear regression model

Dependant variable	β1	P-value
Fabricated metal products	-0.006463	0.9799
Machinery and equipments	-0.039935	0.5376
Office machinery and computers	-0.422520	0.0004**
Electrical machinery and apparatus	-0.096855	0.2126
Radio, television and comm. equip. and apparatus	-0.280197	0.0009**
Medical, precision and optical instruments, watches	-0.129231	0.1190
Motor vehicles, trailers and semi-trailers	-0.056233	0.3769
Other transport equipment	0.057169	0.5986
Construction	0.006671	0.9288
Informatics	-0.235699	0.0497*

*: significant at 95%-level **: significant at 99%-level
Source: FSO

Capital services index

Once standard efficiency units and user costs are computed, it is possible to calculate the overall capital services index. Cost shares are important in this context, as they are used as weights to aggregate services from the different types of assets. Given the fact that user costs shares reflect the relative marginal productivity of the different assets, these weights provide a means to effectively incorporate differences in the productive contribution of heterogeneous investments into the overall measure of capital input. The theoretically recommended index is the Törnqvist index which applies average users cost weights to each asset's rate of change in capital services. The index is computed by:

$$\ln\left(\frac{S_t}{S_{t-1}}\right) = \sum_i \tfrac{1}{2}\left[\frac{u_t^i S_t^i}{\sum_i u_t^i S_t^i} + \frac{u_{t-1}^i S_{t-1}^i}{\sum_i u_{t-1}^i S_{t-1}^i}\right] \ln\left(\frac{S_t^i}{S_{t-1}^i}\right) \qquad (15)$$

Where,
S_t^i = amount of capital service of fixed asset i at year t, and $S_t = \sum_i S_t^i$ u_t^i = user cost of fixed asset i at year t,

Multi-factor Productivity

Numerous papers of research have already discussed the theoretical framework of multi-factor productivity (MFP) (for instance: Schreyer, 2001; OECD, 2001b). Here supplementary information is provided on inputs used, which in turn are based on the methodology applied in the OECD Compendium of productivity indicators (OECD, 2005b).

Methodology

Output is measured as GDP at constant prices[74] for the entire Swiss economy. Year-to-year change is given by $\ln\left(\frac{GDP_t}{GDP_{t-1}}\right)$

Labor input is measured as total hours actually worked in the entire economy. Year-to-year change is given by $\ln\left(\frac{L_t}{L_{t-1}}\right)$.

To measure the **remuneration of labor** input, the average remuneration per employee is multiplied by the total number of persons employed. This adjustment is needed in order to include self-employed persons whose income is logically not a part of the compensation of employees (OECD, 2005b).
Thus, the remuneration of labor input is expressed as:

$$w_t L_t = \left(\frac{COMP_t}{EE_t}\right) E_t \tag{16}$$

Where,

$w_t L_t$	=	Total remuneration of labor input (employees + self-employed) in period t ;
$COMP_t$	=	Compensation of employees for period t;
EE_t	=	Number of employees in period t ;
E_t	=	Total number employed (employees + self-employed) in period t.

No information is available in Switzerland about E_t, for a whole year. As a proxy, the split of E_t between EE_t and self-employed persons is used. This split is only available for the middle of the second quarter of a given year. An assumption is therefore made that the relative part of self-employed persons at the middle of the second quarter for year t is equal to the average relative part of self-employed persons for the year t.

Data on remuneration of employees are computed by national accounts[75] and employment statistics (ES) are provided by the Swiss labor force survey (SFSO, 2004).

74 At prices of preceding year, base year = 2000.

75 Data are available in SFSO (2005).

Using the same methodology (OECD, 2005b), the rate of change of **total inputs** is computed as a weighted average of the rate of change of labor and capital input. The weights of each input are their respective shares in total cost of inputs[76]. Here again, a Törnqvist index is used to evaluate the rate of change:

$$\ln\left(\frac{X_t}{X_{t-1}}\right) = \tfrac{1}{2}(s_t^L + s_{t-1}^L)\ln\left(\frac{L_t}{L_{t-1}}\right) + \tfrac{1}{2}(s_t^S + s_{t-1}^S)\ln\left(\frac{S_t}{S_{t-1}}\right) \qquad (17)$$

Where share of labor input in costs is estimate by:

$$s_t^L = \frac{w_t L_t}{w_t L_t + \sum_i u_t^i S_t^i} \qquad (18)$$

and share of capital input in costs is given by:

$$s_t^S = \frac{\sum_i u_t^i S_t^i}{w_t L_t + \sum_i u_t^i S_t^i} \qquad (19)$$

MFP estimation

MFP is measured as the difference between output and input contributions.

$$\ln\left(\frac{PMF_t}{PMF_{t-1}}\right) = \ln\left(\frac{GDP_t}{GDP_{t-1}}\right) - \ln\left(\frac{X_t}{X_{t-1}}\right) \qquad (20)$$

A measure of MFP of the Swiss economy can therefore be calculated for the period 1992–2004:

Further details are available in the annex 4.

International Comparison of MFP

Before turning to the international comparison, a point made before can be reiterated here. Although the methodology used in this document is compatible with international practice, there are small differences with the OECD practice for estimating capital services. The OECD excludes dwellings from its estimates while this exclusion is not made in Switzerland due to the unavailability of data for the back-calculation model. This being said, the results for Switzerland are benchmarked with data of other members of OECD in graph 4–1, which compares growth rates of MFP:

In comparison with other OECD members, the evolution of MFP for Switzerland is obviously quite weak (0.5% for Switzerland versus 1.1% on average for the whole OECD members). This is particularly true for the period 1991–1996 when the Swiss economy had a really weak growth rate with 0.4% versus 1.1% for OECD. During the period 1996–2000, the situation does not improve with an annual average growth rate of 0.5%, whereas the

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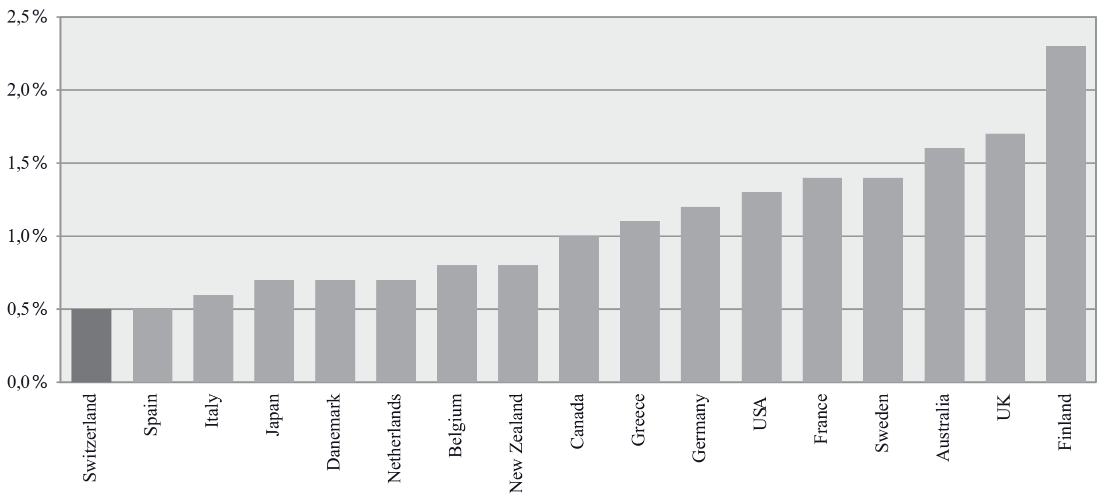
76 Total cost of inputs is given by: $\mathbf{C_t = w_t L_t + \sum_i u_t^i S_t^i}$

T 4 – 4 Evolution of the MFP of the Swiss economy

Years	MFP
1992	0.2%
1993	0.2%
1994	0.1%
1995	0.5%
1996	1.0%
1997	1.6%
1998	0.5%
1999	-1.1%
2000	2.2%
2001	0.9%
2002	0.1%
2003	-0.8%
2004	0.3%
1991–1996	0.4%
1996–2000	0.8%
2000–2003	0.1%
1991–2004	0.4%

Source: FSO

International Comparisons of MFP (1991–2003) **G 4–1**



1. 1991–2002 for Australia, Japan and New Zealand
Source: SFSO and OECD Productivity database

international annual average growth rate is 1.0%. Thus, for the whole analyzed period, Swiss economy has the weakest annual growth rate of MFP in international comparison.

Conclusion

This paper illustrated the various steps which were implemented by the SFSO to provide first estimates of the capital stock and of multifactor productivity. It shows that while the statistical database is not optimal, the conceptual framework of the OECD can be implemented to a great extent in Switzerland. It is worthwhile to mention that the results were cross-checked by the OECD and can thus be compared to those of other countries without reservation. The outcome is a very valuable input for further analytical work and for the evaluation of the overall situation of the Swiss economy.

This being said, a number of interesting features emerged from the production process as such. The SFSO can now identify and make a hierarchy of open points which should be analyzed in the future. Issues like lifetimes of assets and sector allocation have gained in importance, and must be studied in the medium term, taking into account the specific features of the Swiss economy. Besides, these open points may have a backlash on assumptions used by N.A in areas like depreciation. The forthcoming revision of N.A will be a precious opportunity to review some of the assumptions made in the past. Finally, the new figures must at one point be reconciled with an emerging feeling that the Swiss economy has been successfully restructured in the last 13 years. Some qualitative indicators tend to show that the Swiss economy is very competitive. The World Economic Forum just released its global competitiveness report which ranks Switzerland as being the most performing economy in the world for the first time ever[77]. As one can see, a lot of analytical work still lay ahead, but the new figures are a big step forward to critically assess the situation of the Swiss economy.

77 http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm

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Appendix

T4–5 Annexe 1, Fixed Assets and Lifetimes

Assets	Lifetime (years)
Fruits	8
Hops	20
Industrial crops	12
Arboriculture	15
Vineyards	25
Animals	–*
Fabricated metal products	18
Machinery and equipments	18
Office machinery and computers	7
Electricity distribution and control apparatus	15
Radio, television and comm. equip. and apparatus	15
Medical, precision and optical instruments, watches	15
Motor vehicles, trailers and semi-trailers	10
Other transport equipment	20
Construction	50
Software	4

*Animal stock estimation is based on livestock.
Source: FSO

T4–6 Annexe 2, Availability of time series

Assets	GFCF needed since	GFCF available since
Fruits	1974	1940
Hops	1950	1940
Industrial crops	1966	1940
Arboriculture	1960	1940
Vineyards	1940	1940
Fabricated metal products	1954	1971
Machinery and equipments	1954	1971
Office machinery and computers	1976	1971
Electrical machinery and apparatus	1960	1971
Radio, television and comm. equip. and apparatus	1960	1971
Medical, precision and optical instruments, watches	1960	1971
Motor vehicles, trailers and semi-trailers	1970	1971
Other transport equipment	1950	1971
Construction	1890	1948
Software	1982	1971

GFCF = Gross fixed capital formation
Source: FSO

T 4 – 7 Annex 3: Swiss capital stock, 1990–2004

in million CHF, at constant price (reference year: 2000)

Years	Agricul-tural assets	Equipment goods*										Construction	Total
		E1	E2	E3	E4	E5	E6	E7	E8	E9	Total E.		
1990	3,803	345	275,268	11,968	49,736	30,228	46,382	15,080	38,314	7,815	475,137	1,073,253	1,552,193
1991	3,813	352	282,671	12,396	51,448	31,342	47,988	15,548	41,560	8,020	491,326	1,109,223	1,604,361
1992	3,790	362	286,970	12,684	52,611	31,993	49,251	15,820	42,432	8,032	500,156	1,144,350	1,648,295
1993	3,757	370	290,013	12,953	53,734	32,542	50,439	15,805	42,487	7,973	506,315	1,178,547	1,688,619
1994	3,762	378	293,141	13,490	55,069	33,175	51,823	15,983	42,443	8,231	513,733	1,215,232	1,732,727
1995	3,735	384	299,028	14,247	56,124	33,661	53,212	16,174	44,187	8,877	525,894	1,249,725	1,779,354
1996	3,738	392	304,586	15,197	57,074	34,239	54,520	16,326	46,381	9,875	538,590	1,280,822	1,823,150
1997	3,708	398	309,209	16,595	58,327	35,235	56,131	16,386	48,743	11,407	552,432	1,310,698	1,866,838
1998	3,705	386	316,271	17,741	59,179	36,247	58,697	16,684	50,918	13,985	570,108	1,340,373	1,914,186
1999	3,676	406	321,478	19,211	60,075	37,421	61,652	17,161	54,621	17,095	589,120	1,367,929	1,960,725
2000	3,657	400	327,864	21,085	61,270	38,934	65,173	17,809	57,408	19,421	609,364	1,395,931	2,008,952
2001	3,658	397	332,294	22,627	62,580	39,659	69,337	18,511	59,263	21,582	626,250	1,421,917	2,051,824
2002	3,647	414	336,617	23,736	63,147	40,412	73,295	18,945	59,774	24,343	640,682	1,448,099	2,092,429
2003	3,591	430	339,822	24,652	62,705	41,438	76,337	19,356	60,699	26,291	651,730	1,474,344	2,129,665
2004	3,567	441	344,296	25,894	62,162	43,061	78,484	19,790	61,312	28,504	663,944	1,501,591	2,169,102

*E1: Fabricated metal products; E2: Machinery and equipments; E3: Office machinery and computers; E4: Electrical machinery and apparatus; E5: Radio, TV and comm. Equipment and apparatus; E6: Medical, precision and optical instruments, watches; E7: Motor vehicles, trailers and semi-trailers; E8: Other transport equipment; E9: Software. ond order contribution of sex and age.

Source : FSO

T4–8 Annex 3: Swiss capital stock, 1990–2004

Years	GDP at constant prices	Labor input	Labor productivity	Cost share of labor input	Contribution of labor input	Capital input	Capital productivity	Cost share of capital input	Contribution of capital input	Capital intensity	Contribution of capital intensity	Multi-factor productivity
	-1	-2	(3) = (1) - (2)	-4	(5) = (2) * (4)	-6	(7) = (1) - (6)	-8	(9) = (6) * (8)	(10) = (6) - (2)	(11) = (8) * (10)	(12) = (1) - (5) - (9)
1992	0.0%	-0.9%	1.0%	69.1%	-0.6%	1.5%	-1.5%	30.9%	0.5%	2.4%	0.7%	0.2%
1993	-0.2%	-1.0%	0.8%	69.6%	-0.7%	1.1%	-1.3%	30.4%	0.3%	2.1%	0.7%	0.2%
1994	1.1%	0.6%	0.5%	69.9%	0.4%	2.0%	-0.9%	30.1%	0.6%	1.4%	0.4%	0.1%
1995	0.4%	-1.3%	1.7%	70.4%	-0.9%	2.6%	-2.2%	29.6%	0.8%	3.8%	1.1%	0.5%
1996	0.5%	-1.6%	2.2%	70.9%	-1.2%	2.3%	-1.8%	29.1%	0.7%	4.0%	1.2%	1.0%
1997	1.9%	-0.7%	2.6%	71.2%	-0.5%	2.6%	-0.7%	28.8%	0.7%	3.3%	0.9%	1.6%
1998	2.8%	1.8%	1.0%	71.3%	1.3%	3.3%	-0.5%	28.7%	0.9%	1.5%	0.4%	0.5%
1999	1.3%	2.1%	-0.8%	71.1%	1.5%	3.1%	-1.8%	28.9%	0.9%	1.0%	0.3%	-1.1%
2000	3.5%	0.7%	2.8%	70.7%	0.5%	2.8%	0.7%	29.3%	0.8%	2.1%	0.6%	2.2%
2001	1.0%	-0.7%	1.7%	70.5%	-0.5%	2.1%	-1.1%	29.5%	0.6%	2.9%	0.8%	0.9%
2002	0.3%	-0.6%	0.9%	70.7%	-0.4%	2.1%	-1.8%	29.3%	0.6%	2.6%	0.8%	0.1%
2003	-0.2%	0.4%	-0.6%	70.9%	0.3%	1.1%	-1.3%	29.1%	0.3%	0.7%	0.2%	-0.8%
2004	2.3%	2.1%	0.2%	70.6%	1.5%	1.6%	0.6%	29.4%	0.5%	-0.5%	-0.1%	0.3%
1991–1996	0.4%	-0.9%	1.2%		-0.6%	1.9%	-1.6%		0.6%	2.7%	0.8%	0.4%
1996–2000	2.4%	1.0%	1.4%		0.7%	2.9%	-0.6%		0.8%	1.9%	0.6%	0.8%
2000–2003	0.4%	-0.3%	0.7%		-0.2%	1.8%	-1.4%		0.5%	2.0%	0.6%	0.1%
1991–2004	1.1%	0.1%	1.1%		0.0%	2.1%	-1.0%		0.6%	2.1%	0.6%	0.4%

Source: FSO

5. INNOVATION AND LABOUR PRODUCTIVITY GROWTH IN SWITZERLAND
An Analysis Based on Firm Level Data

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Introduction

This study investigates the determinants of labour productivity growth of Swiss firms in the period 1994–2002 particularly emphasizing the role of innovation activities. Thus, the main research question pursued is: to what extent do different types of firm-level innovations affect labour productivity of firms in Switzerland? This is a question of particular interest for Swiss policy-makers in the light of the unsatisfactory growth performance of the Swiss economy in the 1990s (see Federal Department for Economic Affairs 2002). Most observers consider the low growth of labour productivity as the main single factor for explaining this unfavourable performance as measured by GDP growth. Labour productivity depends on physical and human capital as main production factors as well as on new knowledge and innovation. Economies that develop more and more in the direction of a "knowledge-based economy" are relying increasingly on technological innovation. Hence, it is important to gain some insights with respect to the (quantitative) relationship between innovation and economic performance. A better understanding of the relative importance of the factors determining productivity growth could contribute to an explanation of the low productivity growth of the Swiss economy in the 1990s.

The data used in this study come from the KOF panel database and were collected in 1996, 1999 and 2002 respectively based on a questionnaire quite similar to that used in the Community Innovation Surveys (CIS). We use an (unbalanced) panel of in total 793 firms covering the manufacturing sector, a large portion of service industries and the construction sector.

In this study, we specify and estimate econometrically a *labour productivity growth equation* (growth of value added per employee) containing a variable for human capital (share of employees with tertiary-level education), a variable for physical capital (value added share of non-labour firm income) and, alternatively, a series of simple innovation indicators (introduction of innovations yes/no; introduction of product / process innovations yes/no; existence of R&D activities yes/no; at least 1 patent application yes/no; introduction of products new for the world marker yes/no).

[78] The authors thank participants at the OECD Workshop on Productivity Analysis and Measurement, 16–18 October 2006 in Bern, Switzerland for their comments and suggestions.

The new elements that this paper adds to the empirical literature are, first, the consideration of several innovation indicators, thus allowing to test the robustness of the relationship between innovation and economic performance; second, the use of panel data for the period 1994–2002, since only few studies until now could dispose of a panel. It is the first study on the determinants of productivity growth based on Swiss firm data.

The set-up of the study is as follows: the second section gives information on the conceptual framework and a short summary of related empirical literature. In the third section we present the specification of the productivity growth equation. The fourth section deals with the data used in the study and the method applied in the econometric estimations. In the fifth section we discuss the empirical results. The last section contains a summary and some conclusions.

Conceptional framework and literature review

Since the mid-1980s the study of macroeconomic growth and its policy implications vigorously re-entered the research agenda (Romer, 1986; Baumol, 1986). A diverse body of literature appeared trying to explain, both theoretically and empirically, why differences in income over time and across countries did not disappear as the neo-classical models of growth of the 1950s and 1960s developed by Solow (1956) and Swan (1956) predicted. The idea that emerged from this literature is that economic growth is endogenous. That is, economic growth is influenced by decisions made by economic agents, and is not merely the outcome of an exogenous process. Endogenous growth assigns a central role to capital formation, where capital is not just confined to physical capital, but includes human capital and knowledge.

The econometric work on growth is dominated by cross-country regressions (Barro, 1991; Mankiw et al. 1992). In these studies the model of growth collapses to a single growth equation by log-linearizing the model around the steady state. Following the same procedure in our set-up, results in an equation explaining labour productivity growth by a catch-up variable, human capital and the capital-labour ratio. Innovation efforts might be a relevant factor in this kind of models.

The relationship between productivity and innovations can be analyzed on different levels: economy, sector, industry, and firm. The present study is based on firm data. Thus, the reference studies to be considered here are characterized by the fact that they concentrate on productivity at the firm level and use micro data from Community Innovation Surveys (CIS).

Crépon et al. (1998) studied the links between productivity, innovation and research based on a three-equation structural model that explained productivity by innovation output, and innovation output by research investment based on a cross-section of French firm data. They found that firm productivity correlates positively with a higher innovation output, after controlling for labour skill and physical capital intensity. In a further study with French data Duguet (2006) distinguished two types of innovation, namely incremental and radical innovations. He found for a cross-section of French firm data that radical innovations are the only significant contributors to TFP growth.

Lööf et al. (2001), Janz et al. (2003) and Griffith et al. (2006) conducted comparative studies for many countries using the framework of analysis developed by Crépon et al. (1998). All three studies are cross-section investigations based on CIS data. Lööf et al. found that the estimated elasticity of productivity with respect to innovation output is higher in Norway than in the other two countries in their sample, i.e. Finland and Sweden. Rather surprisingly, no significant relationship was found between innovation and productivity in Finland. The authors are reluctant to draw definite conclusions from these findings because of data errors, differences in model specification or unobserved country-specific effects.

Janz et al. analyzed the relationship between productivity, innovation output and R&D expenditure for a pooled sample of German and Swedish firms. The analysis showed that the two main parameter estimates, the elasticity of labour productivity with respect to innovation output and the elasticity of innovation output with respect to innovation input, are not significantly different between the two countries.

Finally, using different innovation output measures, Griffith et al. found that the innovation output is significantly determined by the innovation effort in all four countries of investigation, France, Germany, Spain and the UK. In contrast to that, productivity effects of innovation did not show up for Germany.

Wieser (2005) provides a survey of empirical studies on the impact of R&D on productivity. Despite considerable variation of the estimated returns to R&D from one study to another, the results clearly suggest a positive and strong relationship between R&D expenditures and growth of output or total factor productivity. The studies reviewed indicate that the rates of return vary sometimes significantly between industries, but it is unclear as to which industries generate higher returns. The results of a meta-analysis indicate, first, a significantly higher elasticity of R&D in the 1980s and consistently higher estimates for the 1990s, as compared with the 1970s. Second, the meta-results show that the elasticities of R&D are significantly lower in Europe than in the US.

On the whole, the comparability of existing studies is rather limited due not only to data problems but also to differences with respect to model specification and applied econometric methodology.

Model specification

We assume a production function in which we include labour, human capital and physical capital. Besides firm-, sector- and time-specific dummies, we allow previous innovation activities to explain multifactor productivity (A).

$$Y_{it} = A\left(S_j, T_t, P_t, I_{it-1}\right) f\left(L_{it}, H_{it}, K_{it}\right) \qquad (1)$$

where Y_{it} is the output of firm i in period t, L_{it} is the number of employees in firm i at time t, H_{it} is human capital, and K_{it} is the fixed capital stock of firm i in period t. The term S_j and P_t stand for respectively sector- and time-specific dummies. I_{it-1} represent innovation efforts (per employee) by firm i in the period preceding period t. In the empirical analysis we assume an aggregated Cobb-Douglas production function. We then divide both sides by the number of employees and take natural logarithms, assuming constant returns to scale. In line with the macroeconomic growth literature, we specify the resulting equation in growth rates (which allows us to interpret it as the result of log-linearizing a more fully-specified growth model around its steady state) and arrive at the following equation explaining labour productivity growth:

$$\Delta(y_{it} - l_{it}) = \delta y_{it-1} + \gamma \Delta a_{ij} + \varepsilon \Delta(h_{it} - l_{it}) + \phi \Delta(k_{it} - l_{it}), \quad (2)$$

Lower cases indicate the natural logarithm of the original variables, y_{it-1} serves as a catch-up variable and a_{it} is a linear combination of the dummies for S_j, T_t, P_t, I_{it-1}. Our dependent variable is the change in the natural logarithm of value added (i.e. sales minus material and service intermediates) per employee. The natural logarithm of the human capital-labour ratio we proxy by the natural logarithm of the share of the employees with tertiary-level education and for the natural logarithm of fixed capital-labour ratio we use the natural logarithm share of capital income (value added minus labour costs) per employee.

Our main hypothesis is that innovation activities, via the multifactor productivity term *a*, contribute to an improvement of labour productivity growth. As we will use binary innovation indicators to proxy for innovation, we basically compare labour productivity growth between firms that are and are not involved in such innovation activities.

Data and method

The data used in this study were collected in the course of three surveys among Swiss enterprises in the years 1996, 1999 and 2002 using a questionnaire which included besides questions on some basic firm characteristics (sales, employment, labour costs and employees' vocational education) also several innovation indicators quite similar to those in the Innovation Surveys of the European Community (CIS). The survey was based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all relevant industries of the manufacturing sector, the construction sector and selected service industries (18 manufacturing industries, 9 service industries and the construction industry, on the whole 28 industries) and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms). Quantitative variables (e.g. value added) are referring to the years 1995, 1998 and 2001 respectively, while the innovation variables are referring to the three-year periods 1994–1996, 1997–1999 and 2000–2002 respectively.

To circumvent that the results are driven by outlying observations, we removed potential outlying observations before starting our empirical analysis. As both the mean and the standard deviation are highly sensible to the presence of outlying observations, we used robust counterparts – namely the median and the median absolute deviation – to identify extreme observations. In each cross-section those observations which in absolute sense deviated more than three times the median absolute deviation from the median itself were removed from the sample.

As already mentioned the data cover in total 18 manufacturing sectors, 9 services sectors and the construction sector. The three largest industries with each an approximate share of 10 percent in our final sample are the construction sector, metal-working industry and machinery. Close to 40 percent of the observations stem from the survey conducted in 2002. The two surveys in 1996 and 1999 each represent approximately 30 percent of the observations. This means that our panel is of an unbalanced nature. Our final dataset contained 793 observations. Due to missing values for single variables the sample fluctuates between 768 and 793 observations at maximum in the econometric estimations.

T5–1 Summary statistics

	Obs.	Mean	St.dev.
Labour productivity growth	793	3.8%	24.2%
Log(initial labour productivity)	793	11.73%	0.34%
Lagged foreign ownership (y/n)	793	10.1%	30.1%
Growth in share tertiary education	793	0.1%	49.2%
Growth in capital-labour ratio	793	-1.1%	55.3%
Innovation activity (y/n)	793	69.6%	46.0%
Product innovation (y/n)	793	57.3%	49.5%
Process innovation (y/n)	793	50.7%	50.0%
R&D Activities (y/n)	792	53.2%	49.9%
Patent applications (y/n)	789	20.2%	40.1%
Introduction of new products (y/n)	768	20.3%	40.3%

T5–2 Correlation matrix of the model variables

Obs.\Corr.	Log (initial labour productivity)	Lagged foreign ownership (y/n)	Growth in share tertiary education	Growth in capital-labour ratio	Innovation activity	Product innovation	Process innovation	R&D activities	Patent applications	New products
Labour prod. growth	**0.09**	**-0.26**	**0.03**	**0.52**	**0.05**	**0.05**	**0.01**	**0.05**	**0.04**	**0.07**
Log(initial labour productivity)	793	0.15	0.07	0.09	0.07	0.12	-0.04	0.08	0.04	0.08
Lagged foreign ownership (y/n)	793	793	0.03	-0.13	0.15	0.19	0.14	0.19	0.12	0.12
Growth in share tertiary education	793	793	793	-0.01	0.08	0.10	0.10	0.07	0.03	0.02
Growth in capital-labour ratio	793	793	793	793	0.04	0.03	0.00	0.07	0.00	0.02
Innovation activity (y/n)	793	793	793	793	793	0.77	0.67	0.71	0.33	0.34
Product innovation (y/n)	793	793	793	793	793	793	0.38	0.73	0.41	0.41
Process innovation (y/n)	793	793	793	793	793	793	793	0.46	0.24	0.31
R&D Activities (y/n)	792	792	792	792	792	792	792	792	0.43	0.40
Patent applications (y/n)	789	789	789	789	789	789	789	788	789	0.51
Introduction of new products (y/n)	768	768	768	768	768	768	768	768	765	768

We estimate equation (2) containing besides the first differences of the two basic variables log of share of employees with tertiary-level education and log of capital income per employee alternatively with each one of six different dichotomous innovation indicators (innovation activities yes/no; introduction of product / process innovations; R&D activities yes/no; at east one patent application yes/no; introduction of products new for the (world) market yes/no) (see table 5–1 for some descriptive statistics of the variables used, also table 5–2 for the correlation matrix of the model variables). These indicators cover both the input- and the output-side of the innovation process as well as the two most important kinds of innovation, product and process innovation. Further our estimation equation contains 28 industry dummies, two time dummies and a dummy for a firm being domestic- or foreign-owned (see also table 5–3).[79]

We estimate one OLS version of equation (2) containing contemporaneous innovation indicators and a second Instrumental Variable version where the lagged innovation indicators are used as instruments. In this way, we take the possibility of the innovation variable being endogenous into account.

Empirical results

Table 5–3 shows the results of the econometric estimations of equation (2) with six alternative innovation variables. Column (1) presents the baseline regression without any innovation dummy. The coefficients of both variables for resource endowment are, as expected, positive but only the parameters for the capital-labour ratio are statistically significant at the usual significance level. However, there is a strong positive correlation of the variable for human capital with the *level* of labour productivity, as was found in other studies (Arvanitis 2007). Further, the coefficient of the foreign ownership dummy is also positive and highly significant, which can be interpreted as a clear hint that, after controlling for all other factors, productivity growth is higher in foreign than in domestic firms. The estimated coefficient implies that, when keeping the other attributes in the model constant, foreign firms on average report a (100*ln(1+0.06)=) 5.8 percentage points higher labour productivity growth rate than domestically-owned firms. Given an average labour productivity growth of 3.8 percent in our sample (see Table 5–1), this means that foreign firms on average grow 2.5 times faster than domestic firms. The effect of productivity growth lagged by a period on current productivity growth is, as expected, significantly negative across all estimations and in absolute terms as high as the capital-labour ratio effect.

The next columns of Table 5–3 report the results in case our innovation variables are added one at a time.[80] Unless mentioned otherwise, we focus on the results for the instrumental variables specification.[81] In column (2) we first start by including our broadest defined innovation variable, overall innovation activities. This dummy equals one in case the firm reports to have carried out product or process innovations or both of them during the past three years and is significant. An economic interpretation of this coefficient is that on average a switch from a firm without innovations to a firm that has introduced innovations, is associated with an increase of productivity growth by somewhat more than 10 percentage points. When splitting up these innovation activities into product and process innovations (columns (3) and (4)), it becomes clear that largely product innovations are driving this result.

79 We also experimented with including six dummies for firm size. However, in these growth regressions these dummies did not turn out to be significant and are therefore removed from the regression. The qualitative results are not affected by this.

80 The high correlation (as reported in Table 5–2) between the different innovation dummies refrain us from reporting the results including all innovation dummies at once.

81 We also estimated the same set of equations using only the lagged innovation dummies. The results are qualitatively identical to those of the instrumental variable approach.

T5–3 Estimates of the productivity equation

	(1)	(2)		(3)		(4)		(5)		(6)		(7)	
		OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Number of observations	793	793	793	793	793	793	793	792	783	789	775	768	753
Adjusted R2	0.322	0.324	0.304	0.325	0.321	0.324	0.322	0.323	0.303	0.325	0.320	0.321	0.304
Lagged foreign ownership (y/n)	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
	(2.31)	(2.33)	(2.34)	(2.26)	(2.20)	(2.46)	(2.47)	(2.35)	(2.42)	(2.37)	(2.15)	(2.41)	(2.27)
Log(initial labour productivity)	-0.20	-0.21	-0.22	-0.21	-0.22	-0.21	-0.21	-0.20	-0.23	-0.21	-0.21	-0.20	-0.21
	(-7.63)	(-7.84)	(-7.91)	(-7.92)	(-8.01)	(-7.91)	(-7.19)	(-7.78)	(-7.80)	(-8.00)	(-7.92)	(-7.85)	(-7.74)
Growth in share tertiary education	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	(1.29)	(1.19)	(0.91)	(1.13)	(0.95)	(1.15)	(1.01)	(1.21)	(1.16)	(1.32)	(1.22)	(1.32)	(1.33)
Growth in capital-labour ratio	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.21	0.21	0.21	0.20
	(14.05)	(13.86)	(13.22)	(13.88)	(13.61)	(13.97)	(14.14)	(13.75)	(12.62)	(14.03)	(13.81)	(13.43)	(12.86)
Innovation activity (y/n)		0.03	0.11										
		(1.69)	(2.16)										
Product innovation (y/n)				0.03	0.07								
				(1.99)	(1.71)								
Process innovation (y/n)						0.02	0.04						
						(1.65)	(0.78)						
R&D Activities (y/n)								0.02	0.11				
								(1.40)	(2.36)				
Patent applications (y/n)										0.04	0.06		
										(2.15)	(1.54)		
Introduction of new products (y/n)												0.05	0.11
												(2.59)	(2.30)

Note: All equations include sector and time dummies. Heteroscedasticity robust t-values are reported in brackets.

There is some indication that process innovation is positively correlated to labour productivity growth when looking at the OLS results. However, the instrumental variables regression suggests that this is due to an endogeneity problem (column (4)). To a somewhat lesser extent, the same conclusion holds for our patent application dummy (column (6)). Hence, we cannot find significant effects for process innovation and the dummy variable for at least one patent application when we correct for potential endogeneity in these variables.

Depending on the market environment, firms pass on cost reductions to output prices. If value added is not (appropriately) deflated, mostly due to lack of price data at the firm level, a problem of identifying productivity effects of process innovations could emerge. This could explain the ambiguous results with respect to process innovation.

Besides product innovations (i.e. products new either to the firm or to market), the variable for R&D activities (column (5)) is significantly positively correlated to productivity growth. Concentrating on those product innovations and products which are new for the worldwide market (column (7)) shows that especially this type of product innovation has a strong and significant impact on subsequent labour productivity growth.

Overall, especially those innovation variables which are related to some form of product innovation are statistically significant. Their coefficients vary between 0.06 (product innovations) and 0.11 (R&D activities; new products). Hence, in the case of R&D activities and new products, a respective shift of a firm from an inactive to an active state leads to an increase of productivity growth by over 10 percentage points.

A comparison of our results for product and process innovations, which are the most frequently used binary innovation indicators, with the results for other countries (available only for a cross-section of firms), shows the following picture: a significant positive effect of process innovations was found only for France (Griffith et al. 2006) and Italy (Parisi et al. 2006); for Finland, Spain, the UK and for Sweden (in one of two studies) no effect could be identified (Griffith et al. 2006; Janz et al. 2003); for Germany and Sweden (in the second study) showed even significant negative effects. Thus, also in accordance with the Swiss panel results, process innovation does not seem to be a driver of productivity growth.

Product innovations were taken into consideration in the studies for France, Germany, Spain, the UK and Italy: significant positive effects were found for France, Spain and the UK but not for the other two countries (Griffith et al. 2006; Parisi et al. 2006). Similarly to Switzerland, also in these three countries product innovation contributes considerably to productivity growth.

Concluding remarks

The results for the productivity equations can be summarized as follows: physical capital (but not human capital) growth and foreign ownership definitely matter for labour productivity growth. Besides evidence that less productive firms catch up to those who are more productive, we also find that innovation activities stimulate labour productivity growth.

With respect to latter, we found significantly positive coefficients for four out of six innovation variables; we could not find a significant effect for process innovation and patent applications. Especially product innovations seem to matter for labour productivity growth.

The magnitude of the impact effect on productivity growth varies between 7% and 10%. This means that dependent on the innovation indicator the shift from a firm without innovation activities to the one with such activities correlates with an increase of productivity growth of 7 to 10 percentage points on average over the next three years. With an average growth rate of 3.8 percent in our sample, this effect can be considered to be quite substantial. This result confirms the widespread view that the performance of the Swiss economy crucially depends on innovation. Innovation activities decreased continuously in manufacturing (for which we have more data) between 1993 and 2002 (see Arvanitis et al. 2007). Taking into consideration that manufacturing has been the most productive part of the economy, it is not astonishing that overall productivity growth has stagnated in this period. The negative development of innovation activities offers a (partial) explanation besides the decrease of capital-labour ratio (see table 5–2) for the low growth of productivity of the Swiss economy in the 1990s.

Future research has to take care of some problems that we could not handle in this study. Price deflators were not available neither at firm level nor at a disaggregated industry level, e.g. 3- or 4-digit industries. Further, the problem of double counting (expenditures on labour and physical capital used in R&D should be removed from the measures of labour and physical capital used in production) has to be encountered, especially when using some measure of R&D capital. Schankerman (1981) clearly demonstrated that the failure to remove this double counting has a downward bias on the estimated R&D coefficients. Finally, a future study has to deal with the fact that innovations are to some extent public goods, thus leading to external effects (spillovers), both positive and negative, which have to be taken explicitly into consideration.

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Part 2:

The Measure of Labour Input

6. ON THE IMPORTANCE OF USING COMPARABLE LABOUR INPUT TO MAKE INTERNATIONAL COMPARISON OF PRODUCTIVITY LEVELS
Canada-U.S., A Case Study

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Statistics Canada

Introduction

In 2005, Statistics Canada's Canadian Productivity Accounts released two studies that, for the first time, examined the comparability of labour productivity levels between Canada and the United States.[83] Previously, Statistics Canada limited comparisons to productivity growth rates. Using analogous sources, concepts and methods to obtain the most comparable measure possible of productivity levels, these new studies found that the Canada–U.S. productivity level difference was lower than normally described.

Neither the Canadian nor the American data used to measure work intensity for this project are the same as those used by many who have conducted Canada/U.S. comparisons of the level of labour productivity. Other studies have used data that were assumed to be comparable – such as data from the Labour Force Survey (LFS) in Canada and those from the equivalent American survey, the Current Population Survey (CPS) – but which are not.

This third study[84] focuses in more depth on the construction of the volume of hours worked developed for this project and on the choice of estimates of jobs and population. It describes the reasons why the work intensity measures used in our Canada/U.S. project are superior to alternatives that are readily available but non comparable and therefore inappropriate for studies of Canada/U.S. comparisons of the level of productivity.

[82] The author would like to thank John Baldwin, Tarek Harchaoui and Mustapha Kaci for their invaluable help with the presentation and content of the various drafts that led to this final version. He also wishes to thank Don Drummond, Graham Rose and Gloria Wong for their relevant comments, as well as Mike Harper and Phyllis Otto from the Bureau of Labor Statistics for the many clarifications provided about U.S. labour statistics. This third article on the project comparing Canada–United States productivity levels initiated in fall 2003 by the Canadian Productivity Accounts would never have seen the light of day without the outstanding work of a team of analysts composed of Marc Tanguay, Jin Lee, Fanny Wong and Sean Burrows. However, despite the involvement of all these people, the author remains wholly responsible for any error or omission in this study

[83] Baldwin et all., 2005; Baldwin, Maynard and Wong, 2005.

[84] This paper is a shorter version of a more detailed study The comparative level of GDP per capita in Canada and in the United States: A Decomposition into Labour Productivity and Work Intensity Differences.

This study answers the following questions:

1. What are the reasons for the choice of data to measure the volume of hours worked?
2. Why are the estimates of the volume of hours worked developed for this study the most appropriate for comparing levels of work intensity and hours worked per job between Canada and the United States?
3. What are the problems with traditional data sources that make them inappropriate for comparisons of levels?
4. What is the degree of error that is made if a study relies on alternate but easily accessible labour force sources to compare levels of productivity and work intensity between Canada and the United States?

The first section develops and illustrates the conceptual and methodological framework required to make Canada–United States estimates of labour and population comparable in terms of level.

Using the year 2000 as an example, the second section quantifies the "statistical error" that arises from using inadequate statistics or statistics not designed for this type of international comparison. This exercise reveals that the comparability of data on hours worked per job is especially crucial to identifying the origin of the differences in GDP per capita between labour productivity and hours worked per capita. The worst error involves comparing hours worked estimated from an employer survey with those obtained from a household survey. This type of comparison between Canada and the United States results in assigning an estimated 72% of the difference in GDP per capita to labour productivity when, in reality, it counted for barely 36% in 2000.

The last section of the paper presents a brief Canada-U.S. analysis of the GDP per capita differences and its components based on this comparable measure over the period 1994 to 2005.

Estimation of labour input for comparisons of relative levels of labour productivity in Canada and the United States

Background

Although Canada and the United States are located on the same continent and their culture and institutions are similar, the statistical systems in the two countries rely on concepts and methods that are not always equivalent. There are two possible approaches that can be used to draw cross-country comparisons using Canada/U.S. data:

a) A mechanical approach is to use various labour market data published by the two statistical systems without considering the initial objective for which the series were established and whether series with similar titles are really comparable;

b) A more time intensive approach is to compare sources, concepts and methods and to make modifications to the series of one or other country to reconcile differences.

It was the latter approach that was adopted by Baldwin et al., (2005) and Baldwin, Maynard and Wong (2005), who made a considerable effort to ensure that the various components of the decomposition of GDP per capita were as comparable as possible in terms of concept and coverage.

Selection criteria

There are a number of different sources that can be used to develop estimates of labour inputs for the purpose of comparing productivity levels in Canada and the United States. The suitability of particular sources depends on four factors: the extent to which they are consistent with the required concept, whether their coverage is appropriate, whether their methodology is comparable, and whether their accuracy is similar.

Concept

An estimate of labour input for the purposes of analyzing productivity must allow for the measurement of the derived work effort that most accurately reflects the production of goods and services.

Labour input can be measured by the number of persons employed or by the hours worked. Since workers do not work the same hours in every country, differences in effort are better reflected by the volume of hours worked than by the number of persons employed.

The 1993 System of National Accounts thus proposed hours worked as the preferred measure to be used with gross domestic product (GDP) for productivity estimates. Furthermore, the international definition of what constitutes work is based on time worked.

The System of National Accounts (1993) uses a definition of hours worked that is consistent with the concept defined by the International Labour Office.[85]

According to the retained definition, hours worked means the total number of hours that a person spends working, whether paid or not. In general, this includes regular and overtime hours, breaks, travel time, training in the workplace and time lost in brief work stoppages where workers remain at their posts. On the other hand, time lost due to strikes, lockouts, annual vacation, public holidays, sick leave, maternity leave or leave for personal needs are not included in total hours worked.

Coverage

Estimation of labour inputs must correspond as closely as possible to the National Accounts production boundary, which serves to measure the production of goods and services. This applies to estimates of jobs, hours and population when gross domestic product per capita is calculated. Some labour input sources do not cover all sectors. For example, agriculture is usually excluded from employer surveys. Some population aggregates also exclude a

85 For the official definition, see System of National Accounts 1993, Chapter XVII, Section 3

substantial number of individuals (i.e., those who live in institutions, such as long-term care facilities and penitentiaries or military personnel). Ideally, sources that provide only partial coverage need to be supplemented by data on the excluded part of the population.

Accuracy or quality of estimates

The accuracy of each estimate associated with a survey depends on both sampling error and non-sampling error. Sampling error will depend on the size of the sample and its design, while non-sampling error will depend on administrative practices, coverage problems and definitions.

The quality of an estimate is partially dependent on its intended use. Some estimates may be highly appropriate for some uses and less so for others. For example, a particular source of labour data may be downward biased in terms of levels, while providing a good indication of the trend. Such a data source is appropriate for developing an estimate of labour growth used to derive estimates of labour productivity growth, but it would be inappropriate for estimating the level of labour productivity.

In fact, as we note below, this issue is critical to the choice of a particular estimate of labour input for the United States and Canada if comparable estimates of the productivity levels in each country are to be produced.

Corroboration

Discovering information that corroborates estimates of labour input is one way of evaluating the quality of such estimates. Alternative methods, albeit imperfect, can still be indicative of the appropriateness of the chosen estimate.

Sources of labour inputs

There are two main sources from which estimates of labour input for Canada and the United States can be produced, namely household surveys and employer surveys. The first collects information by asking members of selected households whether they are working and how much time they spend at work, whether paid or unpaid. The second asks employers directly for information on the number of people working at their businesses and the amount of time they work (normally their hours paid).

Each of these surveys differs in terms of accuracy, although it is important to note that accuracy depends on the intended use for each source. What is appropriate for one use is not necessarily appropriate for another. We have already noted that what would be adequate for comparing the employment growth rates in each country may not be adequate for comparing levels. Different series may provide essentially similar estimates of growth rates but different estimates of levels. It should be noted that producing accurate data in terms of levels is much more demanding in terms of statistical quality than what is necessary to provide a trend indicator.

It is important to recognize that surveys are often developed to meet objectives that are different from those of a particular analyst – especially those conducting cross-country comparisons. A household survey may be developed to provide information on short-term trends in the labour market but not necessarily to estimate the level of the employment–population ratio. Moreover, a household survey does not necessarily constitute the best instrument for obtaining full coverage of all jobs in the economy, but may yield a more than adequate estimate of hours worked per job.

In evaluating the extent to which a particular data source is appropriate for a particular use, an analyst needs to ask whether the respondent has the ability to provide the information requested. An equally important consideration is whether the statistical agency is able to deal with the estimation difficulties associated with a particular instrument used for data collection.

Both household surveys and enterprise surveys encounter problems in obtaining hours worked, which is required for measuring productivity. However, the problems and the solutions for dealing with them are different in each case.

Enterprise surveys

Hours worked data from enterprise surveys contain several problems. The first is that firms often do not keep data on jobs that are not paid on an hourly basis. This includes white collar workers or the self-employed. It also includes workers with non-standard working arrangements. The latter make up a substantial part of the workforce. The Upjohn Institute reports that only 70% of workers are in jobs with standard work arrangements (Houseman, 1999). And of this group, only about 70% are hourly workers. This is becoming more of a problem in the service economy as contracts are often specified in terms of annual salaries with unspecified overtime commitments.

A second problem occurs since enterprises can generally only report hours paid and not hours worked. And the size of unpaid hours worked has been increasing over the last two decades. In Canada, almost 9% of jobs report unpaid overtime, accounting for between 2% and 3% of total hours worked.[86]

These problems have been dealt with in the United States in different ways. For example, the Bureau of Labor Statistics (BLS) supplements the hours worked estimates derived from an enterprise survey (the Current Employment Survey, or CES) for hourly workers with data on hours worked for salaried workers and self-employed workers taken from its household survey (the Current Population Survey, or CPS). Hours paid are transformed into hours worked with other information on how many hours worked are unpaid and on how many hours paid have not been worked (e.g., paid vacations, paid sick leave, etc.).

Enterprise surveys may also have problems obtaining data on hours worked from businesses if firms just do not keep track of hours worked data. As the work week becomes less standardized, firms have less of an incentive to keep hours worked as part of their management information systems. Indeed, Statistics Canada gave up asking questions about hours worked on its enterprise manufacturing surveys in the 1990s when the response rate to these questions fell well below 50% and resort to widespread imputations became extensive.

[86] Special extractions from the 1998 Labour Force Survey.

Household surveys

Household surveys have been developed with an extensive set of questions that permit statistical agencies to delve into the labour market status of household members, the type of work that they perform, and the number of hours including usual hours, and overtime hours, hours without remuneration and the reasons for time lost – due to holidays, sickness, etc.

When these surveys are conducted across different classes of workers (paid hourly, salaried, self-employed), they generate estimates with good coverage. And since they ask for both paid and unpaid hours worked, they permit direct coverage of the definition of hours worked that meets international standards of work effort.

While household surveys have the advantage over enterprise surveys in that they directly request information on the concepts required to meet international standards, household surveys do face various problems in providing error-free estimates of hours worked.

First, in many households, the respondent will provide proxy answers for members of the household who are not present. And since respondents are asked for information on the previous week's experience, there may be a case of recall bias – that is, respondents may not remember precisely the hours actually worked in the previous week.

Survey methodologists in statistical agencies have devised ingenious methods to minimize these problems. The solution has been to design detailed questionnaires with special prompts as to unusual events in previous weeks, and to do follow-up surveys to gauge error rates. The result is a professional product in which most statistical agencies place great confidence.

It is nevertheless the case that household surveys often need special editing because they are not continuous surveys and extrapolation of the results from the survey week to other weeks for the purposes of the Productivity Accounts requires recognition that holidays affect each week in a month differently. Household surveys may have problems with unusual events that occur during the reference week. The solution of the Canadian Productivity Accounts is to make detailed use of data on holidays and other events to provide 'corrected' estimates for other weeks in a month.

Enterprise surveys will not have problems with holidays that occur during the reference week if they report hours paid – but to transform this estimate to number of hours worked to other periods not covered by the pay period requires transformations that are extremely complex.

Estimating the volume of hours worked

Despite our preference for the data on hours worked that are produced by household surveys, not all components that are required to estimate total hours worked for various categories (class of worker, industry, region) are available from one source.

Part of this problem arises because of slightly imperfect coverage of the household survey in Canada. Part of it arises because of inadequate industry coverage (low sample size) in the Labour Force Survey at very fine levels of industry detail.

Therefore, the Canadian Productivity Accounts (CPA) proceeds in several stages to develop total hours worked for its industry accounts. Only the first two are relevant here.[87] At the level of the economy as a whole, the CPA first generates estimates of jobs, and then it calculates estimates of hours worked per job. The volume of hours worked is then obtained by multiplying these two components together.

$$\Sigma \, \Sigma \, \Sigma \, (J_{imn} \times H_{imn}) = Vh_{imn} \qquad (1)$$

J = number of jobs
H = average annual hours worked
Vh = total hours worked

where i = industry, m = region et n = category of worker (hourly, salaried, self-employed).

Jobs

The CPA focus on the concept of Jobs instead of Persons Employed since it is this notion that is specified by the System of National Accounts. Jobs is chosen as the basic unit since it corresponds more closely to production than does a person employed in a world where persons can have multiple jobs.

Enterprise surveys tend to capture the number of jobs (though analysts will often incorrectly refer to the measure yielded by an enterprise survey as employment). On the other hand, household surveys focus on the person who is employed – but, with a set of additional questions, can ascertain whether that person has multiple jobs and where those jobs are located and thus estimate both employment and jobs.

In Canada, the Productivity Accounts use the Labour Force Survey to measure both employment and total number of jobs – enhanced by several other sources to cover the small number of segments not covered by this survey. The Labour Force Survey is benchmarked to the Canadian Census of Population – which is taken at five-year intervals and regular revisions are made to benchmark totals derived from Census totals and results are backcast to provide historically consistent series.

However, the U.S. employer survey is considered more reliable than the household survey for estimating number of jobs in the United States for our purposes. Aside from the fact it does not entail any breaks, the aggregated series that comes out of the Current Employment Survey (CES) is adjusted annually to a benchmark based on the administrative data collected for the purposes of managing the unemployment insurance program[88] (Nardone et al., 2003), making the CES a complete source of information on non-agricultural employment. Information on

[87] The reader is referred to Girard, Maynard and Tanguay (2006) for more discussion of how detailed industry labour estimates are obtained for the Canadian Productivity Accounts.

[88] In October 2003, a group of authors from the Bureau of Labor Statistics and the Bureau of Economic Analysis prepared an article analyzing the discrepancy between the employment figures from the Current Population Survey and the Current Employment Survey for a presentation to the Federal Economic Statistics Advisory Committee. The article contains a host of information and explanations on the differences between the two surveys. For further details, see “Examining the Discrepancy in Employment Growth between the CPS and the CES” by Nardone et al.

employment for the groups not covered by the CES, such as unincorporated self-employed workers, family workers and farm workers, is complemented by other sources, the main one being the Current Population Survey (CPS).

An illustration of the differences between the concepts of jobs and of persons employed in the United States **G 6–1**

Sources: Bureau of Labor Statistics Productivity Growth Program and Current Population Survey

For United States data, we choose the enterprise survey rather than the labour force survey to estimate total jobs because of well-known undercoverage in the CPS (Nardone et al., 2003). The CPS, like its Canadian counterpart, is benchmarked to the population census. However, the adjustment is decennial in the United States and quinquennial in Canada. During the 1990s, the U.S. projection system used to extrapolate the 1990 Census estimates fell further and further behind. As a result, the CPS sample frame, i.e., estimates of population aged 16 years and over, has some serious weaknesses for our purposes. The results of the 2000 Census revealed an underestimation of the working-age civilian non-institutional population that was equivalent to 2.7 million people that was mainly reflecting an underestimation of immigration, particularly undocumented and temporary immigrants (Nardone et al., 2003).

The CPS survey results were therefore substantially revised when the 2000 Census results became available. However, these revisions were made only for the period after 2000, resulting in a substantial break between the period prior to 2000 and that which followed (see graph 6–1, which compares the employment estimates derived from the CES to the estimates obtained from the CPS). The fact that the CPS measure of persons employed is subject only to periodic review and incomplete revision makes this source less than ideal for historical international comparisons.

In contrast, it is felt that the CES suffers less from this problem. In light of their undocumented status, Nardone et al. (2003) suspect that this population of immigrants would be very reluctant to respond to household surveys (Nardone et al., 2003) and argue that the CES employer survey would be much more likely to capture the jobs held by undocumented immigrants. Employers must, in fact, report the number of employees they have to the Employment Insurance program once a year. It should be recalled that it is the data from this file that is used as an annual benchmark for the CES. Frequent audits of this file have revealed a significant increase in the number of employees with false Social Security numbers. It was also noted that the use of false numbers was more likely to occur in industries in which employers have a tendency to hire more immigrants.

Jobs versus employment

While we focus on the number of jobs in our analysis, we can reconcile it with the number of persons employed from the sources that are utilized. Table 6–1 illustrates for 2002 the change from the concept of number of persons employed as published by the household surveys of the two countries to that of number of jobs, in keeping with the framework of the System of National Accounts that we are using here.

Some of the differences in table 6–1 between estimates of jobs and employment arise from differences in coverage, some come from differences in concept – since both jobs and employment data come from the same source (the Labour Force Survey [LFS]) for Canada, but different sources for the United States (jobs from the Current Employment Survey [CES] and employment from the Current Population Survey [CPS]).

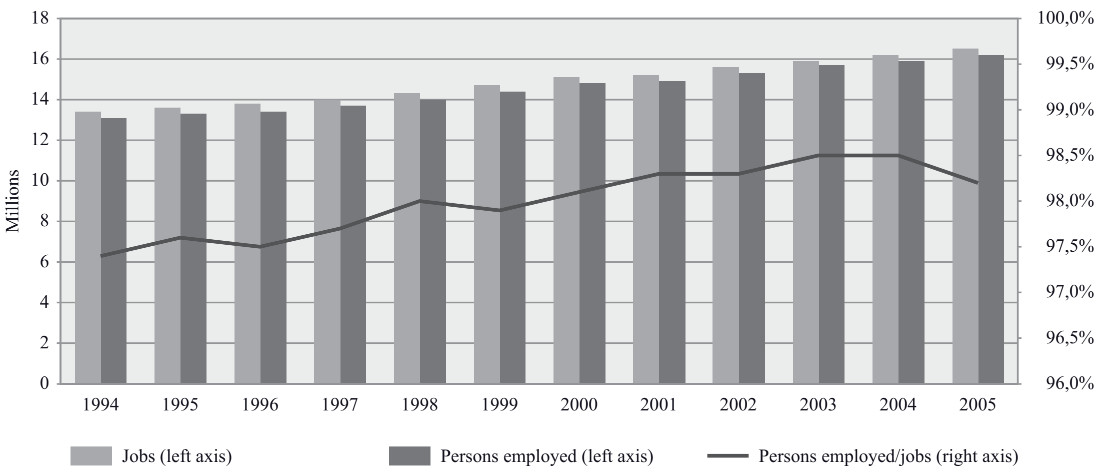
T 6 – 1 Difference between the number of persons employed and the number of jobs, 2002

			Canada (A)	United States (B)	(A) / (B) in percentage
			Thousands		
1.		Persons employed	15,310	136,485	11.2
2.	plus	Persons holding jobs	756	7,691	9.8
3.	minus	Unpaid absences	674	2,076	32.5
4.	plus	Military personnel	82	1,464	5.6
5.	plus	Other adjustments	87	2,386	3.6
6.	equal	Number of jobs	15,559	145,950	10.7
7.		Line [((6) / (1))-1] × 100	2%	7%	-5

Note: Calculations are based on labour sources produced by both countries.
Source: Statistics Canada, Canadian Productivity Accounts.

Line 1 is total employment as derived from the household surveys in both countries. The second line adds multiple jobs to those who are employed as generated by the household surveys. The third adjusts for a difference in concept – people who are absent from work but have a job are not included in the work concept that is required for productivity purposes but are included in the number of people who have a job by labour market analysts. They therefore are subtracted from the second line. The fourth corrects for differences in coverage since the military are often left out of household surveys but need to be added in for complete coverage of labour markets. The fifth line includes additional adjustments to bring the total employment number yielded by the household surveys into line with the number of jobs. For Canada, these include people on First Nation reserves, in the north, and government employees outside of Canada that are missed by the LFS. For the United States, this adjustment comes from taking the difference between the total number of jobs as defined by the CES and the total derived from the CPS using the same adjustments outlined in lines 2, 3 and 4. It will include the same type of adjustments made for Canada – slight geographic extensions – but the primary difference results from a substantial undercoverage of the CPS relative to the CES in terms of number of jobs, as was discussed in the previous section.

An illustration of the differences between the estimate of jobs and of persons employed in Canada **G 6–2**



Sources: Statistics Canada, Canadian Productivity Accounts and Labour Force Survey.

Changing from one concept to the other is associated with a 2% increase in the variable in Canada (column A), as compared to 7% for the United States (column B).

There are many reasons for the difference in the magnitude of the adjustments between the two countries. They have to do with the difference in the way the labour market is regulated and the percentage of military personnel in each country as well as purely geographical questions and their impact on the accuracy of the statistics compiled.

For example, the number of persons who responded that they held a job but who were absent from work and were not paid by their employer, as a percentage of the number of persons employed, was three times higher in Canada than in the United States in 2002. While it was relatively stable until 2000, this percentage has grown significantly in the interim, partly because of the adoption in Canada of legislation supporting parental leave funded through the employment insurance program[89] (see graph 6–2).

Furthermore, Canada differs from the United States in terms of the role and the place held by the armed forces. The number of military, as a percentage of the number of persons employed, in the United States, is approximately double that of Canada.

Lastly, it should be noted that the percentage of other adjustments that we make here, which primarily relates to those of a statistical nature, is three times higher for the United States than for Canada. In Canada, this category reflects the addition of northern Canada and of Aboriginal reserves. For the United States, this category stems from the difference between the figures for the number of persons employed obtained from the CPS and that of the number of jobs derived from the U.S. productivity program, which is obtained by adding the CPS data for jobs in farms, private households and self-employment to the number of paid jobs from the CES.

Hours worked per job

Hours worked in this study are calculated from the labour force surveys of the two countries for the reasons outlined above. But in both countries, adjustments are made to the series since the unadjusted estimates do not adequately take into account holidays. Each of the labour force surveys is conducted monthly but covers only one week. The results of that week need to be extrapolated to other weeks in the month. In doing so, we need to recognize that the reference week used by the household survey may not be representative of the other weeks in the month, either because it has more or less holidays than other weeks.

The Canadian Productivity Accounts (CPA) have developed a procedure to make the corrections to raw Labour Force Survey totals – to correct for what we refer to as reference-week bias. In this study, average hours from the Current Population Survey were subject to the same type of adjustment as those from the CPA so as to correct the estimation bias associated with the choice of reference week. We explain below what these adjustments entail (see Maynard, 2005 for details).

The occurrence of a public holiday or specific vacation during the reference week means that the number of hours worked as collected through the survey for this week are not representative of the 52 weeks that make up the year as a whole. For Canada, we identified 13 statutory public holidays that are recognized by either a provincial or the federal government. Of that number, there are two that appear regularly during the reference week and three others that appear sporadically. We observed a similar phenomenon in the United States, but it was of lesser magnitude. Of the 11 federal holidays granted as days of rest in the United States, only three appear during the CPS reference week, including two that occur on an irregular basis (Eldridge, Manser and Flohr, 2004).

89 The other reason for this large percentage relates to the economic cycle: temporary layoffs tend to increase when the economy is in a downturn. A similar phenomenon was observed during the recessions of 1980 to 1981 and 1990 to 1992. See Galarneau et al., (2005) for further details.

In Canada, the estimation bias associated with the reference week owing to such factors as the sporadic presence of statutory public holidays primarily affects the trend in average hours. However, average annual hours calculated solely from the 12 reference weeks causes a relatively lower error than in the United States in terms of levels. In the United States, average annual hours calculated solely from the 12 reference weeks are nonetheless less vulnerable to trend bias (see table 6–2).

T 6 – 2 Effect of adjustment of hours per job on Canadian and U.S. estimates, all jobs

Total	Unadjusted hours		Adjusted hours		Percentage difference between unadjusted and adjusted hours	
	Canada	United States	Canada	United States	Canada	United States
1994	1,811.8	1,944.5	1,762.2	1,834.9	2.8	6.0
1995	1,799.3	1,951.8	1,761.0	1,828.8	2.2	6.7
1996	1,811.9	1,957.4	1,774.1	1,844.1	2.1	6.1
1997	1,813.0	1,967.0	1,767.4	1,848.9	2.6	6.4
1998	1,796.7	1,954.0	1,766.8	1,853.4	1.7	5.4
1999	1,811.5	1,972.0	1,769.0	1,859.0	2.4	6.1
2000	1,823.8	1,983.0	1,767.7	1,870.8	3.2	6.0
2001	1,788.6	1,955.0	1,762.1	1,860.8	1.5	5.1
2002	1,775.9	1,954.5	1,744.3	1,850.6	1.8	5.6
2003	1,745.1	1,949.3	1,734.0	1,844.4	0.6	5.7
2004	1,762.6	1,955.3	1,752.5	1,851.7	0.6	5.6
2005	1,777.3	1,955.9	1,738.1	1,850.6	2.3	5.7
Average	1,791.9	1,958.4	1,757.6	1,850.2	2.0	5.9

Notes: Calculations are mainly based on Labour Force Survey microdata for Canada and on Current Population Survey microdata for the United States. Unadjusted hours are obtained by using the number of persons employed 15 years and over as denominator while the adjusted hours worked are using the number of SNA jobs as denominator.

Source: Statistics Canada, Canadian Productivity Accounts.

In the CPA's case, adjustment of hours can be summarized in four steps. An initial adjustment entails neutralizing the effect of statutory holidays on the reference weeks by adding the number of hours of absence to actual hours. Weekly hours are then standardized. The next step is a linear interpolation of the number of standardized hours in the reference weeks for the purpose of producing estimates for all weeks of the year. At the same time, estimates of hours of absence relating to statutory holidays and certain specific vacations that arise during the weeks other than the survey's reference weeks are estimated from the number of lost hours observed using the reference weeks for all jobs. These hours of absence as well as those observed during the reference weeks are then subtracted from the estimate of standardized hours. These adjustments give a better annual estimate of hours worked since the hours actually lost because of statutory holidays (which occur every year) are systematically deducted from the CPA database year after year.

The same type of adjustment also applies to certain vacation hours since in some provinces the reference weeks coincide sporadically with vacations on fixed dates, such as those of construction employees in Quebec and the school break for primary and secondary school teachers. A final adjustment is also made to take into account the fact that calendar years do not necessarily start on a Sunday and do not necessarily end on a Saturday.

We applied similar adjustments to the data on hours worked from the Current Population Survey. The information on hours of absence and the reasons for them that had been captured during the reference weeks were used to estimate hours lost owing to public holidays that do not appear during the survey's reference week. We have also made an extensive use of the U.S. time use survey to improve the estimation of hours lost due to holidays. The time use survey was used here to help derive U.S. estimates because the CPS reference weeks do not cover enough statutory holidays.

This series of adjustments eliminated the bias associated with specific events that affect both the level and the trend for hours per job. In both Canada and the United States, this series of adjustments reduced the level of average hours calculated solely on the basis of the 12 reference weeks. Table 6–2 contains series that show the impact of the adjustment of hours worked for Canada and the United States.

In Canada, this adjustment resulted in a decrease in average hours of approximately 2% per year over the period from 1994 to 2005, while in the United States the same type of adjustment represents a 5.9% decrease. The more substantial decrease observed in the United States comes from the fact that the Bureau of Labor Statistics statisticians chose the reference week so as to minimize the presence of public holidays. This means that the comparison of unadjusted hours worked from the household surveys of the two countries exaggerates the difference in hours per job (and per person) between Canada and the United States.

It is useful to ask whether there is outside information on the reliability of our estimates of the number of days lost that corrects for reference week bias. Without a weekly labour force survey, the only way to validate our estimates is through information taken from Canada's labour legislation. Table 6–3 provides estimates of the number of days lost in relation to the primary reasons for absence for Canada and the United States. These data reflect the adjustments described above.

T 6–3 Number of days and hours of work lost by salaried employees, by reason, in Canada and the United States, 2002

Reason	Canada		United States	
	Hours lost	Days lost	Hours lost	Days lost
Annual vacation	96	12.0	67	8.4
Public holidays	54	6.7	30	3.8
Temporary layoff	2	0.3	4	0.6
Illness or accident	34	4.2	26	3.3
Inclement weather	2	0.2	2	0.3
Family or personal responsibilities	10	1.2	10	1.3
Maternity	4	0.5	0	0.0
Other	4	0.5	32	4.0
Total	205	26	174	22

Notes: The number of days in this table is estimated on the assumption that a workday equals 7.5 hours per day. Labour Force Survey and Current Population Survey hours of absence are compiled after adjustment for holidays and vacations.

Source: Statistics Canada, Canadian Productivity Accounts.

Canada's labour legislation requires a minimum of two weeks of vacation per year. An average of 12 days lost through vacation is therefore entirely reasonable. As for public holidays, the majority of full-time Canadian workers are entitled to eight major holidays. Approximately one-quarter of the full-time workforce, largely in the government sector, is entitled to a maximum of 11 statutory public holidays. Given the large percentage accounted for by part-time work, seasonal work and essential services (in health and security, for example), an average of 6.7 days lost for this reason is acceptable. When only full-time workers are taken into consideration, the average number of hours lost through annual vacations is 102.6 hours (13.7 days), while the equivalent figure for statutory holidays is 62 hours lost, or 8.3 days. This suggests that our estimates are comparable to those enforced by the legislation.

In the United States, public holidays and vacations are not mandatory. This probably explains why our adjusted estimates from the CPS show fewer hours lost than in Canada for statutory public holidays and vacations. The same holds true for most other categories, except for temporary layoffs and weather. However, it must be noted that the figure for the "Other" category is eight times higher in the United States. This result could be an indication that the data on causes of days lost for the United States are less accurate.

Measurement of population

For comparisons of gross domestic product (GDP) per capita or of hours worked per capita, estimates of population are also required.

The notion of population and its derivatives, such as working-age population, which is consistent in terms of GDP coverage, is *resident population*. This concept, which includes the armed forces and persons in institutions, is consistent with GDP coverage – because this indicator includes the activities of these groups when measuring the total value of economic activity. It is this concept that is used in the official measure of GDP per capita published in the National Accounts tables of both countries.

There is a different concept of the population that is used in labour force surveys – that of the civilian non-institutional population, which excludes some who are considered not to be relevant by analysts who are trying to estimate how well the economy is supplying jobs to its population. This definition leaves out the young by choosing to look at those above a certain age – 15 years and over in Canada and 16 years and over in the United States. In addition, the military is left out for the anachronistic reason that these individuals are not considered to be voluntarily participating in this labour market, which may have been true when military drafts were common but is no longer the case in either Canada or the United States. Finally, those who are in institutions (penitentiaries, long-term care hospitals) are omitted because of the belief that these individuals cannot participate in labour markets.

Table 6–4 reconciles the two population measures. The differences, calculated as a percentage of the resident population, are about the same.

While there are conceptual differences between the estimates of population that are associated with the labour force surveys, there are also differences in accuracy. Population estimates taken from different sources differ from one another – particularly in the United States. Analysts need to take these differences into account when choosing a particular source.

T 6 – 4 Reconciliation between the two concepts of working-age population, 2002

	Canada	United States	Canada as a percentage of United States
	Thousands		
Resident, total (P)	31,373	288,253	10.9
Resident 15 years and over	25,547	227,344	11.2
Civilian non-institutional, 16 years and over (LFS and CPS)	24,797	217,570	11.4
Difference	750	9,927	7.7
Difference as a percentage	3%	4%	…

… not applicable

Notes: Resident population and resident population 15 years and over come from CANSIM table 051-001 v466668 and v466956 for Canada and from the U.S. Census Bureau for the United States. The civilian non-institutional population 16 years and over comes from the Current Population Survey for the United States and from the Labour Force Survey (special aggregate calculated by the Canadian Productivity Accounts) for Canada.

On the one hand are the estimates of population that are provided in both countries by the census of population from a periodic (five-year intervals in Canada and ten-year intervals in the United States) census. This is regarded as perhaps the most comprehensive and accurate method of collecting data – though it is not without error. But these errors are carefully tracked via post enumeration surveys. For the 1990 Census, the U.S. Census Bureau estimated that the undercount was 1.6%.[90] For the 2000 U.S. Census, the undercount was initially estimated at about 1.2%,[91] but this estimate was revised downward to -0.49%.[92] In neither 1990 nor 2000 was the U.S. Census adjusted since it was felt the error in the Census was within the margin of error that the post-enumeration estimates provided.[93]

But a population program also provides intercensal projections – using data on births, deaths, immigration and emigration – to predict population changes in intercensal years. And as pointed out previously, Canada and the United States have differed in the accuracy of these projections in intercensal periods because of differences in the frequency with which the census is taken (5 years in Canada but 10 years in the U.S.) and differences in the extent to which there is unmeasured immigration in each country. Nardone et al., (2003) have outlined the main reasons for the underestimation of population in the United States for the intercensal estimates. The latter pertained primarily to immigration that appears to have been greatly underestimated in the intercensal data between the 1990 and 2000 censuses. The characteristics of this population are quite different from those of the original population. Research has shown that the number of undocumented and temporary immigrants, large numbers of whom are Hispanic or black, was considerably underestimated between 1990 and

90 See http://www.census.gov/main/www/cen1990.html.

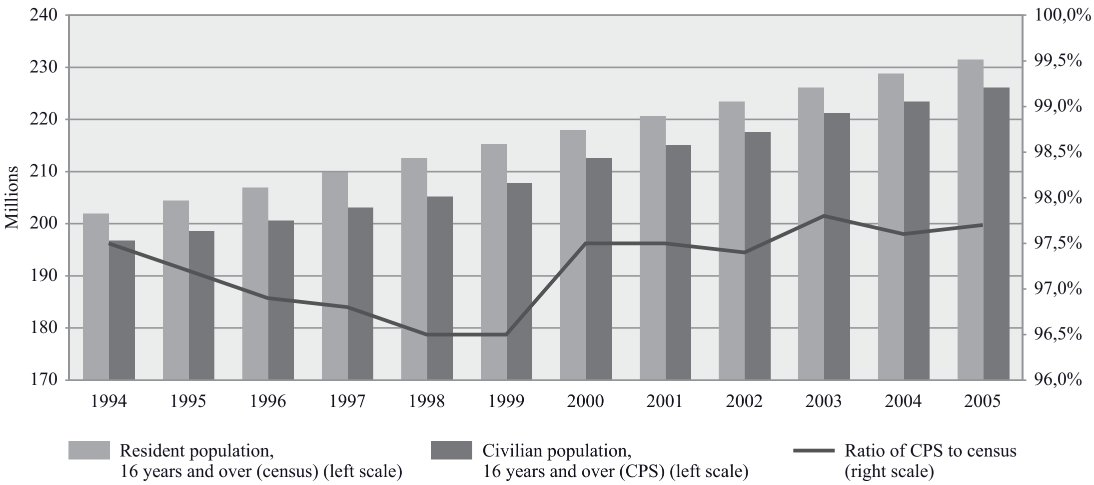
91 U.S., Census Monitoring Board (2001).

92 Robinson and Kostanich (2003).

93 Stark (2002) argues that this is justified since the post-enumeration surveys that are used to estimate the size of the census error themselves are subject to error that is about the same as their estimate of the census error.

2000 (Nardone et al., 2003). But these intercensal estimates can be and are revised backward after benchmarks become available from census years. However, the extent to which this revision is made differs across U.S. sources.

Accuracy of civilian non-institutional population estimates from the Current Population Survey (CPS) as compared to resident population **G 6–3**

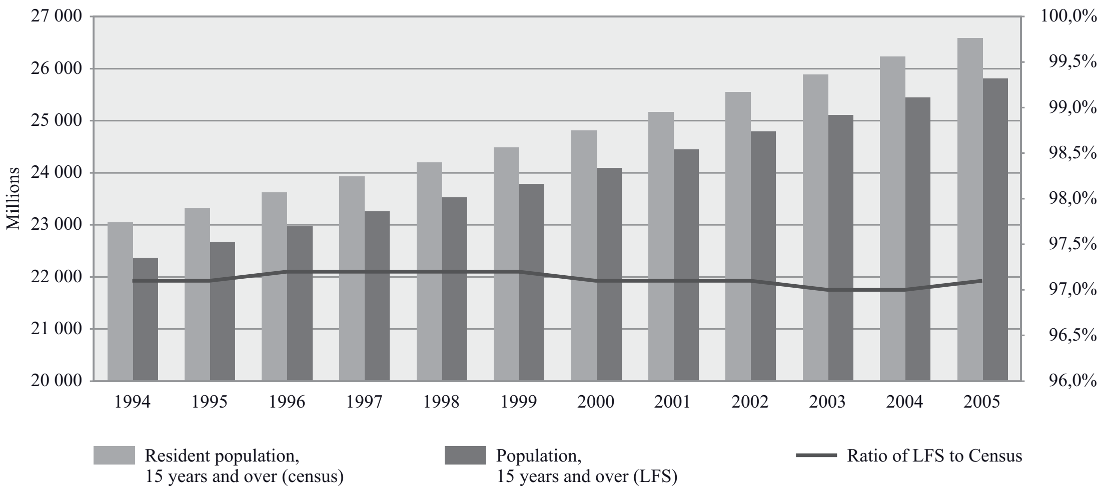


Sources: U.S. Census bureau and Current Population Survey.

The data on resident population that are published by the U.S. Census Bureau are quicker to reflect all of the revisions deemed necessary to make methodological changes to these estimates and do so in most cases without introducing any breaks in continuity. As can be seen from graph 6–3, which compares the estimate of the over 16 years resident population from the census to the population estimate for this group published by the Current Population Survey (CPS), the population estimates that are used by the CPS that are derived from the projections of the population program are not revised backward completely after benchmark adjustments.

The figure shows the breaks that affected the CPS series in 2000 and 2003. In looking at graph 6–4, which compares the same series for Canada, it can be seen that the population aged 15 and up from the Labour Force Survey (LFS) is consistent with that from the post-census estimates of population. The difference between the two arises from the fact that the census is using the resident concept while the LFS is using the civilian non-institutional concept and the fact that the ratio between the two remains constant indicates that the two measures are generally fully reconciled in Canada.

Accuracy of Canadian estimates of civilian non-institutional population from the Labour Force Survey (LFS) compared to resident population **G 6–4**



Notes: Resident population is derived from CANSIM series 051-0005; civilian population, 15 years and over comes from the Labour Force Survey (special aggregate calculated by the Canadian Productivity Accounts).
Source: Statistics Canada, Canadian Productivity Accounts.

Framework for reconciliation between alternative measures

The framework

This section quantifies the errors committed when alternate, easily accessible but non comparable data sources are used in order to compare the sources of differences in GDP per capita between Canada and the United States.

To analyse the impact of these alternate measures, we use a standard identity that decomposes real GDP per capita into its constituent parts, namely labour productivity and work intensity.

$$\frac{GDP}{POP} = \underbrace{\frac{GDP}{HRS}}_{\text{Labour productivity}} \cdot \underbrace{\frac{HRS}{EMP}\cdot\frac{EMP}{WAP}\cdot\frac{WAP}{POP}}_{\text{Work intensity}} = \frac{GDP}{HRS}\cdot\frac{HRS}{POP} \quad (2)$$

where GDP, POP, HRS, EMP and WAP represent, respectively, GDP expressed in comparable currencies using purchasing power parities, population, number of hours, number of jobs, and working-age population (the appropriate measures for these variables are discussed below). The ratios $\frac{HRS}{EMP}$ and $\frac{EMP}{WAP}$ are referred to, respectively, as average number of hours and the employment rate.

To analyse more precisely some key factors of the standard of living, the work intensity variable is divided into three components – the number of hours per job, the number of jobs per member of the potential labour force and the potential labour force relative to the overall population.

Results based on three different alternatives

Table 6–5 presents the results of the decomposition of the Canada–U.S. difference in GDP per capita for the year 2000 using two inappropriate measures that have been occasionally used for Canada/U.S. comparisons. The first inappropriate measure (line 1) uses estimates of labour input developed by the productivity program of each country to measure the *growth* in labour productivity. Note that the primary objective of these programs is to estimate productivity *growth* and not the *level* of productivity relative to other countries. The second measure (line 2) uses data coming from the monthly household surveys of the two countries – the Labour Force Survey (LFS) in Canada and the Current Population Survey (CPS) in the United States. The third measure (line 3) makes use of the data on labour inputs generated in the Statistics Canada project that developed comparable data to be used to estimate the relative level of Canada – U.S. productivity.

T 6 – 5 Reconciliation between the two concepts of working-age population, 2002

Source data	GDP per capita	Labour productivity	Work intensity	Work intensity components		
			Hours worked per capita	Hours worked per job	Job / population aged 15 years and over	Population aged 15 years and over to population
1. CPA / BLS-PA	-20	-14	-6	+1	-10	+3
2. LFS / CPS	-20	-11	-9	-8	-5	+4
3. CPA project	-20	-7	-13	-6	-10	+3

Notes: Differences are expressed in this study in logarithms to preserve their additivity. The three rows make use of different source data. Measure #1 compares official data for the economy as a whole that are used to measure labour productivity growth in the two countries. “CPA” is the acronym for the Canadian Productivity Accounts, while “BLS-PA” stands for Bureau of Labor Statistics - Productivity Accounts. In measure #2, “LFS” refers to Canada’s Labour Force Survey and “CPS” stands for Current Population Survey, the American equivalent. Measure #3 presents results derived from the project to compare productivity levels conducted by the Canadian Productivity Accounts (CPA).

Using the year 2000 as an example and the same GDP per capita measure for the three sources of components, this study shows the crucial importance of using comparable measures to make international comparison of levels. They were developed by harmonizing concepts and coverage and by adjusting data to consider differences in collection methods and in data accuracy. The appropriate comparison (line 3) that uses comparable data shows that labour productivity contributes much less to GDP per capita differences than the two inappropriate techniques.

Measure #1: Problem with hours per job

The first inappropriate measure uses the levels of hours worked and the number of jobs derived from the official measures used to estimate labour productivity *growth* in both countries. Using this comparison, 70% of the 20% gap in gross domestic product (GDP) per capita in favour of the United States in 2000 can be attributed to Canada's weaker level of labour productivity. The correct measure (line 3) indicates that only 35% of the gap is due to lower labour productivity.

In general, both countries produce detailed estimates of the volume of hours worked by estimating the number of jobs and the annual number of hours worked per job. The volume of hours worked is obtained by multiplying these two elements.

The Canadian Productivity Accounts rely mainly on a household survey, the Labour Force Survey (LFS), to estimate employment; in the United States, the starting point for constructing these same estimates is an employer survey, the Current Employment Statistics (CES). Given that this survey has only partial coverage (does not cover, for example, farms and self-employed workers), the Current Population Survey (CPS) estimates are used to complete the coverage. Our assessment is, that based on conceptual, coverage and accuracy criteria, these two measures of employment are appropriate for comparing employment levels between the two countries.

The problem with measure #1 arises because the estimates of hours per job are derived from different types of surveys that in each country yield quite different estimates of hours worked per job. The Canadian Productivity Accounts rely on hours actually worked collected from a *household* survey – the LFS; on the other hand, the Bureau of Labor Statistics (BLS) instead uses the hours paid collected from its survey of *employers*. Although the estimates of hours paid are then converted by the BLS into hours worked by excluding hours of paid leave (vacation, holidays, sick, etc.), these two approaches produce results that are not comparable because household and employer surveys produce estimates that differ in a systematic way.

As part of this project, the Canadian Productivity Accounts conducted a comparison of the estimate of hours worked per job using household and employer surveys in each country. The results from similar surveys were compared across countries (household survey in Canada to household survey in the United States; employer survey in Canada to employer survey in the United States).

In table 6–6, we compare hours worked per job obtained from household surveys with those derived from employer surveys.

The comparison for household surveys made use of a similar methodology to adjust these data for the bias associated with household surveys that do not take into account statutory holidays when extrapolating data from a survey reference week to other weeks in the month.

T6–6 Comparison of estimated aggregations of hours by job according to adjusted data from household surveys with those derived from emplyer surveys, annualized data, 2003

	Canada	United States	Difference (U.S.–Canada)
A – Adjusted household surveys	1,734.0	1,844.4	111
B – Employer surveys	1,601.3	1,714.8	114
Difference (A – B)	133	130	…

… not applicable

Notes: Estimates for Canada are based on data from the Labour Force Survey and the Survey of Employment, Payrolls and Hours; for the United States, adjusted hours were compiled by the Canadian Productivity Accounts based on data from the Current Population Survey while the estimates from the employer survey correspond to hours per job estimated by the Bureau of Labor Statistics productivity program.

Source: Statistics Canada, Canadian Productivity Accounts.

For the United States, the employer survey data correspond to the estimate of hours worked taken from the Bureau of Labor Statistics' productivity growth program.[94] The starting point for the Canadian estimates is data on hours paid for employees paid by the hour, including overtime, combined with the number of hours that reflect the regular work week of workers receiving a fixed annual salary as collected under the SEPH. To transform this data into hours worked, we deducted paid hours of absence as determined by the LFS. Hours worked by workers not covered by the SEPH, such as those in agriculture, religious organizations and private households as well as all self-employed workers, also come from the LFS (see table 6-A1 in attachment).

Table 6–6 shows that, for both countries, the data on hours worked derived from employer surveys are lower than those calculated using the data from household surveys. This underestimation is approximately 133 hours in Canada and 130 in the United States. Hours worked derived from employer surveys are therefore not comparable to those obtained from household surveys, at least for these two countries. This table also suggests the average American works at least 100 hours more than the average Canadian (differences expressed in the last column of the table), regardless of whether the comparisons are derived using the household or the employer surveys. This demonstrates the direction and size of the error that occurs when a household survey in Canada is compared to an employer survey in the United States, as is done for measure #1.

There still remains the issue of whether hours worked for comparisons of levels should be estimated from household or employer surveys. Various studies conducted in several countries, including Canada and the United States, have compared the estimates of hours worked collected from households using a daily survey of time use – in theory the best approach for collecting this information – to the estimates derived both from employer and

94 These estimates are obtained by combining hours paid collected from the employer survey (Current Employment Survey) with Current Population Survey hours worked data to fill the employees categories and industries not covered by the CES. An annual compensation survey is also used to estimate the hours paid not worked due to holidays, vacation, etc.

labour force surveys. The estimates derived from the time-use surveys suggest that labour force surveys provide the most accurate estimates of hours per job. Therefore, these are the estimates that have been adopted in our Canada/U.S. comparison.

This first example demonstrates that the source of the data on hours worked per job is especially important in order to attribute the origin of GDP per capita differences to labour productivity or to hours worked per capita. Comparing hours worked estimated from a survey of employers to those obtained from a household survey has the potential to overestimate the impact of productivity gap on GDP per capita differences between Canada and the United States by about 8%.

Measure #2: Sources of labour intensity

The second inappropriate measure (line 2) compares the levels of the volume of hours worked, the number of persons employed and the civilian population of working age outside institutions obtained directly from household surveys in both countries. For this comparison, the 20% difference in gross domestic product per capita in favour of the United States in 2000 is divided almost equally between labour productivity (-11%) and work intensity (-9%). As was the case with measure #1, this one also attributes more importance to differences in labour productivity than the estimate that our Canada/U.S. project yields (line 3).

The differences with our reference measure originate mainly, in this case, with the absolute measures: the number of jobs and the working age population for the United States.

Although, at first glance, Canada's Labour Force Survey (LFS) and the U.S. Current Population Survey appear to provide fully comparable estimates, a more detailed analysis of these two surveys reveals unsuspected and quite substantial differences due to data coverage. These differences are enough to compromise use of these surveys for direct comparisons of levels of jobs – though not for hours worked per job when comparable methodology is applied to each survey.

While both countries use similar questionnaires, the statistical agencies on opposite sides of the border do not have access to a similar method to calculate the survey frame. In Canada, the demographic weights of the Labour Force Survey are recalibrated every five years using a five-year census, while in the United States, this recalibration occurs only once every ten years. In addition, Canada's recalibration results in an historical revision of the LFS estimates to eliminate any break in the series. In contrast, in the United States, this exercise leads to significant breaks in the Current Population Survey (CPS) series, the most recent having occurred in 2000 and 2003. (As discussed in Section 2.5).

Added to this statistical problem is the much higher proportion of undocumented immigrants in the United States, whom Bureau of Labor Statistics[95] analysts suspect are somewhat reluctant to respond to the CPS survey. On the other hand, legislation requires employers to report all of their employees annually to unemployment insurance officials and this approach appears to provide a better estimate of undocumented immigrants.

95 See Nardone et al., "Examining the Discrepancy in Employment Growth between the CPS and the CES", FESAC, October 2003.

In the United States, it is mandatory to have a social security number in order to obtain a job. It is the data from this file that are used as an annual benchmark for the employer survey (Current Employment Survey [CES]), which would explain why exercises to reconcile the two surveys indicate a substantial under-counting of jobs in the CPS compared to the CES. This problem was particularly evident between 1996 and 2003. Corrections made to the population estimate projection model by the U.S. Census Bureau have made it possible to narrow considerably the differences in job estimates between the two surveys since 2003.

As a result, data from the U.S. household survey (CPS) frequently suffer from a problem of underestimating the levels of jobs and the working age population. Since it only partially revises its series when benchmarking to the Census, this survey also experience breaks in its historical series. These two problems make using job estimates from this survey inappropriate for Canada–U.S. comparisons.

Measure #3: Reference measures from the Canada/U.S. project for comparing levels

Since the last historical revision of the National Accounts, the Canadian Productivity Accounts (CPA) have developed a measure of the volume of hours worked that can be used to measure both the growth and level of labour productivity. This is why Canadian estimates of the volume of hours worked and the number of jobs in measure #3 correspond to the estimates published by the CPA.

In their project to compare Canada–United States productivity levels, analysts with the Canadian Productivity Accounts selected their U.S. data sources to be comparable with the Canadian CPA data.

For several years, the Bureau of Labor Statistics' productivity program has also produced a level of employment that corresponds to the National Accounts concept, which covers the entire American economy and represents the most reliable level of employment that can be developed for that country. These are the estimates derived from their employer survey.

However, there is a problem of comparability with respect to hours per job as described above. As part of the Canada/U.S. comparison project, analysts in the Canadian Productivity Accounts produced estimates of hours worked per job using the Current Population Survey and a similar methodology used for Canadian data to account for holiday bias. It is these estimates that were used to compare the sources of differences in the level of gross domestic product (GDP) per capita.

Lastly, the population estimates used in this article are based on the concept of resident population. This concept is the one used in international GDP per capita comparisons. It is also important to note that it is the U.S. Census Bureau that produces these estimates using a revision procedure that avoids historical breaks.

Although there are differences in the methodologies used by the two countries to produce hours worked estimates that enter into measures of the *growth* in productivity, as long as these differences remain constant, the accuracy of comparisons of growth rates in the two countries will not be greatly affected. However, these differences in methodology make comparisons of productivity *levels* more difficult and some care should be used in interpreting and using the data that have been used for comparisons of growth rates. In order to obtain more accurate estimates of productivity levels in Canada relative to the United States, effort is needed to harmonize data sources and methods.

Canada/U.S. differences

This section examines differences in labour productivity and work intensity between Canada and the United States based on the Canada-US database developed by the Canadian Productivity Accounts.

Using the GDP per capita identity exposed in the previous section which shows that GDP per capita (CAP) is equal to the product of labour productivity (GDP/HRS), effort (the hours worked per job), and the per capita employment rate, (the ratio of the number of jobs to the total population). Or rewriting

$$GDPCAP = PROD * EFFORT * EMPRATE \qquad (3)$$

The amount available for consumption per person in a country (GDPCAP) will be higher when productivity (PROD) is higher, when employees work longer hours (EFFORT), and when a larger proportion of the population is employed (EMPRATE). The variables EFFORT and EMPRATE can also be grouped together in a variable called work intensity which corresponds to the volume of hours worked per capita.

This comparison is accomplished for the total economy of both countries.[96] Therefore, it combines both the business and the government and non-profit sectors to obtain measures of GDP.

Estimates of GDP for the total economy are taken from official estimates (Statistics Canada's System of National Accounts [SNA] and the National Income and Product Accounts [NIPA] Tables of the United States Bureau of Economic Analysis). Both countries generally adhere to the international standards embodied in the SNA (1993) manual (Baldwin et al., 2005). While there are some minor differences, they are not regarded as a major problem for Canada/U.S. comparisons at the level of the total economy.[97]

For comparisons of GDP in Canada and the United States, a deflator must be chosen to allow us to compare estimates of GDP that are produced in different currencies. For the purpose of this paper, we use the bilateral purchasing power parity indices that are produced by Statistics Canada to compare expenditures across these two countries (Temple, 2007). For

96 This means that the productivity estimates in this study also refer to the total economy. Statistics Canada normally only produces productivity growth estimates for the business sector because the estimation procedure followed by the National Accounts for the non-business sector (the non-market sector) essentially assumes that productivity in that sector is zero. Cross-country comparisons of labour productivity for the total economy therefore will be affected by the size of the non-market sector. If all countries follow the same assumption of zero productivity in the non-market sector, those countries with larger non-market sectors will have lower labour productivity because of statistical assumptions not because they are necessarily any less productive.

97 There are differences in specific industries that need to be considered when detailed comparisons are made at the industry level.

this paper, we make use of recently revised estimates.[98] In our accompanying study (Baldwin et al., 2005), we examine the appropriateness of these data for cross-country comparisons and conclude that this measure is somewhat imperfect and suggest several variants which tend to increase the value of Canada's labour productivity relative to that of the United States. For simplicity, we make use of the traditional estimate here.

The ratios needed for Equation (3) are estimated for the period 1994 to 2005 and presented in table 6–7. These include GDP per capita, labour productivity and work intensity for Canada relative to the United States (U.S.=100). To analyse more precisely some key factors of the standard of living, the work intensity variable is divided into three components – the number of hours per job, the number of jobs per member of the potential labour force and the potential labour force relative to the overall population.

The potential labour force is defined as those who are aged 15 years and over. While it might be argued that the elderly should be excluded from this definition, it is difficult to choose a particular age (i.e., 65 years old) when we arbitrarily designate individuals as unemployable. Choosing a lower bound is facilitated by mandated education requirements.

Over the period, GDP per capita in Canada averaged only 83.2% of GDP per capita in the United States (table 6–7). The output gap between the two countries was 16.8% of the U.S. GDP per capita. But the gap between Canada and the United States in labour productivity was much less – at only 7.8% of the U.S. productivity level. The difference in labour productivity accounted for 45% of the total percentage point difference in the GDP per capita between the two countries.[99] That is, if work intensity was the same in the two countries, more than half of the difference in GDP per capita would disappear.

When work intensity is decomposed into the three components mentioned above, substantial differences between Canada and the United States exist in each of the two former areas. Hours worked per job in Canada are only 95.1% of those in the United States and jobs per potential member of the labour force are 92.4% of the United States.

The course of relative Canada/U.S. GDP per capita, labour productivity and hours worked per capita over the period 1994 to 2005 is plotted in graph 6–5. Gross domestic product per capita remained stable over the period around 83.2%. However, the period before 2000 differs substantially from the period after 2000 in terms of the movement in the two components – labour productivity and hours worked per capita.

Prior to 2000, both components – labour productivity and work intensity – are relatively constant. Relative Canadian labour productivity is 93% of U.S. labour productivity and relative Canadian hours worked per capita is 88%. During this time, lower hours worked in Canada account for over two-thirds of the gap in GDP per capita.

In contrast, after 2000, productivity falls while work intensity rises dramatically. Relative Canadian labour productivity decreased from 94.1% in 2000 to 89.0% in 2005. The Canada/U.S. ratio of the number of hours worked per capita increased from 88.4% in 2000 to 94.7% in

98 These purchasing power parity indices (PPPs) have been revised to take into account new data for the government sector that the United States recently released.

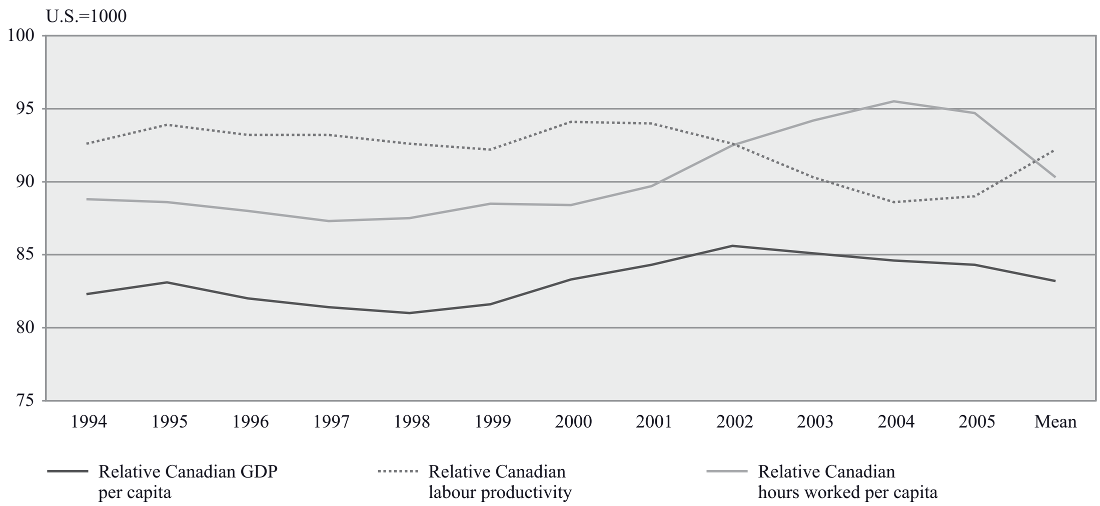
99 And as the accompanying paper (Baldwin et al., 2005) indicates, the actual difference in productivity levels is probably less than the estimate used here.

T 6–7 Decomposition of GDP per capita: Canada relative to the United States (U.S.=100)

Years	GDP per capita	Labour productivity	Work intensity	Work intensity		
				Hours worked per job	Ratio of jobs to population aged 15 years and over	Ratio of population aged 15 years and over to population
1994	82.3	92.6	88.8	96.0	90.7	101.9
1995	83.1	93.9	88.6	96.3	90.1	102.0
1996	82.0	93.2	88.0	96.2	89.5	102.1
1997	81.4	93.2	87.3	95.6	89.3	102.3
1998	81.0	92.6	87.5	95.3	89.7	102.4
1999	81.6	92.2	88.5	95.2	90.6	102.7
2000	83.3	94.1	88.4	94.5	91.0	102.9
2001	84.3	94.0	89.7	94.7	91.9	103.1
2002	85.6	92.6	92.5	94.3	95.0	103.2
2003	85.1	90.3	94.2	94.0	96.9	103.4
2004	84.6	88.6	95.5	94.6	97.4	103.6
2005	84.3	89.0	94.7	93.9	97.0	104.0
Average sub-period						
1994–1999	81.9	93.0	88.1	95.8	90.0	102.2
2000–2005	84.5	91.4	92.5	94.3	94.9	103.4
1994–2005	83.2	92.2	90.3	95.1	92.4	102.8

1. Canada as percentage of United States. United States = 100.
Source: Statistics Canada, Canadian Productivity Accounts.

Canadian gross domestic product per capita relative to the United States, 1994 to 2005 **G 6–5**



Notes: Calculated from Appendix 1, Tables A2 and A3.
Source: Statistics Canada, Canadian Productivity Accounts.

2005. This was due mainly to an increase in the extent to which the Canadian economy was providing jobs for its population. The Canada/U.S. ratio of the number of jobs worked by the population aged 15 years and over increased from 91.0% to 97.0% over the same period. By 2005, most of the gap in GDP per capita now comes from the gap in labour productivity, not the gap in work intensity.

Conclusion

What are the sources of the difference of real gross domestic product (GDP) per capita between Canada and the United States? To what extent do labour productivity and work intensity (the number of hours worked per person) contribute to the gap in the level of real GDP per capita between the two economies?

Answering these questions involves an empirical exercise that seems simple since it depends only on a small number of variables – GDP, population, employment, hours, etc. – that have been published on a regular basis since World War II by most statistical agencies.

In reality, the answer to these questions is more complex than it appears. Statistical agencies produce different variants of these primary indicators of economic activity for different purposes. An analyst who focuses on international comparisons needs to ask which statistic is best suited for this purpose and whether adjustments are necessary to improve their comparability.

There are several criteria that need to be used when choosing among alternatives when measures of work effort are being used for cross-country comparisons of labour productivity or work intensity.

First, the variable should have the correct coverage – that is, it should correspond as closely as possible to the production boundaries used in the System of National Accounts to calculate gross national product since the latter is the numerator used both to calculate GDP per capita or GDP per hour worked. Some measures of employment do not capture all sectors of the economy. Some measures of population exclude members of the military whose wages are included in GDP. Measures of employment need to be made comprehensive with respect to sectors and groups covered.

Second, the variable should be able to measure the correct concept. A measure of hours worked must be able to capture all hours devoted to production. Sometimes hours paid but not worked are included in data sources and this should be excluded from this measure. Sometimes hours worked but not paid (i.e., unpaid overtime) are excluded in data sources and these need to be included.

Third, measures should be as accurate as possible in terms of levels. For the purposes of estimating growth rates of labour input, the accuracy of levels is less important – as long as the error rate remains relatively constant over time. But for comparing employment levels across countries for purposes of estimating productivity levels, the analyst needs to consider whether the available estimates differ in terms of levels. In both Canada and the United States, household surveys provide higher estimates of hours worked per person than do firm-based surveys. International comparisons that choose different sources can therefore be biased.

Fourth, estimates of levels need to ask whether there is corroborative evidence that helps substantiate or triangulate the results. Are there other sources that help us substantiate the differences?

This paper describe how estimates of Canadian and U.S. hours worked, employment and population were developed for purposes of estimating relative levels of GDP per capita, GDP per hour worked and hours worked per capita that meet these four criteria. At the same time, it also examines shortcomings in some measures that are commonly used for Canada/U.S. comparisons – shortcomings with respect to coverage, concept or accuracy.

The paper demonstrates that these imperfect measures can lead to incorrect conclusions about the causes of the gap in GDP per capita between Canada and the United States. The appropriate measures developed here indicate that, as of 2000, only about one-third of the gap is attributed to lower productivity in Canada (lower GDP per hour worked) and about two-thirds to lower work intensity (lower hours worked per capita). This is quite different from some commonly used alternate measures – those labour measures that are used in the productivity growth programs of Statistics Canada and the Bureau of Labor Statistics. Other alternative measures are available – such as the data on hours worked from the labour force surveys. These contain problems that cancel out in some situations but not in others. While the proportion that should be attributed to labour productivity as opposed to work intensity changes over time (by 2005, a larger proportion is due to labour productivity), the lesson to be learned from our explorations is that it is important to make use of comparable data if the correct assessments are to be made over long periods.

International comparisons of labour productivity tend to emphasize data problems. But they have traditionally focused on comparability of GDP or capital – where problems are well known. The size of the problems that are involved in developing comparable estimates of labour inputs often receive less attention.

This paper focuses on two countries whose statistical systems are relatively similar – but where nevertheless there are sufficient differences to create problems if estimates of labour inputs are not carefully chosen to provide comparability in terms of coverage, concept and accuracy. The size of the error that would be made if comparability is ignored emphasizes the need to give careful attention to measurement issues on the labour side for cross-country comparisons of labour inputs, labour intensity and estimates of labour productivity differences.

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Appendix

T 6–A1 Estimate of hours worked based on hours paid from the Survey of Employment, Payrolls and Hours (SEPH), 2003

		Hours by job	Jobs	Hours worked
Employees paid by the hour	SEPH	1,461.3	7,318,397	10,694,090
Salaried workers with regular schedules	SEPH	1,710.1	4,297,410	7,348,860
Other categories of salaried workers	SEPH and LFS1	1,739.2	1,613,307	2,805,783
Agriculture	LFS	2,244.8	142,821	320,611
Hunting and fishing	LFS	1,744.4	8,338	14,545
Religious organizations	LFS	1,547.4	100,020	154,769
Private households	LFS	1,295.2	193,236	250,273
Self-employed workers	LFS	1,799.9	1,540,903	2,773,468
Total		1,601.3	15,214,431	24,362,400

1. The volume of hours worked for the other categories of salaried workers are not collected by SEPH. They were estimated by multiplying these jobs by industry from SEPH by the respective hours worked per job from LFS.
Source: authors' calculation.

Source: Statistics Canada, special tabulations by the Canadian Productivity Accounts based on estimates from the Survey of Employment, Payrolls and Hours, and the Labour Force Survey.

T 6–A2 Canadian data for productivity level estimates

Years	GDP, millions of dollars	GDP adjusted to PPPs, millions of dollars	Hours worked (thousands)	Jobs (thousands)	Population aged 15 years and over (thousands)	Population (thousands)
1994	770, 873	640,595	23,626,206	13,407	23,041	28,999
1995	810,426	675,895	23,985,703	13,620	23,329	29,302
1996	836,864	703,803	24,419,755	13,764	23,625	29,611
1997	882,733	740,613	24,787,390	14,025	23,930	29,907
1998	914,973	774,067	25,336,204	14,340	24,199	30,157
1999	982,441	823,286	26,037,717	14,719	24,485	30,404
2000	1,076,577	888,176	26,606,886	15,052	24, 805	30,689
2001	1,108,048	928,544	26,791,467	15,204	25,167	31,021
2002	1,152,905	975,358	27,181,228	15,583	25,547	31,373
2003	1,213,408	1,014,409	27,593,613	15,913	25,884	31,669
2004	1,290,788	1,077,808	28,377,150	16,193	26,233	31,974
2005	1,371,425	1,142 397	28,607,286	16,459	26,585	32,271

Source: Statistics Canada, Canadian Productivity Accounts.

T6–A3 United States data for productivity level estimates

Years	GDP, millions of dollars	PPPs (US$ per CAN$)	Hours worked (thousands)	Jobs (thousands)	Population aged 15 years and over (thousands)	Population (thousands)
1994	7,072,200	0.831	241 616 008	131 675	205 323	263 455
1995	7,397,700	0.834	246 406 214	134 738	208 007	266 588
1996	7,816,900	0.841	252 829 892	137 101	210 690	269 714
1997	8,304,300	0.839	259 150 256	140 165	213 560	272 958
1998	8,747,000	0.846	265 032 245	143 001	216 374	276 154
1999	9,268,400	0.838	270,372,149	145,436	219,085	279,328
2000	9,817,000	0.825	276,863,193	147,993	221,891	282,429
2001	10,128,000	0.838	274,748,578	147,652	224,610	285,371
2002	10,469,600	0.846	270,105,128	145,955	227,344	288,253
2003	10,960,800	0.836	269,193,074	145,948	230,072	291,114
2004	11,712,500	0.835	273,292,625	147,591	232,864	293,933
2005	12,455,800	0.833	277,647,909	150,034	234,960	296,677

Source: Statistics Canada, Canadian Productivity Accounts, from data produced by the Bureau of Labor Statistics, the Bureau of Economic Analysis and the U.S. Census Bureau.

7. LABOUR PRODUCTIVITY BASED ON INTEGRATED LABOUR ACCOUNTS
Does It Make Any Difference?

By Kamilla Heurlén and Henrik Sejerbo Sørensen,
Statistics Denmark

Introduction

In recent years more attention has been focused on empirical analyses of economic performance. As a consequence of this compilation of productivity growth and productivity levels has been common. These estimations are conducted by a number of different organisations, agencies, institutions, et cetera, but productivity estimates are often based on different data materials, depending on the researcher's choice.

The data material is of growing importance for politicians, analysers, because more accurate estimates can improve their rate of successful decisions. OECD has a precise description of why accurate estimates of productivity are of significant importance in their latest international comparisons of labour productivity levels:

International comparisons of productivity growth can give useful insights in the growth process, but should ideally be complemented with international comparisons of income and productivity levels. An examination of income and productivity levels may give insights into the possible scope for further gains, and also places a country's growth experience in the perspective of its current level of income and productivity.[100]

Because labour productivity growth rates/level serve as official yardsticks of economic performance, it is unfortunate that significant variations of the basis for the estimates are seen. At national level the choice of data and methodology differ from researcher to researcher and when there are considerable variations in national estimates international comparisons are even more difficult.

Especially international organisations, such as Eurostat and OECD, are aware of the problem and put a lot of efforts into the case to minimize the disparities, resulting from different choices of data, methodology, et cetera.

At national level it is often seen that, for instance, statistical agencies compile several estimates of employment and working hours. Especially, statistical offices publish employment and working hours on a regular basis in their labour accounts, but they are also obliged to publish these data within a national account framework. The latter data material is superior to the first in a productivity analysis perspective because of the harmonisation of definitions between numerator and denominator in the productivity fraction.

100 OECD (2005), page 3

Compilation of productivity measures requires two sets of data – three if international comparisons are made – GDP, hours worked and purchasing power parities for international comparisons. Definitions of the first and the latter are well covered within the SNA 1993/ESA 1995 standards compared to working hours where only a limited number of countries compile hours worked which are consistent with SNA 1993/ESA 1995 definitions. Because a chain is not stronger than its weakest link – resources for future improvements should be concentrated on this subject to improve harmonization of data.

Even in countries where working hours are compiled in the labour force statistics and in the national accounts there is a lack of documentation of the disparities between the two sets of data.

The aim of this paper is to give insight into why the two sets of statistics on Danish working hours differ and look at the problem from an empirical point of view for the purpose of clarifying whether Danish productivity results are sensitive to the choice of statistics on working hours.

It is important to emphasize that though National Accounts working hours are preferred in productivity analyses, it does not mean that Working Time Accounts are inferior. The two datasets serve different purposes and Working Time Accounts are an indispensable source for the National Accounts compilation and for many other purposes.

The paper is organized as follows:

Firstly, the paper presents in the next chapter the two data sets of working hours published by Statistics Denmark and explains why and in which industries disparities occur. The Working Time Accounts are presented in a preliminary version.

Secondly, compilation productivity growth rates and levels for Denmark based on labour accounts and national accounts working hours are made in the third chapter. The two sets of data will be compared at both aggregate and industry level and disparities will be quantified and briefly discussed.

Thirdly, in the fourth chapter, the implications at national level are discussed briefly, while the focus is on comparisons of labour productivity at both the national and international level.

Hours worked in the Working Time Accounts and in the National Accounts

Integration of the Working Time Accounts (WTA or also referred to as labour accounts) in the Danish National Accounts (NA) was implemented and published in January 2003 with final compilations of the year 1999 and provisional years 2000–2001. At Statistics Denmark the WTA are prepared by the Division for Labour Market Statistics.

Because of the variety of data sources, their use of concepts for variables as hours worked, the methodology applied in compilation of the WTA in Denmark has been subject to revisions and improvements. After a major revision of the first version of the WTA from December 1998 the second version was published in October 2003. Further refinements and use of alternative data sources resulted in a revised – not yet published – version of the WTA in June 2005. Linked with a data revision of the Danish NA the latter version of the WTA was integrated in the NA for the entire period 1995–2004 and published in July 2005.

The Working Time Accounts

The Danish Working Time Accounts (WTA) compile hours actually worked and related variables, which are based on integration of a range of primary statistical data. The use of administrative data sources (in which concepts may differ from the desired though usually covering the full population) and household surveys (which are flexible but costly to conduct) is optimized. A particularly difficult issue to address is the question of reference period. The integration of data sources in the WTA implies steps of harmonisation, completion, reconciliation and balancing[101].

Data sources applied in the WTA to compile employment, jobs, hours worked and compensation of employees can roughly be listed as the following:

- Register based labour force statistics (RAS)
- Establishment Related Employment Statistics (ERE)
- Earnings Statistics for the private sector and on central and local government employees
- Reports on payments of income tax (MIA)
- Labour Force Survey (LFS)
- ATP labour employment statistics (based on mandatory payments for a supplementary pension scheme)
- Indicators for aggregate payroll costs based on labour market contributions for employees

The WTA aims at coherence with SNA 1993 and ESA 1995 definitions. With respect to specific issues, the WTA, nevertheless, differs from the compilation of, e.g. hours worked in the National Accounts.

The National Accounts

The specific issues in which the WTA differs from the National Accounts can be divided into two types, where a distinction is made between issues that remain neutral on the aggregated variable and issues resulting in a change of level.

The neutral adjustments made are typically a result of relocating activity from one industry to another due to relocation of economic activity in the functional part of the NA. Further descriptions of these adjustments are made in a further section.

The level-changing corrections are made:

1. when alternative sources are preferred to the WTA, which is the case in a limited number of specific industries, and

[101] Naur (2004)

2. as a explicit supplement to the labour input, where this is not included in the WTA, such as non-residents working within the production boundary and underground activity

It is important to emphasize that neither the level-neutral nor level-changing corrections are done due to dissatisfaction or mistakes in the WTA. The revisions should been seen as implementations of an additional source (the National Accounts) and another conceptual framework (SNA 1993 and ESA 1995 definitions).

From Working Time Accounts to National Accounts – The Danish case

The transition from the WTA to the NA is illustrated in table 7–1. It is chosen to present the transition regarding employment and not hours worked, due to the actual method applied in the Danish NA, where hours worked is the result of NA-employment multiplied by the average hours worked per employee or per self-employed as compiled in the WTA.

Corrections number 2, 3, 5 and 7–10 are neutral definable corrections made according to the ESA 1995. These corrections can be described as relocations either between industries or between types (employee/self-employed) and the all remain neutral on the total.

The corrections made in number 6 and 12–15 are definable corrections made according to the ESA 1995, which are not neutral. These level-changing corrections can be caused by either application of alternative sources assessed to be superior to the WTA in view of the way in which the functional National Accounts is compiled or actual supplements due to either underground activity or consideration of economic instead of national boundary.

The corrections referred to in no. 17 are made subsequently to ensure consistency. These corrections are often a result of a thorough analysis of the initial results regarding wage shares and evaluations of the development in compensation per employee, compensation per hour worked, hours worked per person.

Transition described in details on aggregated level[102]

In this section the transition from the WTA to the National Accounts is reviewed in order to elaborate on the content of each head in table 7–1. For completion all heads are included below, though the heads (1, 4, 11, 16 and 18) merely refer to data at some level of compilation, whereas the others refer to a specific correction.

At aggregated level a number of cells are blank since the relocations are neutral. If a similar transition table was presented broken down by industries the relocations would be visible. Later on – in paragraph 2.4 – the transition by activity in 132 industries is illustrated though only divided into the two main types of corrections, the neutral corrections and the level-changing corrections.

No. 1 Working Time Accounts

Data from WTA as supplied from the Division of Labour Market Statistics. In this paper a preliminary version of the WTA is presented.

102 Section based on Heurlén (2003)

No. 2 Transformation to 132 industries

The WTA is divided into industries according to the NA-grouping, except regarding the industry 450000 Construction. This industry is divided into 4 sub-groups in the NA.

No. 3 Not stated

A proportionate distribution of the persons in the item Not stated in the WTA is undertaken in the NA.

No. 4 WTA as input to the NA

Data from WTA as supplied from the Division of Labour Market Statistics accommodated to the format used in the NA.

No. 5 Relocation of private employees in clear-cut public industries

The NA operates with a number of clear-cut public industries in which occurrence of private employees is not allowed. Any private employees engaged in – according to the NA

T 7–1 Overview of transition from Working Time Accounts to National Account

	Employment 2001	Employees	Self-employed	Total
		Persons		
1	**Working Time Accounts**[1]	**2,524,463**	**205,786**	**2,730,249**
2	Transformation to 132 industries	0	0	0
3	Possible distribution of not-stated if any	0	0	0
4	**WTA as input to the NA**	**2,524,463**	**205,786**	**2,730,249**
5	Relocation of private employees in industries purely general governmental	0	0	0
6	Employment in general government consistent with compensation of employees	14,792	0	14,792
7	Relocation of industries due to kind of activity (manufacturing to wholesale)	0	0	0
8	Other relocations due to activity	0	0	0
9	Relocation of self-employed to employees, if there is no production in the household sector	0	0	0
10	Relocation of owners of partnerships employed from self-employed to employees	25,961	-25,961	0
11	**WTA inclusive of neutral relocations and general government**	**2,565,216**	**179,825**	**2,745,041**
12	Alternative sources	-9,437	-2,142	-11,579
13	Hidden economy (here without extra explicit hours)	17,880	0	17,880
14	Non-residents employees in resident production	25,658	0	25,658
15	Special correction-effect when alternative sources only in compensation of employees	9,350	1,902	11,252
16	**National Accounts initial results**	**2 608,667**	**179,585**	**2,788,252**
17	Possible corrections to ensure consistency	-3,300	0	-3,300
18	**National Accounts**	**2,605,367**	**179,585**	**2,784,952**

[1] Preliminary version

clear-cut public industries – the WTA are relocated to adjacent industries, implying that the relocation is neutral. This relocation is undertaken to ensure consistency with the relocation of the compensation of employees and the rest of the NA in clear-cut public industries[103]. An example of illustration is the industry 751100 General (overall) public service activities, in which the WTA has approximately 200 private employees, who are relocated to adjacent industries[104].

No. 6 Employment in general government

The NA compensation of employees for the general government is obtained from Statistics Denmark's Division for General Government Statistics and overrules the WTA source. The reason for this is to take into consideration the consistency and long time series in the NA, as there is a discrepancy in industries between the figures from the General Government statistics and the WTA figures for the general government. In principle, adjustments of employment in the general government are made in such a way that the growth rate in compensation per employee remains the same in relation to the compensation per employee in the WTA. The NA practice of applying the compensation of employees of the General Government Statistics and then relocate employment in the general government according to the compensation of employees includes a step, where the total number of employees in the general government is adjusted to the WTA total, so that the corrections of the NA initially do not cause any changes in total employment in the general government compared to the WTA. A specific not substantial supplement to the employment in general government is made to cover persons that the WTA does not consider as employees, but for whom their compensation – in fact benefit – is included in the General government statistics.

No. 7 Relocation of industries due to kind of activity

In the NA, commercial activity is combined into distributive trades defined by activity, irrespective of their location in the primary statistical data. The practice of adjusting employment and compensation of employees among industries is made in order to ensure consistency between the industrial classification of employment and the functional part of the NA, implying that a number of employees will be relocated from the manufacturing industry to the wholesale trade.

No. 8 Other relocations of industries

Other relocations among some industries are necessary in order to ensure consistency between the industries defined by activity. An example is relocation of compensation and thus employment and hours worked from industries with integrated canteens to the industry 553009 Restaurants.

No. 9 Self-employed in the household sector

In the NA, the number of self-employed is fixed at zero in industries, where the production value in the household sector (S.14) is equal to zero, to comply with the definition of employment as a productive activity, ESA 1995 par. 11.11. Self-employed in industries

103 The clear-cut public industries in the Danish NA are as listed: 014002, 730002, 751100, 751209, 751300, 752002, 801000, 802000, 803000, 804002, 853109, and 920002.

104 The adjacent industries are as listed: 722000, 742009, 747000, 748009, 851209, and 910000.

with a zero-position is in the NA distributed to the other industries. 230000 Mfr. of refined petroleum products etc. and 670000 Activities auxiliary to finance are industries where this paragraph is used.

No. 10 Partnerships

According to ESA 1995 par. 11.13.e, employees comprise owners of corporations and quasi-corporations, provided that the owner is employed in the corporation. In the NA employed persons with partnerships are relocated from self-employed to employees, although the remuneration cannot be distinguished, classified as compensation and relocated. The total number of employed persons will not deviate from the WTA, although the distribution between employees and self-employed will differ. In practice, approximately 25,000 persons, less than 1 percent of the total, shift from self-employed to employees.

No. 11 Consistency with the WTA

Until this point there is still consistency with the WTA[105] although relocations have taken place within the private sector as well as within the general government sector. In the following, it is presented how the use of alternative sources and corrections for both residence and for informal work implies that total employment in the NA differs from that of the WTA.

No. 12 Alternative sources to private employees

In specific industries alternative or additional sources are chosen to calculate private compensation of employees. The choice of industries in which to apply alternative sources than the WTA is based on how the functional part of the NA is compiled and information from here is incorporated. The corrections implied by the use of alternative sources also result in corrections either implicitly or explicitly in employees and hours worked outside the general government. From this point the total employment in the NA deviates from the WTA.

An example of an industry, where alternative sources are applied is 450000 Construction in order to take the seasonal conditions and division in sub-groups into account. The table above illustrates that the correction due to appliance of alternative sources is in the neighbourhood of minus 10,000 persons.

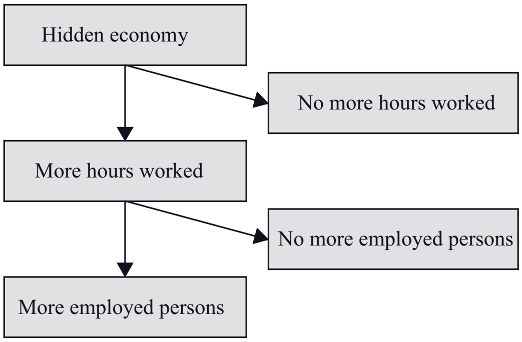
No. 13 Hidden economy

A supplement of persons and/or hours is made in the specific industries, in which the functional part of the NA makes an addition for hidden activity to the economic activity. The industries in question are identified and quantified by a Danish bench-mark study from 1992 replicated in 2004.

In the NA, it is considered when making corrections for hidden activity, whether adjustments in the industries for which supplement to turnover for the hidden work is compiled in the final NA, must be made in employment and/or hours worked in accordance with the principle illustrated in the figure below. It is emphasized that for each individual case, it depends on a specific assessment of the various types.

[105] with the only exception of a minor supplement to employment in general government

Hidden Economy **G 7–1**



When hidden economy does not give rise to hours worked in the case of, e.g. understatement of figures (VAT evasion) or tips, hidden employment is not adjusted. In the industries where hidden economy results in hours worked, but not in more employed persons, e.g. when an employed skilled craftsman or a motor mechanic performs hidden work, adjustments of only black hours are to be made.

Hidden activity performed by persons, who are not already regarded as employed persons, is adjusted in the NA employment.

An explicit supplement of persons informally employed is made in three industries:

1. 524490 Other retail sale, repair work
2. 553009 Restaurants etc.
3. 950000 Private households with employed persons

The supplement adds up to approximately 18,000 employees in 2001.

Regarding the two first-mentioned industries corrections are estimated on the basis of the additional turnover as set out in the National Accounts. Regarding the third industry corrections are estimated by setting compensation of employees equal to the production value, and subsequently calculate employment, thereby adapting employment to the new compensation of employees.

In addition to the supplement of persons due to hidden activity an explicit supplement is estimated of black hours carried out by persons already employed. In 18 industries[106] this supplement of hidden hours is only compiled, and for self-employed 6.5 million black hours are added equivalent to 1.8 percent of the self-employed hours worked in 2001.

No. 14 Correction for residence

In the NA, a specific supplement is made for the employees who contribute to the production but do not reside within the national borders. A specific supplement to employment is made

[106] The 18 industries with an explicit supplement of self-employed hours only are as listed: 050000, 158120, 180000, 200000, 222009, 361000, 362060, 502000, 524490, 602223, 602409, 722000, 741200, 747000, 804001, 851209, 920001, and 930009.

in accordance with ESA 1995 par. 11.17.f, e in 610000 Water transport, i.e. non-residents on Danish ships are added. Information is obtained from statistics compiled by the Danish Maritime Authority.

Furthermore, a supplement to employment is made for non-residents working in Denmark (The Oresund Region, South Jutland) (ESA 11.17.a, b, e and g). The Division for Labour Market Statistics has put forward a proposal containing a classification of industries based on the statistics on commuting (5–7,000 persons), but to ensure consistency with the economic part of the NA, it has been decided to estimate the number of non-residents working in Denmark on the basis of the statistics on compensation of employees abroad, which are extracted from the balance of payments, and subsequently divide this by means of average earnings (22,000 persons in 2001). Due to the choice of methodology, the calculation of a supplement for diplomats is included in this number.

No. 15 Special effect

The special effect adjusts persons according to adjustments and relocations of compensation of employees.

This item is partly in the category of alternative sources mentioned in no. 12. In very few industries an alternative source is chosen to compile only compensation of employees and not explicitly employees. In these cases the number of employees from the original source WTA is adjusted according to the adjustment made in compensation of employees.

In the presentation of the detailed transition table above, this item (no. 15) is made up as the residual.

No. 16 Initial results

Descending from the WTA an adjustment of formats and relocation of persons is carried out. Hence supplements are made due to primarily informal work and non-residents working in Denmark. The initial results are scrutinized and may cause further corrections.

No. 17 Manual corrections

Corrections to ensure consistency is undertaken where needed, for instance suggested by the development or level of wage shares in an industry. Corrections can be undertaken for individual industries in order to adapt compensation of employees and employment to the economic aggregates in the NA.

No. 18 Final results

According to the initial results and possible corrections to ensure consistency the final results are achieved.

Illustration of transition by industry

Examination of the transition by industry reveals information on the size of the corrections and whether these represent the neutral type or the level-changing type of corrections.

In table 7–2 hours worked are presented. The first column contains hours worked for both employees and self-employed in the WTA, and the fourth column presents hours worked in the NA. In the second column the corrections of the neutral type are estimated. Corrections of the level-changing type are the residual as presented in the third column.

The two types of corrections are described in more detail in the previous paragraph. Below, some comments are made to the figures in table 7–2.

From the description in the previous section of corrections made it is expected to find a positive type 1 correction in the industry 553009 Restaurants due to the relocation from the other industries to integrated canteens in 553009 Restaurants. This positive type 1 correction is indeed visible.

In the industries 721009 Computer activities exc. software consultancy and supply and 722000 Software consultancy and supply activity is relocated (due to relocation of activity mentioned in no. 8), thus giving a negative type 1 correction in these industries, whereas 510000 Wholesale except of motor vehicles is the "receiving" industry.

A positive type 1 correction, where 10 million hours are added in the industry 510000 Wholesale except of motor vehicles is seen due to activity relocated *from* amongst others the manufacturing industries cf. no. 7.

Type 2 corrections refer to level-changing corrections, and these are expected to be detected in industries with supplements due to underground or hidden work. In the industries with an explicit supplement of hidden employment the table confirms our expectations in only two out of three cases. There is a positive type 2 correction in as well 524490 Other retail sale, repair work and 950000 Private household with employed persons, while this is not the case in 553009 Restaurants. It seems that the type 1 correction in this industry is so vast that type 2 estimated as the residual becomes negative. In the industries with an explicit supplement of hidden hours worked without supplement of hidden persons, e.g. in 524490 Other retail sale, repair work the positive type 2 correction can be confirmed. The type 2 correction in 524490 is 2.5 million hours equivalent to 2.3 percent of the NA-hours.

In the industry 450000 Construction both type 1 and type 2 corrections are negative despite the fact of an explicit supplement of hidden hours in this industry. The reason for this is the use of additional sources to estimate the yearly average employment in this very seasonal sensitive industry. Further analyses will in future determine whether the WTA information of the seasonal pattern is preferred to the method used at present.

The supplement due to residence is only particularly visible as a positive type 2 correction in 610000 Water transport, while in the remaining industries it is almost proportionally spread out and not as visible.

A large number of industries show negative type 2 corrections. These can be caused by the method used in general government. In each industry where the WTA has public hours *and* the NA has not, the table will display a negative type 2 correction (provided that this is not eliminated by another larger *and* positive type 2 correction). An example is in 900020 Refuse collection and sanitation, which according to the WTA includes public activity, while it is a clear-cut *private* industry in the NA. Consequently, this implies a huge reduction in working hours in 900020 and a corresponding addition of hours in public industries.

If the "noise" from the problematic case of the general government was to be eliminated, one could choose to present a table similar to table 7–2 without general government, in other words only with the private hours worked. However, within the scope of this paper, presenting the sum of private *and* general government is preferred.

T7–2 Overview of transition at industry level – Year 2000

Industry		Working Time Accounts1	1. Level-neutral corrections	2. Level-changing corrections	National Accounts
		Hours			
11009	Agriculture	110,384 214	- 370,678	-6,482,661	103,530,875
11209	Horticulture, orchards etc.	17,249,190	- 62,654	449,907	17,636,443
14001	Agricultural services; landscape gardeners etc. (market)	15,191,835	- 41,856	270,112	15,420,091
14002	Agricultural services; landscape gardeners etc. (other non-market)	1,730,223		- 366,446	1,363,777
20000	Forestry	7,435,608	- 20,317	200,373	7,615,664
50000	Fishing	8,850,371	- 17,803	305,823	9,138,391
110000	Extr. of oil and natural gas	2,291,329	- 2,894	- 32,102	2,256,333
140009	Extr. of gravel and clay etc.	3,202,361	9,768	- 49,646	3,162,483
151000	Production etc. of meat and meat products	34,938,556	46,434	- 270,319	34,714,671
152000	Processing and preserving of fish and fish products	10,163,732	80,948	- 449,088	9,795,592
153000	Processing and preserving of fruit and vegetables	4,096,272	29,632	- 192,125	3,933,779
154000	Mfr. of vegetable and animal oils and fats	1,376,862	7,191	- 48,280	1,335,773
155000	Mfr. of dairy products	16,365,673	163,388	-1 068,978	15,460,083
156009	Mfr. of starch, chocolate and sugar products	18,338,619	15,228	- 13,401	18,340,446
158109	Mfr. of bread, cakes and biscuits	7,276,911	7,822	- 34,849	7,249,884
158120	Baker’s shops	16,204,611	-1,016,561	667,354	15,855,404
158300	Manufacture of sugar	1,864,117	21,544	- 160,414	1,725,247
159000	Manufacture of beverages	10,300,481	29,908	- 147,231	10,183,158
160000	Manufacture of tobacco products	1,988,836	1,136	6,955	1,996,927
170000	Mfr. of textiles	13,802,277	- 5,534	97,716	13,894,459
180000	Mfr. of wearing apparel	7,974,239	9,796	42,163	8,026,198
190000	Mfr. of leather and footwear	2,523,687	119,666	- 580,081	2,063,272
200000	Mfr. of wood and wood products	25,968,239	- 12,277	220,554	26,176,516
210000	Mfr. of pulp, paper and paper products	14,413,958	1,642	33,734	14,449,334
221200	Publishing of newspapers	16,942,110	- 41,583	542,041	17,442,568
221309	Publishing activities, excluding newspapers	21,062,859	- 33,270	272,284	21,301,873
222009	Printing activities	27,418,039	- 36,646	364,890	27,746,283
230000	Mfr. of refined petroleum products etc.	1,032,758	-68	10,342	1,043,032
241109	Mfr. of industrial gases and inorganic basic chemicals	1,198,712	19,119	- 150,483	1,067,348
241209	Mfr. of dyes, pigments and organic basic chemicals	8,082,941	- 5,610	-2,715,604	5,361,727
241500	Manufacture of fertilizers	812,803	5,436	- 45,845	772,394
241617	Mfr. of plastics and synthetic rubber	1,010,940	1,344	- 4,390	1,007,894
242000	Manufacture of pesticides and other agro-chemical products	1,511,369	- 2,324	25,929	1,534,974
243000	Mfr. of paints, varnishes and similar coatings, printing ink and mastics	4,383,685	24,812	- 150,407	4,258,090
244000	Mfr. of pharmaceuticals etc.	19,000,137	- 11,470	308,051	19,296,718
245070	Mfr. of detergents and other chemical products	9,495,299	54,611	- 340,936	9,208,974
251122	Mfr. of rubber products and plastic packing goods etc.	16,102,695	15,967	- 67,828	16,050,834
252300	Mfr. of builders ware of plastic	3,364,583	2,569	- 3,429	3,363,723

T7–2 Overview of transition at industry level – Year 2000

Industry		Working Time Accounts1	1. Level-neutral corrections	2. Level-changing corrections	National Accounts
		Hours			
252400	Manufacture of other plastic products n.e.c.	15,859,021	2,693	80,287	15,942,001
261126	Mfr. of glass and ceramic goods etc.	10,688,722	- 12,930	-1,310,083	9,365,709
263053	Mfr. of cement, bricks, tiles, flags etc.	2,790,137	2,807	- 8,140	2,784,804
266080	Mfr. of concrete, cement, asphalt and rockwool products	21,597,805	22,599	- 83,242	21,537,162
271000	Mfr. of basic iron and steel and of ferro alloys	2,359,326	- 4,724	34,024	2,388,626
272030	First processing of iron and steel	6,977,211	8,059	- 53,667	6,931,603
274000	Mfr. of basic non-ferrous metals	2,834,644	- 4	18,735	2,853,375
275000	Casting of metal products	3,992,103	4,266	- 11,088	3,985,281
281009	Mfr. of building materials of metal	46,157,030	- 37,182	315,237	46,435,085
286009	Mfr. of various metal products	29,705,125	22,884	- 156,739	29,571,270
291000	Mfr. of marine engines and compressors	35,378,153	30,750	- 1,257	35,407,646
292000	Mfr. of ovens and cold-storage plants	34,536,338	32,943	- 163,798	34,405,483
293000	Mfr. of agricultural machinery	9,440,609	8,324	- 53,987	9,394,946
294009	Mfr. of machinery for industries	27,792,216	- 1,770	75,793	27,866,239
297000	Mfr. of domestic appliances	6,790,895	38,062	- 211,450	6,617,507
300000	Mfr. of office machinery and computers	2,988,762	- 3,092	56,574	3,042,244
310000	Mfr. of other electrical machinery and apparatus	31,814,347	11,379	33,420	31,859,146
320000	Mfr. of radio and communication equipment	19,799,432	18,000	- 84,460	19,732,972
330000	Mfr. of medical and optical instruments	25,336,443	6,066	17,259	25,359,768
340000	Manufacture of motor vehicles etc.	12,358,948	546	30,066	12,389,560
351000	Building and repairing of ships and boats	11,646,031	- 10,459	79,313	11,714,885
352050	Mfr. of transport equipment excl. ships, motor vehicles etc.	3,644,013	5,807	- 21,110	3,628,710
361000	Mfr. of furniture	38,400,185	- 28,046	462,839	38,834,978
362060	Mfr. of toys, gold and silver articles etc.	12,947,805	88,358	- 493,625	12,542,538
370000	Recycling of waste and scrap	683,919	3,328	- 24,404	662,843
401000	Production and distribution of electricity	15,532,162	- 20,771	-1,977,773	13,533,618
402000	Manufacture and distribution of gas	2,208,170	- 2,948	85,675	2,290,897
403000	Steam and hot water supply	3,262,161	- 8,368	1,886,796	5,140,589
410000	Collection and distribution of water	3,502,843	- 10,390	1,295,697	4,788,150
450000	Construction	302,311,951	- 2,009,084	- 9,601,184	290,701,683
501009	Sale of motor vehicles and motorcycles	57,274,270	- 9,014,844	- 398,042	47,861,384
502000	Maintenance and repair of motor vehicles	34,137,939	15,426,852	- 6,219,519	43,345,272
505000	Retail sale of automotive fuel	14,175,687	- 5,305,461	2,862,577	11,732,803
510000	Wholesale except of motor vehicles	275,260,501	10,688,295	- 5,680,320	280,268,476
521090	Retail trade of food	81,037,037	6,187,320	1,692,731	88,917,088
522990	Department stores	30,945,909	- 119,396	477,685	31,304,198
523000	Re. sale of phar. goods, cosmetic art.	12,139,058	- 31,439	- 94,447	12,013,172
524190	Re. sale of clothing and footwear	34,385,082	- 123,049	180,038	34,442,071
524490	Other retail sale, repair work	104,810,318	- 307,711	2,493,868	106,996,475
551009	Hotels	29,335,053	- 106,280	555,920	29,784,693
553009	Restaurants	86,704,933	13,046,167	- 7,701,437	92,049,663
601000	Transport via railways	15,421,705	- 21,276	174,539	15,574,968
602100	Other scheduled passenger land transport	22,308,525	- 46,859	100,029	22,361,695

T 7 – 2 Overview of transition at industry level – Year 2000

Industry		Working Time Accounts1	1. Level-neutral corrections	2. Level-changing corrections	National Accounts
		Hours			
602223	Taxi operation and coach services	27,982,318	- 71,862	893,477	28,803,933
602409	Freight transport by road and via pipelines	67,833,888	- 140,547	3,187,795	70,881,136
610000	Water transport	26,961,515	- 58,178	7,821,844	34,725,181
620000	Air transport	19,624,667	- 655,446	- 1,753,081	17,216,140
631130	Cargo handling, harbours etc., travel agencies	28,466,615	- 53,789	1,741,800	30,154,626
634000	Activities of other transport agencies	21,418,825	- 40,157	801,757	22,180,425
640000	Post and telecommunications	85,178,251	- 185,621	- 208,717	84,783,913
651000	Financial institutions	66,560,352	- 103,455	1,687,114	68,144,011
652000	Mortgage credit institutions	16,910,802	- 23,657	206,191	17,093,336
660102	Life insurance and pension funding	3,442,923	- 5,350	414,743	3,852,316
660300	Non-life insurance	21,348,673	- 29,269	2,092,728	23,412,132
670000	Activities auxiliary to finance	6,036,058	- 7,771	- 95,283	5,933,004
701109	Real estate agents etc.	15,444,769	- 33,191	265,781	15,677,359
702009	Dwellings	29,803,025	- 73,158	102,550	29,832,417
702040	Letting of non-residential buildings	11,184,895	- 25,965	- 46,396	11,112,534
710000	Renting of transport equipment and machinery	10,401,542	460,796	- 15,914	10,846,424
721009	Computer activities exc. software consultancy and supply	14,577,333	- 2,190,680	1,948,605	14,335,258
722000	Software consultancy and supply	52,265,160	-5,811,549	7,900,477	54,354,088
730001	Research and development (market)	6,148,348	- 7,559	- 631,396	5,509,393
730002	Research and development (other non-market)	11,464,660		225,157	11,689,817
741100	Legal activities	16,704,340	- 36,206	188,353	16,856,487
741200	Accounting, book-keeping, auditing	31,573,528	- 54,399	599,220	32,118,349
742009	Consulting engineers, architects	65,408,807	- 189,059	2,928,550	68,148,298
744000	Advertising	20,817,335	- 121,198	507,702	21,203,839
747000	Building-cleaning activities	65,953,053	- 168,682	-9,199,999	56,584,372
748009	Other business activities	88,126,340	- 233,516	4,017,946	91,910,770
751100	General (overall) public service activities	102,559,789		3,388,432	105,948,221
751209	Administration of public sectors exc. for business	32,295,198		8,883,487	41,178,685
751300	Regulation of and contribution to more efficient operation of business	18,558,055		3,888,170	22,446,225
752001	Defence, police and administration of justice (market)	10,125,030	- 21,020	1,108,858	11,212,868
752002	Defence, police and administration of justice (other non-market)	95 572 199		-7 563 598	88 008 601
801000	Primary education	141 087 232		-3 627 719	137 459 513
802000	Secondary education	66 858 681		-1 311 609	65 547 072
803000	Higher education	41 929 761		2 838 076	44 767 837
804001	Adult and other education (market)	7 290 415	- 16 464	543 109	7 817 060
804002	Adult and other education (other non-market)	38 458 441		10 063 417	48 521 858
851100	Hospital activities	135 956 356	- 1 875	-6 069 709	129 884 772
851209	Medical, dental and veterinary activities	66 079 903	- 98 320	1 936 217	67 917 800
853109	Social institutions etc. for children	208 901 343		-1 346 234	207 555 109
853209	Social institutions etc. for adults	226 501 031	- 22 115	-1 084 370	225 394 546
900010	Sewage removal and purifying plants	3 925 522	- 9 863	1 446 377	5 362 036
900020	Refuse collection and sanitation	26 072 545	- 11 179	-20 406 117	5 655 249

Industry		Working Time Accounts1	1. Level-neutral corrections	2. Level-changing corrections	National Accounts
		Hours			
900030	Refuse dumps and refuse disposal plants	3,403,218	- 6,355	5,444	3,402,307
910000	Activities of membership organizations	73,469,868	- 97,110	984,735	74,357,493
920001	Recreational, cultural, sporting activities (market)	54,919,394	- 129,887	2 598,193	57,387,700
920002	Recreational, cultural, sporting activities (other non-market)	23,451,846		- 683,933	22,767,913
930009	Other service activities	34,192,276	- 100,961	880,895	34,972,210
950000	Private households with employed persons	1,296,347	- 66,069	15,042,322	16,272,600
Total		4,271,881 693	2 352,009	6,198,462	4,294,339 741

Note: Due to limited space only industry codes are shown. Information about names and codes for each industry is available in appendix 1.

Compilation of labour productivity based on two different sets of labour accounts

As seen before, working hours in labour accounts preliminary version and in the national accounts differ due to the different framework in which they are compiled. In this section compilation of labour productivity with the two sets of labour input will be presented. The purpose is to investigate what impact a change of denominator has on the result.

Analyses of productivity growth are often divided into two categories. First, the most common way of compiling labour productivity:

$$\Delta LP = \frac{\Delta VA}{\Delta H} \qquad (1)$$

where ΔLP is the percentage change in labour productivity, ΔVA is the percentage change in gross value added between two periods and ΔH is the percentage change in number of working hours between two periods.
The second way to analyse these sets of data are in level:

$$LP_t = \frac{VA_t}{H_t} \qquad (2)$$

where VA_t is the gross value added in period *t* and H_t is the actual number of working hours in period *t*.

The focus of this paper is working hours and the consequences of differences in working hours. Both equations (1) and (2) can be affected by differences in the number of working hours. Adaptations of national accounts definitions to the WTA and NA are not similar from period to period and hence it is expected that labour productivity with the two sets of working hours will differ both in growth rates and in levels.

Labour productivity – growth rates

In this section labour productivity following equation 1 based on the two sets of working hours are presented for the period 1995 to 2003. The data are divided into the most detailed level (six-digit level) at which the Danish national accounts working hours are available.

The labour productivity compilations are based on gross value added at 2000 constant prices. The left side of the table shows labour productivity based on labour accounts and on the right side the compilations are carried out with the national accounts working hours. For both series yearly average growth rates are shown and the differences between these are presented far right. The main focus is on the average growth rates while some noise in the year-to-year growth rates can be reduced by conducting this. Nevertheless, the purpose of this paper is not to discuss uncertainty in compilation of productivity measures in general, but to quantify disparities between the two datasets.

Table 7–3 shows that the average labour productivity for the total economy is reduced 0.2 percent point as a consequence of the adaptation of the national accounts definitions. Looking at the yearly growth rates it appears that these can differ to a great extent. For example, growth rates in 2003 differ -1.3 percent points and in 2001 has the sign changed from plus to minus. For the total economy the conclusion is that for the average growth rate the choice of denominator is of lesser importance, but looking at the yearly growth rates it is seen that disparities can be of major importance for productivity conclusions.

Looking at the industries significant disparities for both yearly growth rates and average growth rates can be seen. The growth rates at industry level are influenced in single years and at the average growth rates. Among the biggest differences (in actual hours) are 011009 Agriculture, 610000 Water transport, 8040022 adult and other education and 900020 Refuse collection and sanitation.

Even though 011009 Agriculture is altered significantly the average growth rates remain unchanged, but growth rates in single years differ in some years significantly. The reason why agriculture is altered is that alternative national accounts sources are used (see last chapter revision point 12) instead of the WTA, however in this case the influence of a significant alteration is modest. A similar correction is made for 110000 Extraction of oil and natural gas, but in this case it has major implications for the labour productivity growth rates. Both single year's growth rates and average growth rates are considerably changed as a consequence of the revisions.

Working hours in industry 610000 Water transport are increased significantly due to non-resident workers at Danish ships; see point 14 in chapter 2.2 for further information. Because of the increase in working hours labour productivity growth rates are reduced significantly, but labour productivity in Water transport is still very high.

Industries including activities from general government are also based on the use of additional sources. Because wages and salaries in the national accounts differ from what is compiled in the labour statistics a similar revision is made of the working hours. This implicates that working hours in 804002 Adult and other education (other non-market) are increased significantly, and the average growth rate is reduced from 4.4 % to -2.7%. Another industry which is affected by general government data is 900020 Refuse collection and sanitation. According to the WTA nearly 5/6 of the working hours in this industry is performed in general government, but per convention general government cannot be placed in this industry; see point 3 in the last chapter for further information. Therefore, 5/6 of the working hours are moved to other industries which include general government. Naturally, the comprehensive transfers of working hours affect the labour productivity especially at yearly basis, but also the average growth rate is reduced from -4.8 % to – 8.8 %.

In the secondary industries revisions are common due to the use of additional sources. One of the reasons is to ensure consistency between the industrial classification of employment and the economical part of the national accounts; see point 7 in the last chapter for further information. It implicates that working hours in these industries are in many cases revised significantly, and therefore the labour productivity growth rates are modified significantly. Examples could be 501009 Sale of motor vehicles and distribution of water and 502000 Maintenance and repair of motorcycles where growth rates differ between the two data sets, primarily with respect to the yearly growth rates.

The overall result of these compilations seems to be that productivity growth rates are influenced by the choice of working hours at both aggregate and detailed level. The use of average growth rates seems to reduce the influence, but cannot eliminate the effect.

Labour productivity – levels

In the previous section it was seen that compilations of labour productivity growth rates were sensitive to the choice of working hours. In this section focus will be on what consequences the choice of dataset has on the compilation of labour productivity levels.

Adaptations of new definitions do not necessarily have a significant effect on the growth rates. If working hours are increased X percent in industry Y in every year it does only have a modest effect on the productivity growth rates and are therefore not necessarily discussed in section 3.1. Nevertheless, the order of the most productive industries, measured as gross value added per hour can change dramatically and it is therefore also important to quantify the impact on the productivity levels.

Table 7–4 shows the levels of labour productivity for each industry and for the total economy. As in the previous section compilations are based on gross value added at 2000 constant prices. The left side of table shows levels based on labour accounts and on the right side the compilations are conducted with the national accounts working hours. For both series annual yearly average growth rates are shown and the difference between these is presented far right.

A closer look at the table shows that the total has changed -1.4 percent due to the change in working hours. The reduction of the productivity level is not surprising, primarily because hours are added due to the adoptions of SNA 1993/ESA 1995 definitions. The hidden economy is one of the main reasons for the reduction of the productivity level, but as mentioned in section 2 several other factors have an influence.

Contrary to the total, a difference at industry level seems to be of major importance. The revisions have two significant implications. Firstly, productivity levels for some industries have changed dramatically. Industries such as 11000 Extraction of oil and natural gas, 271000

T7–3 Labour productivity based on two different sets of working hours

Industry	Working Time Accounts								National Accounts									Yearly average difference	
	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	
	Annual percentage change Hours																		(pct. point)
11009	10.8	6.4	7.5	1.1	10.3	-6.3	-5.6	11.1	4.9	12.9	5.8	8.3	2.4	9.9	-5.4	-6.6	14.2	4.9	0.1
11209	-8.9	12.6	-0.9	-5.3	-7.8	-10.0	-10.8	26.2	-1.3	-9.2	11.8	-1.3	-5.4	-7.2	-11.2	-11.0	31.3	-1.2	0.1
14001	-2.9	8.4	-4.8	-1.1	8.6	18.6	-11.1	20.6	4.6	-2.9	7.9	-4.9	-0.7	9.1	18.0	-10.9	15.6	3.4	-1.2
14002	9.1	-10.7	2.0	-11.8	12.2	12.3	6.0	16.5	4.6	11.3	-6.8	-0.4	2.2	1.7	10.8	20.8	5.9	5.4	0.8
20000	-2.4	12.9	0.7	2.5	-19.5	35.5	-4.8	12.5	4.1	-2.4	10.4	1.4	2.4	-20.4	36.0	-5.0	15.7	3.7	-0.4
50000	-10.3	23.5	2.0	5.6	-7.5	7.8	-18.1	-25.8	-3.5	-9.3	23.3	-2.9	11.6	-7.9	7.0	-18.3	-25.3	-3.9	-0.4
110000	21.7	16.0	-10.3	27.3	12.8	-17.1	-37.3	-19.8	-3.0	21.3	8.5	-9.5	18.7	12.1	-13.5	32.9	-5.8	7.0	10.0
140009	13.6	1.9	-4.5	-6.3	3.4	2.0	15.3	12.4	5.2	13.5	0.8	-3.2	-5.7	4.9	1.4	15.2	1.1	3.3	-1.9
151000	-4.3	1.6	22.2	16.6	-20.1	16.6	-1.0	-19.4	0.4	-4.8	2.7	20.7	17.5	-18.3	15.7	-1.3	-22.7	0.0	-0.4
152000	8.8	3.5	-19.4	10.7	-13.1	-18.1	-2.2	5.2	-3.3	7.9	4.3	-17.6	12.6	-14.6	-18.6	1.0	9.0	-2.8	0.5
153000	26.7	17.5	-9.9	-15.7	12.9	-5.2	92.4	-14.2	12.5	27.4	17.6	-10.6	-15.0	15.9	-8.0	96.4	-17.8	8.8	-3.7
154000	9.4	103.0	-12.1	-38.4	162.2	19.9	-5.7	-15.7	25.0	7.9	111.9	-12.6	-37.8	164.4	15.3	-6.0	-13.3	15.1	-9.9
155000	1.9	10.4	-11.2	-6.7	22.1	-7.6	5.7	104.9	16.0	2.2	10.5	-15.3	-5.4	15.7	-8.8	0.2	97.1	8.2	-7.7
156009	0.5	7.7	6.5	6.7	-18.4	14.0	-0.4	-11.0	0.2	-1.0	7.7	6.7	7.5	-18.3	13.4	0.2	-7.1	0.7	0.5
158109	-3.7	9.6	-6.5	4.6	-1.7	12.2	-8.6	-0.8	0.4	-1.3	6.3	-6.7	5.4	-0.7	10.8	-8.1	1.3	0.7	0.3
158120	-3.7	6.9	-4.0	-4.4	-1.0	-0.5	20.3	2.3	1.8	-3.2	7.0	-4.2	-4.0	0.3	-0.6	20.4	3.3	2.1	0.3
158300	-11.8	-6.6	32.3	-11.7	50.0	-0.5	53.0	-14.2	11.1	-11.0	-0.7	28.1	-10.4	57.7	3.0	54.7	18.0	14.8	3.7
159000	-20.4	26.9	-5.1	-16.8	-13.2	-2.2	15.9	11.8	-1.5	-21.1	26.3	-5.6	-16.1	-12.1	-2.8	15.7	18.5	-1.0	0.6
160000	4.2	8.5	-15.8	-0.3	-13.3	0.6	0.1	-6.0	-2.8	3.9	8.2	-15.7	0.7	-12.9	-0.1	-1.2	-3.4	-2.9	-0.1
170000	0.9	3.0	3.5	7.1	1.7	-4.0	7.1	8.8	3.9	1.1	2.6	3.9	7.8	1.6	-4.6	6.9	9.4	3.5	-0.4
180000	16.0	4.1	-4.7	-2.7	-5.3	9.5	7.6	-5.5	2.2	14.7	4.8	-5.2	-1.9	-4.8	9.4	6.1	0.7	2.8	0.5
190000	-25.8	38.9	-7.9	9.4	14.8	-41.2	89.6	-15.7	1.5	-11.5	45.2	-6.7	9.7	13.2	-34.7	28.4	-6.9	1.9	0.4
200000	-15.9	18.6	-3.2	-2.0	1.6	0.1	2.7	10.9	1.2	-17.2	19.2	-3.3	-1.2	2.4	-0.5	2.5	9.0	0.9	-0.3
210000	15.8	21.2	0.9	9.1	7.3	-5.6	4.0	4.8	8.8	12.8	21.5	0.5	9.9	8.4	-6.8	3.9	4.3	6.5	-2.3
221200	-1.9	-1.1	-6.0	4.9	6.6	-0.2	-15.7	10.5	-0.6	-3.6	-1.5	-6.0	4.7	7.4	-1.8	-15.7	10.1	-1.1	-0.5
221309	-5.8	-2.2	-2.3	-6.4	16.2	-1.3	-11.1	10.4	-0.6	-5.8	-3.2	-2.0	-7.5	17.4	-2.1	-14.5	-1.3	-2.7	-2.1
222009	3.6	6.5	-3.6	-0.6	-5.4	-3.8	3.1	8.9	1.0	2.2	6.2	-3.6	-0.4	-4.6	-4.6	2.8	5.6	0.4	-0.6
230000	-46.4	-27.7	228.7	-47.6	-49.2	-12.2	20.0	-2.6	-8.1	-44.4	-36.1	231.3	-47.2	-49.9	-13.1	20.3	-34.8	-17.6	-9.5
241109	-5.2	-5.0	-3.4	-17.5	5.5	-10.7	11.6	29.8	-0.3	-12.7	1.7	-1.1	-15.8	6.7	-1.3	0.9	24.8	-0.2	0.0
241209	0.2	59.9	-15.2	13.6	-54.5	49.1	41.8	9.6	7.8	29.9	23.1	-15.1	-5.7	-15.6	-4.7	43.4	10.8	6.4	-1.5

T 7 – 3 Labour productivity based on two different sets of working hours

Industry	Working Time Accounts								National Accounts									Yearly average difference	
	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	
	Annual percentage change Hours																		(pct. point)
241500	57.5	10.2	-28.8	83.5	-29.4	-10.7	303.7	-13.6	49.9	49.7	22.8	-29.1	89.5	-33.0	-10.7	304.3	-13.2	22.8	-27.1
241617	-9.7	36.9	16.2	-32.5	46.9	5.6	71.4	49.2	35.5	-10.3	39.5	14.8	-32.4	48.5	5.6	61.6	40.4	16.8	-18.8
2420001	-5.9	-16.0	5.5	-9.6	17.0	0.1	-34.9	76.6	0.2	-8.8	-3.5	4.9	-9.3	18.1	-0.1	-34.8	60.4	0.4	-0.2
243000	-2.1	-1.9	4.2	-13.2	-12.1	-23.6	8.8	-17.8	-6.0	-4.6	1.2	5.3	-12.5	-12.7	-25.1	9.5	-18.9	-7.9	-1.9
244000	-0.1	21.1	8.9	37.3	25.9	-7.6	-28.8	-7.7	4.8	-0.2	21.6	9.4	37.3	25.6	-8.2	-28.3	-4.7	4.6	-0.1
245070	9.8	33.8	-12.6	-2.5	-6.9	7.9	-7.1	-21.6	-1.0	9.0	32.1	-11.7	-1.6	-6.4	7.4	-0.5	-24.1	-0.6	0.4
251122	4.0	4.0	-7.0	-3.3	4.4	-7.6	15.5	-4.4	0.5	3.5	4.1	-7.1	-2.9	6.0	-8.8	15.5	-3.8	0.6	0.1
252300	-4.0	3.9	-4.0	3.2	-2.4	-5.6	4.3	-4.1	-1.1	-4.1	4.6	-4.3	4.1	-1.6	-6.5	3.5	-4.6	-1.2	-0.1
252400	-2.2	4.1	-0.1	7.3	-2.6	-9.4	7.8	-3.4	0.0	-2.8	4.0	-0.1	7.8	-1.8	-10.9	8.1	-5.1	-0.3	-0.3
261126	9.8	6.7	-15.3	-6.0	-26.7	7.2	25.5	1.0	-0.9	9.4	6.9	-15.6	-2.9	-17.1	-3.5	20.2	1.1	-0.9	0.0
263053	5.7	2.4	5.5	-5.9	7.2	-9.7	-4.6	-1.0	-0.2	5.6	2.5	5.3	-5.1	8.3	-11.3	-3.5	-1.7	-0.2	0.0
266080	-2.5	5.4	-1.4	8.7	7.0	-14.8	8.7	1.6	1.4	-3.3	5.3	-1.0	9.2	7.3	-15.4	9.3	8.1	2.1	0.8
271000	57.8	64.3	0.7	-59.1	39.4	29.9	21.7	57.2	33.7	58.4	63.1	1.0	-58.9	40.0	28.6	54.2	156.1	28.9	-4.8
272030	-13.9	-16.3	-4.7	-0.9	-11.0	17.2	53.1	19.8	3.8	-14.7	-15.6	-5.2	-0.3	-9.6	16.1	53.8	41.7	5.7	1.9
274000	11.0	18.0	-0.8	2.9	-7.6	-20.0	58.1	8.4	8.7	7.9	18.1	-1.1	3.2	-6.1	-21.5	58.2	13.1	7.0	-1.7
275000	-21.7	-3.0	-10.6	-16.8	-21.4	-4.9	73.4	16.2	-1.9	-5.6	16.3	-2.1	10.0	-20.3	-6.6	74.6	-13.3	3.7	-6.0
281009	-3.7	-0.9	0.0	-2.3	2.8	6.2	-2.9	4.6	0.4	-6.1	-0.9	0.2	-1.8	3.7	5.3	-3.1	5.4	0.3	-0.2
286009	-3.6	5.7	3.9	-0.8	8.9	-4.3	14.2	3.1	3.6	-7.5	6.0	4.6	-0.2	9.6	-5.0	14.5	6.0	3.3	-0.4
291000	-7.2	22.4	-13.6	-5.6	6.3	1.6	-1.2	3.7	0.3	-9.7	22.7	-13.9	-5.1	6.7	1.0	-1.3	3.9	0.0	-0.3
292000	-16.0	3.2	-6.1	-8.5	4.7	0.5	3.4	-0.8	-2.5	-20.1	4.4	-6.4	-7.9	5.4	-0.1	3.1	-1.1	-3.2	-0.7
293000	5.9	-5.7	16.1	-24.5	23.6	-23.2	34.0	3.8	2.0	5.2	-4.4	14.9	-24.2	24.7	-23.8	33.6	10.9	2.7	0.7
294009	-12.6	3.4	1.8	-3.3	7.3	-1.5	5.6	11.8	1.4	-13.3	3.9	1.9	-3.1	8.0	-2.1	5.5	9.7	1.1	-0.3
297000	4.4	3.7	4.2	-1.1	3.5	-7.2	33.5	11.7	7.5	3.3	4.8	4.2	-0.2	5.8	-9.0	33.0	7.9	5.7	-1.8
300000	121.2	47.0	17.1	35.1	4.2	26.9	-3.2	4.9	73.8	122.7	47.5	16.2	35.7	2.2	26.6	-0.3	-13.0	24.6	-49.2
310000	-7.8	-1.9	-1.3	-8.6	20.8	-1.2	-24.9	-3.3	-3.7	-8.6	-1.5	-1.8	-8.2	21.7	-2.1	-25.0	-0.8	-4.0	-0.4
320000	7.0	10.2	-8.5	8.0	-9.9	21.5	11.7	1.3	5.5	5.4	11.4	-8.6	8.3	-9.4	19.6	12.2	14.2	6.2	0.6
330000	-1.8	6.1	11.8	2.6	7.0	8.2	-8.4	-0.4	3.3	-2.4	5.7	12.2	2.9	8.0	7.2	-8.6	2.4	3.3	0.0
340000	-9.6	35.2	-1.7	-1.8	-4.6	4.6	19.0	35.0	11.1	-11.3	36.4	-2.2	-1.1	-4.0	4.1	15.3	48.7	9.1	-2.1
351000	-5.9	-43.2	50.1	1.8	-14.1	3.0	-31.8	174.0	4.4	-6.3	-43.2	50.6	2.5	-13.3	1.8	-35.0	133.4	1.2	-3.2
352050	2.7	-6.2	-24.9	2.8	42.6	21.7	14.5	-17.0	2.8	1.2	-5.9	-25.2	3.3	43.9	20.7	13.9	-14.9	2.7	-0.1
361000	-1.3	0.0	-2.4	-1.4	3.4	-2.6	-0.3	8.3	0.4	-2.0	0.3	-2.6	-1.0	4.3	-2.8	-0.5	8.8	0.5	0.1

T7–3 Labour productivity based on two different sets of working hours

Industry	Working Time Accounts								National Accounts									Yearly average difference	
	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	
	Annual percentage change Hours																		(pct. point)
362060	-3.4	5.0	-18.5	21.4	-11.4	-2.9	3.8	-24.3	-4.0	-4.6	3.6	-16.1	17.9	-10.8	-1.9	8.0	-21.3	-3.9	0.1
370000	-251.8	-291.8	-95.8	1399.9	74.5	7.8	-1.1	-0.8	29.9	-263.0	-300.1	-96.0	1470.4	63.8	5.3	-1.8	-14.8	14.6	-15.2
401000	12.1	-0.2	-2.8	15.1	10.1	12.6	-15.9	-12.2	1.8	11.3	-0.2	-6.6	16.8	3.7	13.3	-12.3	-12.0	1.2	-0.6
402000	6.3	9.6	3.1	24.8	10.9	2.5	-28.1	-41.4	-3.5	14.5	12.6	5.2	32.8	-3.3	17.9	-21.3	-27.2	2.0	5.6
403000	14.6	1.4	1.7	-3.6	-5.1	-5.1	-9.5	9.1	0.2	12.7	0.0	-1.2	-1.5	-5.1	13.8	4.8	13.2	4.3	4.2
410000	7.8	-10.9	-22.3	4.3	2.2	-10.4	-30.7	2.2	-6.2	-4.3	-7.4	-27.3	3.8	0.2	0.0	-26.8	0.5	-8.4	-2.3
450000	5.1	-8.5	4.2	1.4	-4.7	-5.9	0.6	2.2	-0.8	6.9	-8.5	4.1	0.8	-4.6	-5.3	-0.5	3.5	-0.6	0.2
501009	-2.4	-8.0	10.4	-2.3	-0.9	15.0	3.1	-6.6	0.8	0.3	-15.0	9.5	2.1	1.4	14.2	3.3	-7.7	0.6	-0.1
502000	-0.7	-9.6	-2.6	-4.7	-8.1	4.1	-6.1	1.4	-3.0	-2.5	-3.0	-1.4	-16.2	-9.2	2.4	-6.5	1.7	-4.5	-1.5
505000	-22.1	-16.8	-1.1	-11.2	5.3	-1.8	19.7	-8.5	-4.4	-19.2	-19.7	-3.0	6.0	5.7	-0.4	22.0	-7.4	-2.8	1.6
510000	16.9	-9.8	-0.9	7.4	9.4	-1.3	-1.1	5.2	3.3	17.0	-9.9	-1.0	7.7	10.3	-2.3	-1.2	2.9	2.6	-0.6
521090	-12.3	-0.8	-4.6	-1.7	-9.0	-8.2	12.1	4.9	-2.5	-13.0	-0.1	-4.7	-1.4	-8.3	-8.9	12.2	1.8	-3.1	-0.6
522990	6.7	9.9	0.3	0.2	-6.5	-2.2	-1.5	4.4	1.4	6.6	9.7	0.0	0.6	-5.7	-3.0	0.5	1.9	1.2	-0.1
523000	1.8	7.7	9.4	11.3	-0.8	4.0	-5.9	1.6	4.0	-2.4	7.7	9.1	12.9	2.7	2.8	-6.0	0.8	3.3	-0.7
524190	-1.1	3.4	4.2	-6.8	-3.5	14.2	-10.0	2.7	0.1	-1.0	3.0	4.4	-7.0	-2.9	13.1	-8.7	2.7	0.3	0.1
524490	2.6	0.5	-0.3	-6.9	1.4	1.1	-0.6	3.5	0.1	2.7	-0.1	-0.7	-7.1	2.0	0.1	-0.9	4.1	0.0	-0.2
551009	-13.8	11.2	-3.9	-7.2	2.9	-8.0	10.3	17.4	0.6	-13.9	11.0	-4.0	-7.4	4.3	-8.5	10.2	-2.2	-1.7	-2.3
553009	-7.7	1.1	-3.7	2.7	-15.0	2.4	-0.5	0.6	-2.5	-7.8	0.8	-3.5	2.6	-14.5	1.5	-0.5	-1.9	-3.1	-0.6
601000	-1.3	9.9	-3.5	-29.3	11.3	22.3	4.2	-0.5	0.6	-1.5	9.9	-3.6	-29.0	11.8	21.8	4.1	4.1	1.1	0.5
602100	12.0	-15.8	-4.2	51.5	1.3	17.8	-15.3	11.7	6.8	11.4	-15.8	-4.5	52.1	2.5	16.6	-15.4	7.1	5.0	-1.9
602223	-16.0	4.5	3.1	6.9	-9.2	1.0	10.9	0.7	-0.1	-15.8	4.7	3.3	7.4	-8.9	0.3	10.7	-8.1	-1.2	-1.1
602409	-6.5	0.1	-0.2	4.4	-2.7	1.5	2.2	0.0	-0.2	-6.9	-0.6	-1.0	4.0	-1.8	0.3	2.2	-0.1	-0.5	-0.3
610000	43.5	16.5	-34.0	99.1	27.9	13.6	5.3	26.2	19.8	38.9	14.8	-35.1	95.5	26.0	10.1	4.5	17.3	16.7	-3.1
620000	4.2	-13.1	15.0	19.6	1.6	13.3	20.3	-11.5	5.4	8.7	-14.4	10.5	17.3	0.0	9.9	13.0	-11.3	3.6	-1.8
631130	-3.2	-6.5	-8.7	14.2	7.3	-13.2	2.4	0.3	-1.3	-2.2	-8.6	-9.5	15.8	8.2	-13.7	1.0	-1.3	-1.7	-0.4
634000	-3.8	-5.4	-5.9	-0.5	14.8	-9.8	0.8	-3.1	-1.8	-3.2	-5.7	-6.0	-1.5	16.2	-10.7	4.1	-2.4	-1.4	0.4
640000	14.0	4.1	-1.5	2.0	1.3	13.1	-9.6	20.0	5.0	13.7	3.6	-1.9	2.4	2.0	10.1	-9.7	13.5	4.0	-1.1
651000	2.1	15.6	14.7	-0.9	5.2	7.1	-2.3	6.3	5.8	2.0	15.8	14.3	0.2	6.8	5.6	-2.5	5.4	5.8	0.0
652000	37.8	-5.9	-9.4	-23.1	1.9	10.8	-3.9	-0.9	-0.4	20.9	5.6	-10.2	-23.0	2.9	8.8	-4.2	5.7	0.0	0.4
660102	0.4	-1.8	5.1	17.4	5.6	-10.1	-37.9	68.6	2.4	8.5	-3.8	15.1	56.0	-7.1	-0.4	-48.5	63.2	4.8	2.4
660300	37.0	2.5	7.9	0.1	-8.7	-12.7	8.7	24.9	6.4	26.5	-0.1	6.5	-0.1	-0.4	-12.7	4.5	27.3	5.7	-0.7

T7–3 Labour productivity based on two different sets of working hours

Industry	Working Time Accounts								National Accounts									Yearly average difference	
	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	
	Annual percentage change Hours																		(pct. point)
670000	-14.5	38.9	-4.0	-2.4	3.1	15.9	-25.7	13.7	1.5	-13.6	38.1	-4.4	-2.5	3.4	14.6	-26.3	18.2	1.8	0.3
701109	-4.8	-4.8	-9.4	-22.0	-17.9	-12.8	-36.8	11.8	-13.1	-4.3	-5.4	-9.1	-22.1	-17.3	-13.2	-36.7	10.2	-13.3	-0.1
702009	-2.0	-2.3	0.7	2.1	6.8	0.6	-3.2	0.4	0.3	-2.4	-3.3	0.3	2.1	7.4	-0.1	-3.2	5.6	0.7	0.4
702040	-5.9	-16.8	1.6	4.6	-5.9	-5.9	-12.8	-4.1	-5.9	-4.9	-18.0	1.6	5.2	-6.2	-5.7	-12.3	2.3	-5.0	0.9
710000	5.3	-13.8	-2.9	-6.3	-4.1	-9.4	7.9	4.3	-2.6	5.5	-14.1	-3.1	-9.7	-3.3	-9.8	7.9	7.3	-2.7	-0.1
721009	-28.0	64.5	-15.7	-3.1	-13.3	-12.9	66.0	5.8	3.2	-13.6	64.6	-15.2	-11.9	-2.7	-10.6	55.8	3.0	5.0	1.8
722000	-2.7	32.7	21.1	1.4	-9.4	16.8	14.8	15.9	10.6	-4.2	32.2	20.5	1.7	-8.4	16.0	13.8	9.1	9.4	-1.2
730001	49.7	-27.9	-5.4	-50.8	35.3	-36.9	61.1	6.4	-3.8	50.0	-30.1	-2.0	-13.5	-8.0	-0.7	-14.8	2.0	-4.3	-0.5
730002	0.7	-4.5	1.8	11.7	2.9	1.8	-0.2	2.1	1.9	3.6	-5.9	4.4	0.4	4.9	1.1	4.4	-7.7	0.5	-1.4
741100	-5.4	-0.9	-0.1	-0.7	5.2	3.4	-1.3	-3.2	-0.4	-5.4	-1.5	0.1	-0.9	5.8	2.8	-1.5	-3.5	-0.6	-0.2
741200	-4.2	2.4	-1.9	-4.3	1.3	-2.7	5.1	-2.2	-0.9	-4.4	2.1	-2.0	-4.0	2.3	-3.4	5.1	-4.3	-1.1	-0.3
742009	0.1	17.0	-16.8	-0.4	-4.5	5.9	-9.3	-2.5	-1.8	-0.9	16.9	-17.9	0.4	-2.7	4.0	-10.8	-3.9	-2.3	-0.6
744000	8.4	-4.7	-2.0	8.5	-17.4	1.7	-26.8	-8.4	-5.8	8.7	-4.7	-1.8	8.5	-17.0	0.9	-27.0	0.1	-4.8	1.0
747000	-4.8	-11.5	1.8	-2.0	-6.8	0.2	2.2	-6.0	-3.5	-8.1	-2.6	0.6	-1.3	-7.0	-0.8	1.9	-2.9	-2.6	0.9
748009	-17.7	3.1	-5.9	-6.1	6.2	-4.3	-10.7	-2.9	-5.0	-18.2	0.2	-3.5	-7.5	7.3	-5.8	-11.6	-4.8	-5.8	-0.7
751100	-1.0	4.9	7.7	7.8	-0.2	2.6	0.5	-4.8	2.1	1.7	1.2	1.3	2.5	3.8	2.6	-2.9	-0.8	1.2	-0.9
751209	6.2	23.6	-1.8	1.5	3.9	-7.1	5.4	0.8	3.8	5.2	-1.0	1.1	4.2	0.8	-23.9	-0.1	-1.1	-2.3	-6.0
751300	4.5	39.6	-10.4	-2.7	-8.2	-0.4	0.4	6.5	2.8	7.5	-9.2	9.6	-1.6	10.5	0.9	1.5	-0.5	2.2	-0.6
752001	11.4	21.4	-10.1	-8.2	-22.9	-0.4	9.4	1.3	-0.6	11.0	20.7	-10.2	-11.8	-22.2	-2.1	8.6	5.7	-0.9	-0.3
752002	3.1	-1.2	-2.6	-0.5	5.1	1.5	0.9	1.9	1.0	2.6	-1.3	-0.6	0.5	6.6	-0.9	3.5	1.5	1.5	0.5
801000	3.0	-3.1	3.9	-0.2	1.3	-2.4	-2.1	3.4	0.4	5.3	-5.0	4.8	0.3	2.8	-3.5	0.8	-1.0	0.5	0.1
802000	0.0	-5.6	0.3	-2.5	5.5	4.8	0.4	1.5	0.5	2.4	-3.4	0.3	0.2	7.1	5.2	-1.4	-0.4	1.2	0.7
803000	6.2	-4.3	4.7	-0.2	1.1	-6.8	5.9	0.1	0.7	0.3	-1.0	0.8	5.0	0.0	-0.1	6.0	2.4	1.7	0.9
804001	-2.2	-4.2	-12.5	-13.0	-18.6	-8.3	-5.7	9.5	-7.2	1.3	-3.8	-11.0	-12.3	-18.1	-8.4	-5.1	12.9	-6.0	1.2
804002	3.1	-4.0	0.6	-8.3	36.4	0.3	7.7	4.5	4.4	4.2	0.2	0.2	1.0	1.5	0.8	1.9	3.6	1.7	-2.7
851100	6.4	0.0	3.0	2.5	1.0	0.4	3.0	1.0	2.1	6.7	0.3	3.5	1.1	3.9	1.3	2.3	-2.8	2.0	-0.1
851209	-0.7	-2.3	0.2	0.7	1.9	0.6	2.3	-0.2	0.3	-1.0	-2.3	0.4	-0.9	2.3	0.0	1.4	-3.2	-0.4	-0.7
853109	3.3	-2.7	-0.4	-1.1	-0.3	-0.4	2.9	-0.2	0.1	2.7	0.1	1.1	-2.4	2.2	-1.1	3.5	-0.7	0.7	0.5
853209	3.9	-6.2	-3.7	-0.6	3.1	2.8	-1.8	1.6	-0.2	0.2	-1.9	-4.3	-1.4	5.7	2.6	0.2	-1.9	-0.2	0.0
900010	-26.1	-10.8	-5.7	-5.3	-0.5	2.5	-11.0	-3.3	-7.9	5.3	-8.3	-8.9	5.4	-5.3	8.2	-5.6	8.5	-0.4	7.6
900020	-4.2	-11.2	3.4	-14.7	1.4	-16.4	12.4	-5.6	-4.8	-19.6	-21.4	6.3	-16.3	-2.9	-25.7	8.4	9.0	-8.8	-4.0

T7–3 Labour productivity based on two different sets of working hours

Industry	Working Time Accounts								National Accounts									Yearly average difference	
	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	1996	1997	1998	1999	2000	2001	2002	2003	Yearly avg.	
	Annual percentage change Hours																		(pct. point)
900030	22.4	6.6	5.3	-10.5	-19.4	-17.4	5.4	0.6	-1.7	23.0	6.6	4.8	-9.5	-18.1	-18.7	4.7	-8.9	-2.9	-1.2
910000	-3.4	1.9	3.9	-2.6	-1.5	2.9	1.5	7.9	1.3	-1.2	3.9	2.0	-1.5	0.2	1.1	3.2	-0.2	0.9	-0.4
920001	-4.0	-7.3	-5.1	1.9	-8.0	-4.5	-6.8	6.7	-3.5	-4.3	-7.5	-4.8	1.3	-7.5	-5.0	-6.9	0.5	-4.3	-0.8
920002	-1.3	1.1	0.7	0.4	1.8	-2.7	-8.4	7.2	-0.2	-1.7	1.3	2.8	0.6	4.3	-3.0	0.8	-3.3	0.2	0.4
930009	-4.1	-5.1	0.8	-6.6	-5.3	2.1	3.3	5.0	-1.3	-5.0	-4.3	-2.2	-5.7	-4.7	1.4	3.5	4.9	-1.6	-0.3
950000	-4	-3.9	-18.8	-4.2	-7.5	-2.1	-34.2	-15	-11.9	0	-3.8	-11.2	-3.9	-0.5	-3.2	10	-15	-3.7	-8.2
Total	1.6	0.3	-0.8	1.4	1.5	0.5	-0.6	3.4	0.9	1.5	0.1	-0.9	1.6	2.4	-0.3	-0.8	2.1	0.7	-0.2

Note: Due to limited space only industry codes are shown. Information about names and codes for each industry is available in appendix 1.

Manufacturing of basic iron and steel and of ferro alloys, 620000 Air transport, 747000 Building-cleaning activities, 900020 Refuse collection and sanitation are some of the industries which have experienced significant increases in their productivity level. As mentioned in sections 2.2 and 3.2 the revisions are made to ensure consistency between working hours and the rest of the national accounts.

Others, such as 275000 Casting of metal products, 403000 Steam and hot water supply, 410000 Collection and distribution of water, 610000 Water transport, 660102 Life insurance and pension funding, 900010 Sewage removal and purifying plants have experienced significant decreases in there productivity level. Again revisions are made to secure consistency between working hours and the rest of the national accounts. Several of the industries mentioned above were also mentioned in the previous section. It is not surprising that revisions seem to influence both levels and growth rates and therefore have an effect on either conclusion.

Secondly, the order of industries proving to be the most productive changes due to the revisions of working hours. The five most productive industries are characterized by being very capital intensive and therefore have a very high value added per hours worked. The "members" of this group remain unchanged whether they are compiled on the basis of labour accounts or national accounts working hours. But the order within this group has changed. 403000 Steam and hot water supply has experienced a reduction in its productivity level at 42 percent due to the change in working hours, this industry is now ranked fifth, instead of third.

If we look further down the list of the most productive industries it appears that a great number of changes have occurred. In the group of the fifth to tenth most productive industries according to the national accounts definitions includes only two industries from the same compilation conducted on the basis of the labour accounts working hours.

In the light of these compilations it seems that this does indeed change the productivity level results significantly, if a change in data material is made. In this case, primarily industries were under the influence of the choice of denominator, while the total was not influenced dramatically.

Findings and recommendations

The purpose of this paper was twofold. Firstly, to obtain insight into why hours worked are different in the Labour Force Statistics and in the National Accounts Statistics and secondly, to quantify how much impact these disparities have on the measurement of productivity.

The second chapter showed that many efforts are put into secure consistency between National Accounts and hours worked, and therefore a comprehensive number of neutral corrections between industries are made. These are made to secure consistency between a firm's production and the hours worked at industry level. When international productivity comparisons are made, with few exceptions aggregate comparisons are made. A quite significant number of the corrections are therefore never visible in productivity data. However, in the forthcoming years it is likely that international productivity comparisons at industry level will be much more common that at present, and therefore corrections like these will see the daylight in international productivity results.

Level changing corrections are the second modification that was presented in the second chapter. These corrections are primarily made to adapt the SNA 1993/ESA 1995 definitions. These do not only have an effect within industries but also at aggregate level. Compared to the reallocations within industries the total number of hours was changed modestly, but nevertheless the average growth rate was revised 0.2 percentage point due to these revisions. Bearing this in mind the importance of using hours worked compiled within the same framework as the value added is obvious. These findings are only based on Danish data and a generalization to an international phenomenon should be subject to caution. Even with that in mind it is likely to believe that international productivity comparisons at aggregate level are encumbered with a significant uncertainty because SNA 1993/ESA 1995 defined working hours is not common today.

If international comparisons of productivity at aggregate level are encumbered with a significant uncertainty, analyses at industry level seem to be difficult. The third chapter showed that industry comparisons of Danish productivity estimates based on Working Time Accounts data and National Accounts data differed substantially. Disparities were found in both growth rates and level compilations. If the results from Denmark reflect an international phenomenon it is necessary to treat international productivity analyses at industry level with caution as long as working hours are not consistent with National Accounts data.

In OECD's latest published estimates of productivity (at aggregate level) only twelve of thirty countries were able to deliver working hours based on National Accounts definitions[107]. With the Danish findings in mind it is necessary to be cautious when these results are analysed – even though it is only on aggregate data. Future analyses of international productivity results at industry level seem to be difficult as long as National Accounts working hours are only available for a limited number of countries.

In the next few years it seems that there is room for improvements within this area. A great amount of work has been carried out to harmonize Value Added and Purchasing Power Parties. The time has now come where some efforts should be put into improvements of harmonisation within National Accounts consisting working hours estimates. Some work is already ongoing in the Paris group, et cetera, but there is room for further initiatives which can enhance the compilations of National Accounts consisting of working hours in the years to come.

[107] OECD (2005)

T7–4 Level of labour productivity based on two different sets of working hours

Industry	Working Time Accounts									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly Avg.
	Gross value added (Danish kroner) per hour									
11009	139	154	164	177	179	197	185	174	194	174
11209	148	134	151	150	142	131	118	105	133	135
14001	191	185	201	191	189	205	243	216	261	209
14002	229	250	223	228	201	226	253	269	313	244
20000	166	162	183	184	189	152	206	196	221	184
50000	230	206	255	260	275	254	274	224	166	238
110000	7,818	9,515	11,035	9,903	12,607	14,222	11,788	7,396	5,930	10,024
140009	301	342	348	332	312	322	329	379	426	343
151000	197	189	192	234	273	218	254	252	203	223
152000	211	229	237	191	212	184	150	147	155	191
153000	190	240	282	254	215	242	230	442	379	275
154000	108	118	240	211	130	341	409	386	325	252
155000	238	242	268	238	222	271	250	264	542	281
156009	240	241	259	276	295	240	274	273	243	260
158109	247	238	260	244	255	251	281	257	255	254
158120	135	130	140	134	128	127	126	152	155	136
158300	242	214	200	264	233	350	348	533	458	316
159000	451	359	456	432	360	312	306	354	396	381
160000	947	987	1,070	902	899	780	784	785	738	877
170000	187	189	195	202	216	220	211	226	246	210
180000	169	196	204	194	189	179	196	210	199	193
190000	195	145	201	185	203	232	137	259	219	197
200000	213	179	212	205	201	204	205	210	233	207
210000	162	187	227	229	250	268	253	263	276	235
221200	212	208	206	194	203	217	216	182	201	204
221309	238	224	219	214	201	233	230	204	226	221
222009	256	265	282	272	270	256	246	254	276	264
230000	1,198	642	464	1,526	799	406	357	428	417	693
241109	514	487	462	446	368	389	347	387	503	434
241209	273	274	438	372	422	192	286	406	445	345
241500	162	255	282	201	368	260	232	937	810	390
241617	234	211	289	336	227	333	352	603	900	388
242000	602	566	475	502	454	531	532	346	612	513
243000	263	257	253	263	228	201	153	167	137	214
244000	310	310	375	408	561	706	652	464	428	468
245070	242	266	356	311	303	282	305	283	222	286
251122	265	275	286	266	257	269	248	287	274	270
252300	230	221	230	220	227	222	210	219	210	221
252400	245	240	249	249	267	260	236	254	245	250
261126	190	208	222	188	177	130	139	175	176	178
263053	368	389	398	420	395	424	382	365	362	389
266080	231	225	237	234	254	272	232	252	256	244
271000	109	172	282	284	116	162	210	256	402	221
272030	372	321	268	256	253	226	265	405	485	317

T7–4 Level of labour productivity based on two different sets of working hours

Industry	National Accounts										Yearly average difference
	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly Avg.	
	Gross value added (Danish kroner) per hour										(in percent)
11009	144	163	172	186	191	210	199	186	212	185	**6.0**
11209	146	132	148	146	138	128	114	101	133	132	**-2.2**
14001	187	182	196	186	185	202	238	212	246	204	**-2.5**
14002	266	297	276	275	281	286	317	383	406	310	**21.4**
20000	167	163	180	182	187	149	202	192	222	183	**-1.1**
50000	221	200	247	240	267	246	263	215	161	229	**-4.2**
110000	9,108	11,050	11,991	10,847	12,879	14,442	12,494	16,598	15,636	12,783	**21.6**
140009	298	338	341	330	311	326	331	381	385	338	**-1.6**
151000	194	185	190	229	269	220	254	251	194	220	**-1.4**
152000	214	231	241	198	223	191	155	157	171	198	**3.6**
153000	191	243	286	256	218	252	232	456	375	279	**1.4**
154000	107	115	245	214	133	352	406	381	330	254	**0.6**
155000	274	280	309	262	248	286	261	262	515	300	**6.0**
156009	241	239	257	274	294	240	273	273	254	261	**0.2**
158109	246	243	258	241	253	252	279	256	260	254	**0.0**
158120	136	131	141	135	129	130	129	155	160	138	**1.4**
158300	236	210	209	268	240	378	389	603	711	360	**12.4**
159000	456	359	454	428	360	316	307	355	421	384	**0.8**
160000	934	970	1,050	885	892	776	775	766	740	866	**-1.3**
170000	185	187	192	199	215	218	208	223	244	208	**-1.1**
180000	167	191	200	190	187	178	194	206	207	191	**-0.8**
190000	191	169	245	229	251	284	186	238	222	224	**11.9**
200000	210	174	207	200	198	203	202	207	225	203	**-2.0**
210000	163	184	223	224	247	267	249	259	270	232	**-1.3**
221200	210	202	199	187	196	210	207	174	192	197	**-3.5**
221309	237	224	216	212	196	230	225	193	190	214	**-3.4**
222009	254	259	276	266	265	253	241	248	262	258	**-2.3**
230000	1,292	718	459	1,520	803	402	350	421	274	693	**0.0**
241109	553	483	491	486	409	437	431	434	542	474	**8.5**
241209	268	348	428	364	343	290	276	395	438	350	**1.3**
241500	166	248	304	216	408	274	244	988	857	412	**5.3**
241617	232	208	290	333	225	334	353	571	801	372	**-4.2**
242000	529	482	465	488	443	523	522	340	546	482	**-6.0**
243000	266	254	257	270	237	207	155	170	138	217	**1.5**
244000	304	303	368	403	553	695	638	457	436	462	**-1.4**
245070	249	271	358	316	311	291	313	311	236	295	**3.2**
251122	261	271	282	262	254	270	246	284	273	267	**-1.0**
252300	226	217	226	217	226	222	208	215	205	218	**-1.4**
252400	242	236	245	245	264	259	231	250	237	245	**-1.7**
261126	186	204	218	184	179	148	143	172	174	179	**0.2**
263053	362	382	392	413	392	424	376	363	357	385	**-1.2**
266080	231	223	235	233	254	273	231	252	273	245	**0.6**
271000	107	169	275	278	114	160	206	317	813	271	**18.3**
272030	370	315	266	252	251	227	264	406	575	325	**2.5**

T 7–4 Level of labour productivity based on two different sets of working hours

Industry	Working Time Accounts									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly Avg.
	Gross value added (Danish kroner) per hour									
274000	220	244	288	286	294	272	218	344	373	282
275000	279	253	283	289	240	189	180	311	362	265
281009	214	206	204	204	199	205	218	211	221	209
286009	189	182	193	200	198	216	207	236	244	207
291000	239	222	272	235	222	236	240	237	245	239
292000	292	245	253	237	217	227	229	236	235	241
293000	203	215	203	235	178	219	169	226	235	209
294009	234	205	211	215	208	223	220	232	260	223
297000	192	201	208	217	214	222	206	275	307	227
300000	56	123	181	212	287	299	379	367	385	255
310000	270	249	244	241	220	266	263	197	191	238
320000	214	229	252	231	249	225	273	305	309	254
330000	262	257	273	305	313	335	362	332	330	308
340000	189	171	232	228	224	213	223	265	358	234
351000	252	238	135	203	206	177	183	125	341	207
352050	206	212	199	149	154	219	266	305	253	218
361000	225	222	222	217	213	221	215	214	232	220
362060	194	187	197	160	195	172	167	174	131	175
370000	113	-171	328	14	207	361	389	385	381	223
401000	413	463	462	449	517	570	641	539	473	503
402000	1,454	1,545	1,693	1,745	2,177	2,414	2,474	1,780	1,043	1,814
403000	2,315	2,654	2,692	2,737	2,639	2,506	2,379	2,152	2,348	2,491
410000	452	488	434	338	352	360	323	224	229	355
450000	210	221	202	211	214	204	191	193	197	205
501009	177	172	159	175	171	169	195	201	188	178
502000	218	216	195	190	181	167	174	163	166	186
505000	127	99	83	82	72	76	75	90	82	87
510000	234	274	247	245	263	288	284	281	296	268
521090	235	206	204	195	192	174	160	179	188	193
522990	137	146	161	161	162	151	148	146	152	151
523000	149	152	163	179	199	197	205	193	196	181
524190	135	134	138	144	134	129	148	133	136	137
524490	159	163	164	163	152	154	156	155	160	158
551009	181	156	173	167	155	159	146	161	189	165
553009	172	159	161	155	159	135	138	138	138	151
601000	410	405	445	429	303	338	413	431	429	400
602100	91	102	86	82	125	126	149	126	141	114
602223	161	135	141	145	156	141	143	158	159	149
602409	242	226	226	226	236	229	233	238	238	233
610000	221	318	370	244	486	622	706	743	938	516
620000	184	192	166	191	229	233	263	317	281	228
631130	369	358	334	305	349	374	325	333	334	342
634000	348	335	316	298	296	340	307	309	300	316
640000	239	273	284	279	285	289	326	295	354	292

T7–4 Level of labour productivity based on two different sets of working hours

Industry	National Accounts										**Yearly average difference**
	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly Avg.	
	Gross value added (Danish kroner) per hour										(in percent)
274000	221	239	282	279	288	270	212	336	379	278	**-1.3**
275000	201	189	220	216	237	189	177	308	267	223	**-18.9**
281009	215	202	200	200	196	204	214	208	219	206	**-1.3**
286009	194	179	190	199	198	217	206	236	250	208	**0.2**
291000	244	220	270	233	221	236	238	235	244	238	**-0.4**
292000	301	241	251	235	217	228	228	235	233	241	**-0.1**
293000	202	212	203	233	177	221	168	224	249	210	**0.4**
294009	232	201	209	213	206	223	218	230	252	220	**-1.3**
297000	191	197	207	216	215	228	207	276	298	226	**-0.4**
300000	55	124	182	212	287	294	372	371	323	247	**-3.2**
310000	269	246	242	238	218	266	260	195	194	236	**-0.7**
320000	214	226	251	230	249	225	269	302	345	257	**1.1**
330000	260	254	268	301	310	335	359	328	336	306	**-0.7**
340000	189	168	229	224	221	213	221	255	379	233	**-0.1**
351000	248	232	132	198	203	176	179	117	272	195	**-5.8**
352050	208	210	198	148	153	220	265	302	257	218	**-0.1**
361000	221	216	217	211	209	218	212	211	229	216	**-1.8**
362060	204	195	202	169	200	178	175	189	149	184	**4.9**
370000	110	-179	359	14	227	372	392	385	328	223	**0.1**
401000	520	579	578	540	631	654	740	650	572	607	**17.1**
402000	1,338	1,531	1,724	1,813	2,407	2,327	2,744	2,158	1,570	1,957	**7.3**
403000	1,529	1,722	1,722	1,701	1,676	1,590	1,809	1,896	2,147	1,755	**-42.0**
410000	393	376	348	253	263	263	263	193	194	283	**-25.6**
450000	216	231	212	220	222	212	200	199	207	213	**4.0**
501009	210	210	179	196	200	203	232	239	221	210	**15.0**
502000	185	180	175	173	145	131	135	126	128	153	**-21.3**
505000	131	106	85	82	87	92	92	112	104	99	**11.7**
510000	228	267	240	238	256	283	276	273	281	260	**-3.0**
521090	212	185	184	176	173	159	145	162	165	174	**-11.0**
522990	135	143	157	157	158	149	145	145	148	149	**-1.8**
523000	150	146	157	172	194	199	205	193	194	179	**-1.4**
524190	134	133	137	143	133	129	146	133	137	136	**-0.5**
524490	156	160	160	159	148	151	151	150	156	155	**-2.4**
551009	177	152	169	162	150	157	143	158	154	158	**-4.5**
553009	162	149	151	145	149	127	129	129	126	141	**-7.0**
601000	404	398	437	421	299	334	407	424	441	396	**-1.0**
602100	90	101	85	81	123	126	147	124	133	112	**-1.8**
602223	154	130	136	140	151	137	138	152	140	142	**-4.9**
602409	235	219	217	215	224	219	220	225	225	222	**-4.7**
610000	189	263	302	196	383	483	531	555	651	395	**-30.8**
620000	220	239	205	226	265	265	291	329	292	259	**11.9**
631130	348	341	311	282	326	353	305	308	304	320	**-7.0**
634000	334	324	305	287	283	328	293	305	298	306	**-3.3**
640000	240	273	283	278	284	290	319	288	327	287	**-1.6**

T7–4 Level of labour productivity based on two different sets of working hours

Industry	Working Time Accounts									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly Avg.
	Gross value added (Danish kroner) per hour									
651000	333	341	393	452	447	470	504	493	524	440
652000	577	795	748	678	522	532	589	566	560	619
660102	502	504	494	520	610	644	579	359	606	535
660300	326	446	457	493	494	451	393	427	534	447
670000	525	449	623	598	584	602	698	518	589	576
701109	350	333	317	287	224	184	160	101	113	230
702009	2,783	2,728	2,664	2,682	2,738	2,925	2,943	2,847	2,860	2,797
702040	2,627	2,471	2,056	2,089	2,184	2,056	1,934	1,686	1,617	2,080
710000	538	567	489	475	445	427	386	417	435	464
721009	320	231	379	320	310	269	234	389	411	318
722000	166	161	214	259	263	238	278	319	370	252
730001	296	444	320	303	149	202	127	205	218	252
730002	196	198	189	192	214	220	225	224	229	210
741100	313	296	293	293	291	306	316	312	302	303
741200	279	268	274	269	257	261	254	267	261	265
742009	300	300	351	293	291	278	294	267	260	293
744000	257	278	265	260	282	233	237	174	159	238
747000	153	146	129	131	129	120	120	123	115	130
748009	270	223	229	216	203	215	206	184	179	214
751100	197	196	205	221	238	237	244	245	233	224
751209	246	262	324	318	323	335	311	328	331	309
751300	533	558	779	698	679	623	620	623	663	642
752001	256	285	346	311	285	220	219	240	243	267
752002	219	226	223	217	216	227	231	233	237	226
801000	197	203	197	205	204	207	202	197	204	202
802000	186	186	176	176	172	181	190	191	194	184
803000	264	280	268	281	281	284	264	280	280	276
804001	368	360	345	302	262	213	196	185	202	270
804002	141	145	139	140	128	175	176	189	198	159
851100	204	218	217	224	230	232	233	240	242	227
851209	245	243	238	238	240	244	246	251	251	244
853109	145	149	145	145	143	143	142	146	146	145
853209	169	176	165	159	158	162	167	164	167	165
900010	1,264	934	834	786	745	741	759	676	654	821
900020	123	118	105	109	93	94	79	88	83	99
900030	343	420	448	472	422	340	281	296	298	369
910000	184	178	182	189	184	181	186	189	204	186
920001	372	357	331	314	320	294	281	262	279	312
920002	232	229	231	233	234	238	232	212	228	230
930009	187	180	171	172	161	152	155	160	168	167
950000	1,440	1,382	1,328	1,078	1,032	955	934	615	522	1,032
Total	253	257	258	256	260	264	265	263	272	261

Note: Due to limited space only industry codes are shown. Information about names and codes for each industry is available in appendix 1.

T7–4 Level of labour productivity based on two different sets of working hours

Industry	National Accounts										**Yearly average difference**
	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly Avg.	
	Gross value added (Danish kroner) per hour										(in percent)
651000	318	325	376	430	430	459	485	473	499	422	**-4.3**
652000	579	700	739	663	511	526	572	548	579	602	**-2.8**
660102	330	358	345	397	619	575	573	295	482	442	**-21.2**
660300	307	388	388	413	412	411	359	375	477	392	**-13.9**
670000	532	460	635	607	592	613	702	518	612	586	**1.6**
701109	342	327	309	281	219	181	157	99	110	225	**-2.1**
702009	2,812	2,746	2,656	2,664	2,720	2,922	2,919	2,827	2,984	2,805	**0.3**
702040	2,646	2,518	2,064	2,097	2,205	2,069	1,952	1,711	1,752	2,113	**1.5**
710000	533	563	483	469	423	409	369	398	428	453	**-2.5**
721009	265	229	377	319	281	273	244	381	392	307	**-3.7**
722000	161	154	204	246	250	229	266	302	330	238	**-5.9**
730001	275	413	289	283	245	225	224	190	194	260	**3.1**
730002	202	209	197	205	206	216	219	228	211	210	**0.3**
741100	310	293	289	289	286	303	312	307	296	298	**-1.4**
741200	273	261	266	261	251	256	248	260	249	258	**-2.8**
742009	287	285	333	273	274	267	278	247	238	276	**-6.2**
744000	250	272	259	254	276	229	231	169	169	234	**-1.8**
747000	169	155	151	152	150	140	139	141	137	148	**12.7**
748009	263	215	216	208	192	206	195	172	164	203	**-5.1**
751100	207	211	213	216	221	230	236	229	227	221	**-1.3**
751209	238	250	247	250	261	263	200	200	198	234	**-31.9**
751300	442	476	432	473	466	515	519	527	524	486	**-32.0**
752001	241	267	322	289	255	199	195	211	223	245	**-9.1**
752002	229	235	232	231	232	247	245	253	257	240	**6.0**
801000	196	207	196	206	206	212	205	206	204	204	**1.3**
802000	174	178	172	172	173	185	195	192	191	181	**-1.4**
803000	252	253	251	253	266	266	265	281	288	264	**-4.5**
804001	320	324	312	277	243	199	182	173	195	247	**-9.3**
804002	129	135	135	135	137	139	140	143	148	138	**-15.3**
851100	209	222	223	231	234	243	246	251	244	234	**3.0**
851209	241	239	233	234	232	237	237	241	233	236	**-3.1**
853109	138	142	142	144	140	143	142	147	146	143	**-1.5**
853209	167	167	164	157	154	163	167	168	164	163	**-1.0**
900010	618	651	597	544	573	542	587	554	601	585	**-40.4**
900020	793	637	501	533	446	433	322	349	380	488	**79.7**
900030	334	411	438	459	415	340	276	289	264	358	**-2.9**
910000	173	171	178	181	179	179	181	187	186	179	**-3.9**
920001	357	342	316	301	305	282	267	249	250	296	**-5.3**
920002	228	224	227	234	235	245	238	240	232	234	**1.7**
930009	186	177	169	166	156	149	151	156	164	164	**-2.3**
950000	93	93	90	80	76	76	74	81	69	81	**…**
Total	250	254	254	252	256	262	262	259	265	257	**-1.4**

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Appendix

T7–5 Appendix 1: Overview of industries codes and names

Code	Name
11009	Agriculture
11209	Horticulture, orchards etc.
14001	Agricultural services; landscape gardeners etc. (market)
14002	Agricultural services; landscape gardeners etc. (other non-market)
20000	Forestry
50000	Fishing
110000	Extr. of oil and natural gas
140009	Extr. of gravel and clay etc.
151000	Production etc. of meat and meat products
152000	Processing and preserving of fish and fish products
153000	Processing and preserving of fruit and vegetables
154000	Mfr. of vegetable and animal oils and fats
155000	Mfr. of dairy products
156009	Mfr. of starch, chocolate and sugar products
158109	Mfr. of bread, cakes and biscuits
158120	Baker's shops
158300	Manufacture of sugar
159000	Manufacture of beverages
160000	Manufacture of tobacco products
170000	Mfr. of textiles
180000	Mfr. of wearing apparel
190000	Mfr. of leather and footwear
200000	Mfr. of wood and wood products
210000	Mfr. of pulp, paper and paper products
221200	Publishing of newspapers
221309	Publishing activities, excluding newspapers
222009	Printing activities
230000	Mfr. of refined petroleum products etc.
241109	Mfr. of industrial gases and inorganic basic chemicals
241209	Mfr. of dyes, pigments and organic basic chemicals
241500	Manufacture of fertilizers
241617	Mfr. of plastics and synthetic rubber
242000	Manufacture of pesticides and other agro-chemical products
243000	Mfr. of paints, varnishes and similar coatings, printing ink and mastics
244000	Mfr. of pharmaceuticals etc.
245070	Mfr. of detergents and other chemical products
251122	Mfr. of rubber products and plastic packing goods etc.
252300	Mfr. of builders ware of plastic
252400	Manufacture of other plastic products n.e.c.
261126	Mfr. of glass and ceramic goods etc.
263053	Mfr. of cement, bricks, tiles, flags etc.

T7–5 Appendix 1: Overview of industries codes and names

Code	Name
266080	Mfr. of concrete, cement, asphalt and rockwool products
271000	Mfr. of basic iron and steel and of ferro alloys
272030	First processing of iron and steel
274000	Mfr. of basic non-ferrous metals
275000	Casting of metal products
281009	Mfr. of building materials of metal
286009	Mfr. of various metal products
291000	Mfr. of marine engines and compressors
292000	Mfr. of ovens and cold-storage plants
293000	Mfr. of agricultural machinery
294009	Mfr. of machinery for industries
297000	Mfr. of domestic appliances
300000	Mfr. of office machinery and computers
310000	Mfr. of other electrical machinery and apparatus
320000	Mfr. of radio and communication equipment
330000	Mfr. of medical and optical instruments
340000	Manufacture of motor vehicles etc.
351000	Building and repairing of ships and boats
352050	Mfr. of transport equipment excl. ships, motor vehicles etc.
361000	Mfr. of furniture
362060	Mfr. of toys, gold and silver articles etc.
370000	Recycling of waste and scrap
401000	Production and distribution of electricity
402000	Manufacture and distribution of gas
403000	Steam and hot water supply
410000	Collection and distribution of water
450000	Construction
501009	Sale of motor vehicles and motorcycles
502000	Maintenance and repair of motor vehicles
505000	Retail sale of automotive fuel
510000	Wholesale except of motor vehicles
521090	Retail trade of food
522990	Department stores
523000	Re. sale of phar. goods, cosmetic art.
524190	Re. sale of clothing and footwear
524490	Other retail sale, repair work
551009	Hotels
553009	Restaurants
601000	Transport via railways
602100	Other scheduled passenger land transport
602223	Taxi operation and coach services
602409	Freight transport by road and via pipelines
610000	Water transport
620000	Air transport

T7–5 Appendix 1: Overview of industries codes and names

Code	Name
631130	Cargo handling, harbours etc., travel agencies
634000	Activities of other transport agencies
640000	Post and telecommunications
651000	Financial institutions
652000	Mortgage credit institutions
660102	Life insurance and pension funding
660300	Non-life insurance
670000	Activities auxiliary to finance
701109	Real estate agents etc.
702009	Dwellings
702040	Letting of non-residential buildings
710000	Renting of transport equipment and machinery
721009	Computer activities exc. software consultancy and supply
722000	Software consultancy and supply
730001	Research and development (market)
730002	Research and development (other non-market)
741100	Legal activities
741200	Accounting, book-keeping, auditing
742009	Consulting engineers, architects
744000	Advertising
747000	Building-cleaning activities
748009	Other business activities
751100	General (overall) public service activities
751209	Administration of public sectors exc. for business
751300	Regulation of and contribution to more efficient operation of business
752001	Defence, police and administration of justice (market)
752002	Defence, police and administration of justice (other non-market)
801000	Primary education
802000	Secondary education
803000	Higher education
804001	Adult and other education (market)
804002	Adult and other education (other non-market)
851100	Hospital activities
851209	Medical, dental and veterinary activities
853109	Social institutions etc. for children
853209	Social institutions etc. for adults
900010	Sewage removal and purifying plants
900020	Refuse collection and sanitation
900030	Refuse dumps and refuse disposal plants
910000	Activities of membership organizations
920001	Recreational, cultural, sporting activities (market)
920002	Recreational, cultural, sporting activities (other non-market)
930009	Other service activities
950000	Private households with employed persons

8. ARE THOSE WHO BRING WORK HOME REALLY WORKING LONGER HOURS?
Implications for BLS Productivity Measures[108]

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Introduction

Advancements in information technology have increased workers' abilities to conduct their jobs in multiple locations. An ongoing debate surrounding U.S. Bureau of Labor Statistics (BLS) productivity data is that official productivity numbers may be overstated because of an increase in unmeasured hours worked outside the traditional workplace. To shed light on this debate, this paper examines two recent data sources for information on U.S. workers who bring work home from their primary workplace – the 2003 – 2006 American Time Use Survey (ATUS) and the 1997, 2001, and 2004 May Current Population Survey Work Schedules and Work at Home Supplements (CPS Supplement). The ATUS provides detailed information on time spent on work, work-related activities, and non-work activities on one diary day, as well as locations for these activities. The CPS Supplements provide information on the number of hours worked at home each week, whether or not workers had a formal arrangement to be paid for work at home, and reasons for working at home.

Previous research on work at home has almost entirely focused on home-based workers or part-time teleworkers. This study examines work that is brought home from the workplace. The study achieves three goals: determines the characteristics of those who bring work home from the workplace and sheds light on why they bring work home; determines whether those who bring work home work longer hours or whether they are simply shifting the location of work; and finally, assesses whether the BLS captures the hours worked at home by those who bring work home from the workplace in its hours and productivity measures and whether unmeasured hours worked at home affect productivity trends.

Prior Research

Previous research both on hours worked in other time-use surveys and on work-at-home arrangements are relevant to this paper; however, only Callister and Dixon (2001) specifically

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examined workers who work both at the workplace and at home on the same day. Using the 1999 New Zealand Time-Use Survey, they showed that 15.5 percent of non-agricultural weekday workers combined work at a traditional workplace with work at home on their diary day. This was much more common than working exclusively from home (8.3 percent). The majority of work at home lasted for less than two hours and a significant proportion was done in the evenings and on weekends.

Recent research on work-at-home arrangements in North America often includes paid work done by home-based workers or occasional telecommuters. Oettinger (2004) used the 1980, 1990, and 2000 U.S. Census to examine the growth in home-based employment. He showed that the wage penalty for working at home has decreased over time and that the increase in home-based work has been greatest for highly-educated workers. Using the May 1997 CPS Work at Home supplement, Schroeder and Warren (2004) analyzed workers who did any work at home, including home-based workers, occasional telecommuters, and those who combine work in a traditional workplace with work at home. They found that compared to traditional office workers, workers who did any work at home are likely to be older, better educated, married, white, and live in an urban area. They also found that managers and professionals are more likely to report some work at home than other occupational groups.

Using the 2001 CPS Supplement, Wight and Bianchi (2004) examined women who did some work at home. They found that being white, college-educated, married, and working in a higher paying occupation increased the probability of doing some (but not all) work at home versus doing no work at home. They found that for women with children there is an increased probability of working all of their hours at home versus none but no difference in the probability of working some of their hours at home versus none.

Using the Canadian Workplace and Employee Survey, Pabilonia (2005) analyzed the decision of employees to do paid work at home during part of their normal working hours (referred to as telecommuters) and the decision of firms to allow these employees to telecommute. In 2001, the 5.9 percent of telecommuters among Canadian workers were more likely to be tech-savvy, experienced white-collar workers than their non-telecommuting counterparts.

Evidence from older household time-use diaries indicated that respondents to labor force surveys similar to the CPS report higher hours worked compared to estimates from time-use diaries (Hamermesh (1990) used Michigan time use diary data for 1975 and 1981; and Robinson and Bostrom (1994) used three separate studies in 1965, 1975, and 1985).[109] Robinson and Bostrom (1994) showed that the difference between these surveys is greater for those who work long hours. Hamermesh (1990) and Robinson and Bostrom (1994) both showed that this difference increased over time. However, Jacobs (1998) found that independent, self-reported measures of working time based on time of departures to and returns from work support the estimates obtained from hours of work questions in labor force surveys. Until recently, no studies have compared hours worked from time diaries to hours reported to the post-redesign (1994) CPS questions, which were changed to enhance respondents' recall concerning their

[109] Note that the sample sizes in these studies are smaller than the ATUS sample.

hours of work in the prior week.[110] Using similar definitions of hours worked, Frazis and Stewart (2004) found that CPS reported hours of work are similar to hours constructed from the ATUS for the 12 CPS reference weeks in 2003.[111] However, Frazis and Stewart (2004) also found that ATUS respondents worked five percent fewer hours per week than reported in the CPS for weeks other than CPS reference weeks. Frazis and Stewart (2004) indicate that this is expected given that these weeks include holidays whereas the reference weeks were chosen to minimize holidays.[112] Robinson, Gershuny, Martin, and Fisher (2007) find a higher incidence of over- reporting of CPS hours worked by those who work longer hours.

Data Sources

Productivity trends for the U.S. are watched closely by businessmen, policymakers, and others interested in business cycles and U.S. competitiveness. The most widely watched BLS productivity statistics are the quarterly labor productivity measures for the nonfarm business sector.[113] Throughout this paper, we focus our study on nonfarm business employees, defined as household survey respondents who are fifteen-years-old and older, work outside of the farm sector, and are classified as employees of private for-profit entities. Although the self employed and unpaid family workers are in the nonfarm business sector, we exclude them because they may have the ability to shift freely between work and non-work activities and may lack a clear definition of the principal workplace; therefore, for this group, the concept of bringing work home is not well defined and beyond the scope of this study. For the ATUS, the analysis is further restricted to nonfarm business employees who worked on their diary day.

The American Time Use Survey

The ATUS, which began collecting data in 2003, is a survey of how people living in the United States spend their time. The ATUS sample consists of one household member aged fifteen or older from a subset of households completing their final month of interviews for the CPS.[114] In 2003, there were 20,720 ATUS interviews. Beginning in December 2003, the

110 In the 1994 revised CPS, the question on usual hours is asked first, followed by questions about overtime and taking time off for reasons such as illness, slack work, vacation or holiday. Polivka and Rothgeb (1993, p. 16) report that "The mean of reported hours measured with the current [pre-1994] wording was 39.0 compared to 37.9 hours measured with the revised [1994- and later] wording." This is a combined survey effect of the employment and hours questions.

111 The CPS reference week is the calendar week that contains the 12th day of the month.

112 Data was compiled across all months due to the limited number of observations.

113 The BLS also produces quarterly measures of labor productivity for the U.S. business and nonfinancial corporations sectors, and durable, nondurable, and total manufacturing sectors, as well as measures of multifactor productivity for major sectors and labor productivity for select detailed industries.

114 The CPS is collected monthly for individuals in a sample of about 60,000 households. The CPS provides information on employment, hours worked, and demographics. Households are in the survey for four months, out for eight months, and back in for four months.

sample size was reduced by 35 percent, yielding 13,973 completed diaries in 2004. In 2005 and 2006, approximately 13,000 individual diaries were completed. The ATUS collects a 24-hour diary of activities that a respondent was engaged in starting at 4 A.M on the day prior to their interview. These diaries include information on work time, such as time at work, time spent on work activities at home, and interruptions of 15 minutes or longer that took place during the work day.[115] In addition to the types of activities and the time spent doing these activities, there is information on the demographic characteristics of the respondents, the locations where the activities took place, and the people who were with the respondent at the time of the activity.

In order to analyze hours of work, we aggregated minutes spent on activities coded as work at main job for each ATUS respondent by location from the ATUS activity files, and constructed measures of work time at the workplace and at home. We restrict our analysis to work done for a respondent's main job in order to focus on those who bring work home rather than those who may be doing some part-time work at home in the evenings. This restriction will also allow us to compare results with the CPS supplement, which only collected information about work at home for the main job. We may be underestimating work done at home to the extent that people combine work at their workplace with work at home on their second jobs. As the focus of this study is unmeasured hours of work, we expect that those who are working at home on a second job are in fact being paid for these hours and the hours would be captured in measured hours. Hours of work brought home from the primary job may be 'extra hours' and thus not explicitly paid for and potentially unmeasured.

For respondents whose diary day was a nonholiday weekday, we define those who bring work home as respondents who report any minutes of work for their main job at the workplace and at home on the same day. This weekday group of employees represents primarily those who work at home before or after a typical work day. For respondents whose diary day is on a weekend or holiday, we define those who bring work home as respondents who report any minutes of work at home on their diary day. Unfortunately, we can not identify whether those who worked exclusively at home on a weekend diary day were home-based workers, telecommuters, or traditional 9–5 office workers who bring extra work home to do over the weekend. However, when we describe the relative hours worked below, it will become clear that this group consists primarily of employees who bring work home rather than home-based workers.

The CPS Work Schedules and Work at Home Supplements

The Work Schedules and Work at Home Supplements were collected as part of the May CPS in 1997, 2001 and 2004. Although changes in industry and occupational coding and changes

[115] ATUS interviewers are trained to ask for work breaks of 15 minutes or longer any time a respondent reports that he or she worked. Beginning in January 2004, an automated probe was introduced into the survey instrument. If a respondent reports working for more than 4 hours at one time, the interviewer automatically is prompted to ask "Did you take any breaks of 15 minutes or longer?" If the respondent reports taking a break, the interviewer records the start and stop time and what was done on that break; if no break, the solid work episode is recorded.

in the sequence and wording of the questions on work at home limit the direct comparability of some data collected in 1997, we include data from all three years, noting the limitations as they occur. As previously mentioned, these supplements only collected information on whether respondents do any work at home as part of their main job. Wage and salary respondents who reported work at home were asked whether they had a formal agreement with their employer to be paid for work at home or whether they were just taking work home.

We focus our analysis on those who reported that they were just taking work home, since their hours at home are those most likely to be unmeasured. We refer to this group as those who bring work home. We note here that this question did not allow for the possibility that an employee had a formal arrangement to be paid for work at home and also took work home.[116] Respondents were asked their reasons for working at home, how frequently they worked at home, and the number of hours per week worked at home. In 1997, respondents were asked for actual hours worked at home while they were asked for usual hours in 2001 and 2004. The 2001 and 2004 respondents were also given a choice of "it varies" as a possible response; therefore, it is not possible to determine a numerical measure of work hours for all respondents.

ATUS and CPS Supplement Matched Data

CPS Supplement respondents in 2004 who were in their 5th through 8th months in the May CPS were eligible for an ATUS interview in 2004. We are able to directly match 745 nonfarm business employees who were in the same industry and occupation in both data sets, did not change employers between their last month in the CPS and their ATUS interview, and worked on their diary day.[117]

From the directly matched respondents, there are 93 who reported that they brought work home in the CPS supplement, and 90 that brought work home on their ATUS diary day. However, there are definitely limitations associated with the matched data. Some respondents to the supplement questions answered that they did not do any work at home as part of their job, although their time diary clearly stated that they did some work at home. For example, of the 45 individuals who we observed bringing work home on their weekday diary day, only 21 reported that they ever work at home in the CPS supplement. This may be because the nature of their job changed between the CPS Supplement and the ATUS interviews, which could have been anywhere from two to five months apart. Alternatively, the CPS Supplement questions may have been misinterpreted by the respondents, or answers may be subject to proxy reporting bias. From the 2004 directly matched data, we find that 69 percent of those who worked at home on their weekend/holiday diary day did not have a formal arrangement to be paid for work at home in the CPS Supplement. This suggests that most employees who worked at home on the weekend are not home-based or occasional telecommuters.

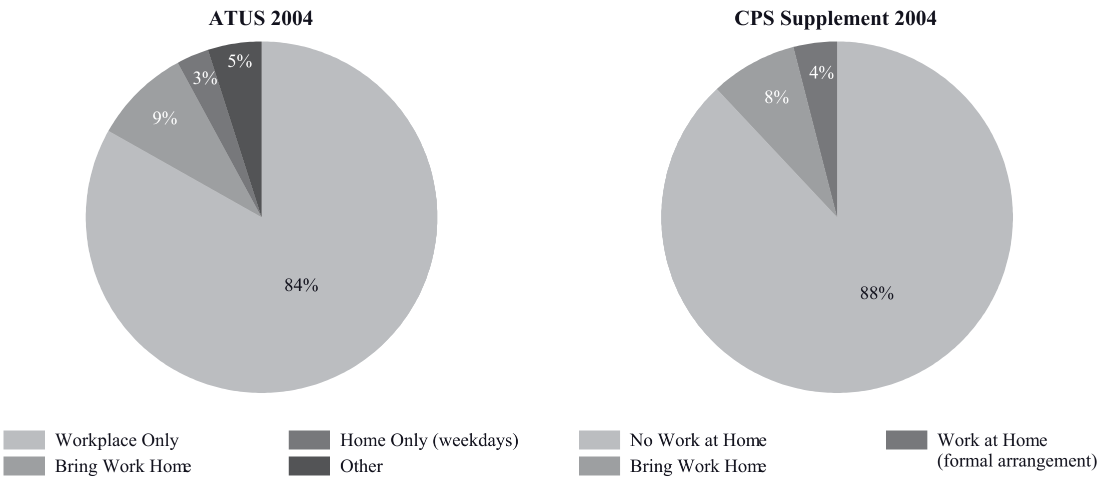
116 The 1997 CPS Supplement included a probing question later on in the survey asking for the existence of additional unpaid hours; however, it is unclear how this information may be appropriately analyzed.

117 Of the 13,973 ATUS interviewed in 2004, 7,558 had a May CPS Supplement interview. Of these, 2,429 were employed in both the ATUS and CPS.

Who is Bringing Work Home?

Nonfarm business employees do, in fact, bring work home from the workplace. From the 2004 ATUS diaries, we find that although 84 percent of nonfarm business employees who worked on their diary day worked exclusively in a workplace, 9 percent brought some of their work home, while 3 percent worked exclusively at home on weekdays (Figure 1).[118] The 2004 CPS Supplement data show that approximately 12 percent of nonfarm business employees do some work at home (Graph 8–1). The CPS supplement specifically asked those who do work at home whether they bring work home; 8 percent of employees reported bringing some work home in 2004, while 4 percent reported that they had a formal arrangement to be paid for work conducted at home. The shares of those who bring work home in the ATUS and in the CPS Supplement are surprisingly similar.[119] Throughout the paper, all ATUS estimates have been weighted using the ATUS respondent final weight.[120] All CPS Supplement estimates have been weighted using the work schedules supplement weight.

ATUS 2004 and CPS Supplement 2004
2004 data for figures **G 8–1**



Note : ATUS respondents represent only those who work on their diary day. The other category consists of those who work at locations other than home or the workplace or those who combine other locations with the workplace.
CPS Supplement respondents represent those who answered the question "As part of this job, do you do any of your work at home?"

118 The "other" category in Figure 1 consists of those who work at locations other than home or the workplace, such as a restaurant or someone else's home, or those who combine other locations with the workplace. The ATUS does not ask for secondary activity, except for secondary childcare. Therefore, if a respondent reports commuting to work, there are recorded as commuting and not working.

119 The distributions of work locations for other years are not statistically different from the 2004 results.

120 In 2006, the ATUS created updated final weights (TU06FWGT) to allow for pooling data across years.

The main reason reported in the CPS supplement for bringing work home was to finish up on work not completed at the usual workplace (Table 8–1).[121] The second reason most frequently sited for working at home was that it was the nature of the job. Five percent of workers specifically reported that they work at home to coordinate their work schedule with personal or family needs. This is supported by ATUS data that shows 17 percent of parents who bring work home in the ATUS worked at home in the presence of at least one of their children over the 2003–2006 period.

T8–1 Proportion of Nonfarm Business Employees Who Bring Work Home
by Reason for Work at Home (CPS Supplement)

	2001	2004
Finish or catch up on work	0.59	0.56
Business is conducted from home	0.04	0.04
Nature of the job	0.24	0.29
Coordinate work schedule w/ personal or family needs	0.05	0.05
Reduce commuting time or expense	0.01	0.01
Local transportation or pollution control program	0.00	0.00
Some other reason	0.06	0.06
Number of observations	2,895	3,143

Note: Proportions are weighted to account for sampling design.

Frequency of Bringing Work Home

From the ATUS data, we find that those who bring work home are roughly divided proportionally between weekday and weekend diaries (about 70 percent have a weekday diary day and 30 percent have weekend diary days). Among those who bring work home on a weekday, we find that in general fewer employees bring work home on Fridays than other weekdays. Table 8–2 presents the proportion of nonfarm business employees who bring work home by what time of day they conduct work at home. On weekdays, we find that the majority of those who bring work home do their work at home in the evenings. Over the 2003–2006 period, 59–66 percent did some work at home between 6 P.M. and 12 A.M. During the conventional working hours of 8 A.M. to 4 P.M., 26–33 percent did some work at home. A smaller percentage (20–23 percent) did some work at home between 6 A.M. and 8 A.M before heading to their primary workplace. This work reportedly done outside traditional working hours suggests that workers are either bringing extra work home or shifting the timing of their work. On weekends, a greater percentage of work at home is done during the daytime hours (49–58 percent) while less is done in the evenings (45–55 percent).

121 The 1997 CPS Supplement reasons for work at home are not comparable and, therefore, not reported here.

T 8–2 Proportion of Nonfarm Business Employees Who Bring Work Home
by Time of Day Working at Home (ATUS)

	Weekdays				Weekends			
Time of Day	2003	2004	2005	2006	2003	2004	2005	2006
12AM–6AM	0.11	0.10	0.09	0.15	0.08	0.07	0.04	0.03
6AM–8AM	0.20	0.22	0.23	0.23	0.10	0.10	0.10	0.13
8AM–4PM	0.32	0.33	0.29	0.26	0.49	0.52	0.54	0.58
4PM–6PM	0.19	0.22	0.16	0.22	0.25	0.20	0.28	0.28
6PM–12AM	0.60	0.59	0.66	0.64	0.51	0.55	0.45	0.45
Number of observations	246	175	155	163	308	228	201	211

Note: Proportions are weighted to account for sampling design. Numbers are rounded and do not sum to 1 because a worker could be working in more than one time period.

Table 8–3 presents the proportion of nonfarm business employees who bring work home by the specific number of minutes worked at home. We find that the amount of work done at home is economically significant. Only 17–23 percent of those who bring work home reported working at home for less than 15 minutes on their diary day, while 36–45 percent worked more than one hour at home (of these 21–26 percent worked at home for more than two hours).

Among the 8 percent of nonfarm business employees who bring work home according to the CPS Supplement, we find that over 70 percent report working at home at least once a week, about 12–13 percent work from home at least every two weeks, 10 percent at least once a month and 5–6 percent less than once a month (Table 8–4). When asked to report hours worked at home, roughly 31 percent of nonfarm business employees who bring work home did not report how many hours they worked at home, but rather that their hours at home varied in 2004 (23 percent reported working 1–2 hours per week at home, 14 percent reported working 3–4 hours per week at home, 12 percent reported 5–6 hours per week at home, and the remaining respondents reported anywhere from 8–60 hours per week at home).

T 8–3 Proportion of Nonfarm Business Employees Who Bring Work Home
by Minutes Worked at Home (ATUS)

Minutes per day	2003	2004	2005	2006
≤15	0.17	0.20	0.23	0.21
16–30	0.17	0.18	0.18	0.17
31–60	0.24	0.24	0.22	0.18
61–120	0.21	0.18	0.13	0.19
121–180	0.09	0.09	0.11	0.12
181–240	0.04	0.06	0.05	0.05
241+	0.10	0.06	0.07	0.09
Number of observations	554	403	356	374

Note: Proportions are weighted to account for sampling design. Numbers are rounded.

T8–4 Proportion of Nonfarm Business Employees Who Bring Work Home
by Frequency (CPS Supplement)

	2001	2004
At least once a week	0.71	0.73
At least every two weeks	0.13	0.12
At least once a month	0.10	0.10
Less than once a month	0.06	0.05
Number of observations	2,889	3,129

Note: Proportions are weighted to account for sampling design.

Characteristics of Those Who Bring Work Home

In Table 8–5, we examine the characteristics of nonfarm business employees in the ATUS, comparing those who bring work home from the workplace with those who work exclusively in the workplace.[122] In all years, employees who brought work home from the workplace were more likely to be older, white[123], married, have at least a bachelor's degree, and work in a management or professional occupation compared with employees who worked exclusively in the workplace. They were less likely to be black, Hispanic, work part time, or paid hourly. For example, among nonfarm business employees in 2006, 58 percent of those who brought work home held at least a bachelor's degree, while only 45 percent of those who worked exclusively in the workplace held at least a bachelor's degree. Of those who brought work home, only 23 percent reported being paid hourly, while 67 percent of nonfarm employees who worked exclusively in the workplace were paid hourly. Contrary to popular perceptions, not all work brought home is done by white-collar office workers. For example, among nonfarm business employees who brought work home in 2006, 5 percent worked in construction and maintenance occupations.

In Table 8–6, we use the 2001 and 2004 CPS supplement data to examine the characteristics of nonfarm business employees, comparing those who bring work home with those who do no work at home.[124] In both years, employees who brought work home were more likely to be older, white, married, have at least a bachelor's degree, have a child, and work in a management or professional occupation compared with those employees who do not bring work home. They were less likely to be female, black, Hispanic, or work part time.

122 Results are presented for combined weekday and weekend diaries. The analysis was also conducted separately for weekday and weekends, and the results are similar.

123 The "other race" category listed in Table 8–5 includes individuals of mixed-race categories, Asians, American Indians, Alaskan Natives, and Hawaiian/Pacific Islanders.

124 Although we include 1997 information in our measurement discussion later, the surveys are not comparable to the time period investigated in the ATUS nor are the industry and occupation variables comparable. Therefore, we do not include 1997 estimates in the descriptive analysis.

T8–5 Means and Proportions of Nonfarm Business Employees in the ATUS, comparing Bring Work Home with Workplace Only

	2003		2004		2005		2006	
	Bring work home	Workplace Only	Bring work home	Workplace Only	Bring work home	Workplace Only	Bring work home	Workplace Only
Female	0.41	0.40	0.33	0.43	0.32	0.44	0.33	0.44
Age	42.00	38.09	41.82	38.39	41.88	38.38	40.99	38.06
	(0.65)	(0.26)	(0.74)	(0.32)	(1.08)	(0.35)	(0.92)	(0.39)
White	0.86	0.84	0.87	0.84	0.87	0.84	0.84	0.83
Black	0.05	0.11	0.07	0.11	0.05	0.11	0.06	0.11
Other race	0.09	0.05	0.06	0.05	0.08	0.05	0.09	0.06
Hispanic	0.05	0.16	0.06	0.16	0.05	0.17	0.05	0.18
Single	0.16	0.35	0.24	0.32	0.26	0.34	0.22	0.35
Married	0.69	0.54	0.66	0.56	0.64	0.53	0.68	0.53
Divorced	0.13	0.11	0.10	0.12	0.12	0.13	0.10	0.12
Part time	0.11	0.18	0.12	0.17	0.10	0.17	0.06	0.18
Paid hourly	0.26	0.67	0.33	0.67	0.25	0.67	0.23	0.67
EDUCATION								
High school dropout	0.04	0.16	0.04	0.15	0.04	0.15	0.03	0.15
High school degree	0.19	0.34	0.21	0.35	0.12	0.36	0.10	0.35
Some college	0.24	0.28	0.27	0.28	0.27	0.28	0.29	0.29
Bachelor's degree	0.34	0.16	0.29	0.15	0.39	0.15	0.36	0.16
Advanced degree	0.19	0.05	0.19	0.06	0.18	0.06	0.22	0.05
YOUNGEST CHILD IN THE HOME								
No children	0.55	0.63	0.54	0.63	0.75	0.74	0.55	0.63
Infant	0.08	0.07	0.08	0.07	0.06	0.09	0.09	0.08
Preschooler	0.14	0.11	0.12	0.11	0.11	0.11	0.12	0.09
Elementary student	0.12	0.09	0.10	0.10	0.11	0.09	0.11	0.10
Adolescent	0.11	0.10	0.14	0.10	0.10	0.10	0.13	0.10
OCCUPATIONS								
Management and professional	0.58	0.26	0.49	0.27	0.53	0.26	0.64	0.25
Service	0.06	0.16	0.05	0.17	0.05	0.15	0.04	0.17
Sales and office	0.27	0.26	0.29	0.25	0.28	0.28	0.23	0.28
Farming, fishing, and forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Construction and maintenance	0.05	0.12	0.08	0.12	0.09	0.12	0.05	0.10
Production, transportation, & material moving	0.04	0.20	0.09	0.18	0.04	0.19	0.04	0.19
INDUSTRY								
Mining	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
Construction	0.05	0.08	0.05	0.08	0.07	0.09	0.06	0.08
Manufacturing	0.19	0.19	0.19	0.19	0.14	0.20	0.19	0.18
Wholesale and retail trade	0.16	0.20	0.16	0.20	0.17	0.20	0.09	0.21
Transportation and utilities	0.40	0.05	0.04	0.05	0.04	0.06	0.05	0.05

	2003		2004		2005		2006	
	Bring work home	Work-place Only	Bring work home	Work-place Only	Bring work home	Work-place Only	Bring work home	Work-place Only
Financial activities	0.10	0.08	0.10	0.08	0.14	0.08	0.18	0.09
Professional and business services	0.16	0.11	0.16	0.11	0.19	0.10	0.20	0.10
Educational and health services	0.16	0.11	0.16	0.11	0.10	0.12	0.13	0.11
Leisure and hospitality	0.06	0.10	0.06	0.10	0.06	0.09	0.03	0.10
Other services	0.02	0.04	0.02	0.04	0.03	0.03	0.02	0.04
Weekend	0.33	0.11	0.34	0.12	0.33	0.11	0.33	0.12
Number of Observations	554	3,746	403	2,466	356	2,359	374	2,317

Note: Sampling weights are used to account for survey design. Standard errors are in parentheses.

Regression Analysis

We estimated a multinomial logit model in order to determine the demographic and job characteristics of employees associated with bringing work home, compared with working exclusively in the workplace using the ATUS sample and compared with doing no work at home using the CPS Supplement. A third alternative in this model, but not discussed here, includes those who work in other locations on all diary days and exclusively at home on weekday diary days when using the ATUS and includes work in other locations and paid work at home when using the CPS Supplement. Independent variables in the model include educational degree attainment indicators, demographic characteristics (gender, age and age squared, indicators for race, Hispanic ethnicity, indicators for married or divorced, indicators for age of youngest child – infant, preschooler, elementary school student, or adolescent, and indicators for the interaction of these latter child variables with gender), job characteristics (part-time indicator, hourly indicator for ATUS sample[125], five occupation indicators, and ten industry indicators), and geographic characteristics (three region indicators), as well as a holiday diary indicator, day of the week indicator, and year indicators for the ATUS sample.

We estimated this model first using the pooled 2003–2006 ATUS data. We also examined salaried employees separately, because they are more likely to bring work home and more likely to have unmeasured hours worked.[126] Table 8–7 reports the marginal effects and standard errors from these estimations for all employees and then for salaried employees only. Next, we estimated the model using CPS supplement data for 2001 and 2004 sequentially. Table 8–8 presents the marginal effects and standard errors from these estimations.

Holding all else equal, overall results from both data sets indicate that highly-educated employees are much more likely to bring work home than less-educated employees, black

125 We do not include an hourly indicator in the CPS Supplement, because pay status is only collected in the outgoing rotation.

126 In the matched data, among nonfarm business employees that were observed to bring work home in the ATUS and reported that they took work home in the CPS Supplement, 86 percent were salaried employees.

T8–6 Means and Proportions of Nonfarm Business Employees in CPS Supplement, comparing Bring Work Home with No Work at Home

	2001		2004	
	Bring home work	No work at home	Bring home work	No work at home
Female	0.39	0.45	0.38	0.45
Age	40.96	37.48	42.48	38.04
	(0.22)	(0.09)	(0.26)	(0.09)
White	0.90	0.83	0.88	0.81
Black	0.06	0.12	0.05	0.12
Other race	0.05	0.05	0.07	0.07
Hispanic1	0.04	0.14	0.05	0.16
Single	0.18	0.33	0.19	0.35
Married	0.70	0.54	0.70	0.52
Divorced	0.12	0.13	0.11	0.13
Part-time2	0.06	0.18	0.07	0.19
EDUCATION				
High school dropout	0.01	0.17	0.02	0.16
High school degree	0.15	0.36	0.12	0.35
Some college	0.23	0.29	0.23	0.30
Bachelor's degree	0.41	0.15	0.39	0.15
Advanced degree	0.20	0.04	0.24	0.04
YOUNGEST CHILD IN THE HOME				
No children	0.55	0.68	0.6	0.68
Infant	0.08	0.06	0.08	0.06
Preschooler	0.13	0.09	0.11	0.09
Elementary student	0.11	0.08	0.09	0.08
Adolescent	0.13	0.09	0.12	0.09
OCCUPATIONS				
Management and professional	0.56	0.18	0.38	0.16
Service	0.11	0.06	0.03	0.19
Sales and office	0.13	0.05	0.25	0.29
Farming, fishing, and forestry	0.05	0.01	0.00	0.00
Construction and maintenance	0.02	0.07	0.03	0.11
Production, transportation, & material moving	0.01	0.01	0.02	0.19
INDUSTRY				
Mining	0.01	0.01	0.00	0.01
Construction	0.01	0.01	0.05	0.08
Manufacturing	0.04	0.07	0.15	0.17
Wholesale and retail trade	0.11	0.13	0.16	0.20
Transportation and utilities	0.07	0.08	0.03	0.05
Information	0.03	0.05	0.05	0.03
Financial activities	0.03	0.02	0.16	0.08

	2001		2004	
	Bring home work	No work at home	Bring home work	No work at home
Professional and business services	0.01	0.01	0.20	0.10
Educational and health services	0.08	0.05	0.15	0.12
Leisure and hospitality	0.10	0.23	0.03	0.12
Other services	0.16	0.07	0.01	0.04
Number of Observations	2,908	30,124	3,160	34,389

Note: Sampling weights are used to account for survey design. Standard errors are in parentheses.

1. Hispanic proportions for 2001 are based upon 32,716 non-missing observations.

2. Part-time proportions for 2001 are based upon 30,688 non-missing observations on hours worked per week.

employees are less likely to bring work home than white employees, and Hispanic employees are less likely to bring work home than non-Hispanic employees. We also find some evidence that divorced workers are more likely to bring work home than single workers. We find that females are less likely to bring work home than males, except in the 2001 CPS Supplement; although, the magnitude of these gender effects is small compared with the magnitude of the education effects. It is possible that these gender differences may actually capture occupation and industry differences in jobs held by gender that are not specified in our model. Several *more detailed* occupation groups, such as management and computer and mathematical science, have a high percentage of employees who bring work home, are male-dominated occupations, and constitute a large percentage of total employees in our sample. In the ATUS, those paid hourly are eight percent less likely to bring work home than salaried employees.

From the CPS supplement, we find that older employees are more likely to bring work home than younger employees. We also find some small differences in the probability of bringing work home between those who have children and those who do not. In the CPS Supplement in both 2001 and 2004, we find that men with a child aged 0–5 are more likely to bring work home than men without children; in 2001, fathers whose youngest child was elementary school-aged were also more likely to bring work home than males without children. In the ATUS only, mothers of preschooler and elementary school-aged children are more likely to bring work home than women without children. This suggests that some parents may bring work home to better balance work and family responsibilities when the children are young. In the CPS Supplement, we also find that mothers of infants are less likely to bring work home than fathers of infants. It is possible that mothers, as opposed to fathers, may choose not to bring work home because they traditionally spend more time on childcare and household production than their male spouses.

Do Those Who Bring Work Home Work Longer Hours?

We are interested in determining whether those who bring work home work longer hours, or whether they are simply shifting the location of work. Using the 2003–2006 ATUS data, we find different results for weekday diaries compared with weekend/holiday diaries. For respondents who bring work home on a weekday, we find that their daily hours worked are

T8–7: Marginal Effects of Select Covariates on the Probability of Bringing Work Home from Multinomial Logit Model Using the ATUS

(Comparison group = Work Exclusively in a Workplace)

	All employees	Salaried Employees
Female	-0.035*** (0.010)	-0.061*** (0.014)
Age	0.001 (0.002)	0 (0.003)
Age squared/1000	0.002 (0.024)	0.006 (0.033)
Black	-0.030*** (0.011)	-0.043*** (0.012)
Other race	0.014 (0.014)	0.042* (0.022)
Hispanic	-0.047*** (0.009)	-0.050*** (0.013)
Married	0.008 (0.010)	0.01 (0.015)
Divorced	0.018 (0.014)	0.037 (0.022)
High school degree	0.011 (0.020)	0.092** (0.041)
Some college	0.065** (0.025)	0.145** (0.060)
Bachelor's degree	0.105*** (0.032)	0.204*** (0.060)
Advanced degree	0.131*** (0.038)	0.246*** (0.072)
Part time	-0.008 (0.011)	0.023 (0.020)
Paid hourly	-0.076*** (0.019)	–
Youngest child aged 0–2	0.005 (0.017)	0.001 (0.019)
Youngest child aged 0–2 * female	0.008 (0.026)	0.053 (0.042)
Youngest child aged 3–5	0.01 (0.013)	0.011 (0.017)
Youngest child age 3–5 * female	0.021 (0.021)	0.04 (0.031)
Youngest child aged 6–10	0.011 (0.014)	0.009 (0.017)
Youngest child aged 6–10 * female	0.023 (0.022)	0.065* (0.037)
Youngest child aged 11–17	-0.005 (0.012)	0 (0.016)
Youngest child aged 11–17 * female	0.052 (0.027)	0.07* (0.037)
F-statistic	14.35	46.92
Number of observations	13,655	5,736

Notes: A third alternative in the model, not shown here, includes work in other locations on all diary days and work exclusively at home on weekdays. All regressions include region, occupation, industry, weekend diary day, and year indicators as well as a constant. Marginal effects are evaluated at the mean. Sampling weights are used to account for survey design. Standard errors are in parentheses. Significance levels: * =p<.10;**=p<.05;***=p<.01.

greater than the hours worked by those who work exclusively in a workplace; daily hours are 11 percent greater in 2003, 5 percent greater in 2004, 13 percent greater in 2005, and 15 percent greater in 2006. However, we also find that daily hours worked **at the workplace** by those who bring work home on a weekday are less than the daily hours worked **at the workplace** for those who work exclusively at a workplace on their weekday diary day – 10 percent less in 2003, 12 percent less in 2004, 7 percent less in 2005, and 3 percent less in 2006 (Table 8–9). Thus, those who bring work home on a weekday are shifting some hours of work from their workplace to their home, but they work more hours in total on their diary day.

T 8 – 8: Marginal Effects of Select Covariates on the Probability of Bringing Work Home from Multinomial Logit Model Using the CPS Supplement

by year {Comparison Group = No Work at Home)

	2001	2004
Female	0.002 (0.003)	-0.012*** (0.003)
Age	0.006*** (0.001)	0.004*** (0.001)
Age squared/1000	-0.061*** (0.011)	-0.034*** (0.010)
Black	-0.026***(0.004)	-0.021***(0.003)
Other race	-0.027*** (0.004)	-0.014*** (0.004)
Hispanic	-0.026*** (0.004)	-0.016*** (0.004)
Married	0.011*** (0.004)	0.004 (0.003)
Divorced	0.009* (0.006)	0 (0.004)
High school degree	0.072*** (0.015)	0.016* (0.010)
Some college	0.130*** (0.019)	0.042*** (0.012)
Bachelor's degree	0.317*** (0.033)	0.099*** (0.019)
Advanced degree	0.485*** (0.042)	0.181*** (0.032)
Part time	-0.027*** (0.004)	-0.023*** (0.003)
Youngest child 0–2	0.015** (0.007)	0.021*** (0.007)
Youngest child 0–2* female	-0.021*** (0.007)	-0.016*** (0.006)
Youngest child aged 3–5	0.021*** (0.007)	0.016*** (0.006)
Youngest child age 3–5 * female	-0.01 (0.007)	-0.004 (0.007)
Youngest child aged 6–10	0.012* (0.007)	0.006 (0.005)
Youngest child aged 6–10 * female	-0.016** (0.007)	-0.01 (0.007)
Youngest child aged 11–17	0.008 (0.006)	0.002 (0.005)
Youngest child aged 11–17 * female	-0.005 (0.007)	0 (0.007)
F-statistic	37.13	712.84
Number of observations	31,542	39,549

Notes: A third alternative, not shown here, includes work in other locations and paid work at home. All regressions include region, occupation, industry, and year indicators as well as a constant. Marginal effects are evaluated at the mean. Sampling weights are used to account for survey design. Standard errors are in parentheses. Significance levels:
* =p<.10;**=p<.05;***=p<.01.

Because we only observe a single diary day, we defined those who do any work at home on a weekend/holiday diary day as those who bring work home. For those who work at home on a weekend or holiday, we find that their daily hours worked are significantly less than the hours worked by those who work exclusively in the workplace. The daily hours for those who bring work home on a weekend/holiday are 2–3 hours per day compared with a 7-hour work day by those who work exclusively at the workplace. Although some of the bring-work-home weekend respondents may be home-based workers, their hours at home are quite similar to the 1–2 hours worked at home by weekday respondents who bring work home from the workplace.

T8–9: Daily Hours Worked for Nonfarm Business Employees (ATUS)

		Weekday Diaries		Weekend/holiday Diaries	
		Workplace Only	Bring Work Home	Workplace Only	Bring Work Home
	ATUS: daily hours	8.2	9.1	7.1	2.1
2003	ATUS: daily workplace hours	8.2	7.4	7.1	0.6
	ATUS: daily hours at home	–	1.6	–	1.5
	ATUS: daily hours	8.2	8.6	7.5	2.7
2004	ATUS: daily workplace hours	8.2	7.2	7.5	0.9
	ATUS: daily hours at home	–	1.4	–	1.8
	ATUS: daily hours	8.1	9.2	6.9	2.2
2005	ATUS: daily workplace hours	8.1	7.5	6.9	0.6
	ATUS: daily hours at home	–	1.4	–	1.5
	ATUS: daily hours	8.2	9.4	7.0	2.5
2006	ATUS: daily workplace hours	8.2	7.9	7.0	0.4
	ATUS: daily hours at home	–	1.4	–	2.0

Note: F-test results for differences in means are all significant at the 5 percent level.

In order to determine whether workers who bring work home on their diary day work more hours in general than do those who work exclusively in a workplace and are not completely off-setting hours at home on their diary day with fewer hours on another day during the week, we compare each group's CPS actual average weekly hours (Table 8–10).[127] Using either weekday or weekend/holiday diary data, we find that those who bring work home from their workplace reported significantly higher average weekly hours than those who work exclusively in a workplace. From the weekday diaries, average weekly hours for those who bring work home are 8–13 percent greater than those who work exclusively in the workplace. From the weekend/holiday diaries, the average weekly hours of those who bring work home are 15–23 percent greater than those who work exclusively in the workplace on their diary day. This provides additional evidence that those who work at home on weekends are bringing work home from the workplace. Recall that daily hours worked for these respondents were approximately 2 hours per weekend day, while their average weekly hours are over 42 hours per week. Assuming a five day work week, this suggests that the average daily hours for those who are working at home on a weekend should be about 8 hours per day. Thus, their daily and weekly hours closely resemble those of respondents who bring work home on weekdays. This suggests that combining weekday and weekend reports to calculate the share of workers who bring work home and their average hours worked is appropriate.

127 To analyze hours worked, we further restrict the sample to those who have the same employer, occupation and usual duties as they reported to the CPS two to five months prior.

T 8–10: Average Weekly Hours Worked for Nonfarm Business Employees (ATUS)

		Weekday Diaries		Weekend/holiday Diaries		All Diaries	
		Workplace Only	Bring Work Home	Workplace Only	Bring Work Home	Workplace Only	Bring Work Home
2003	Average weekly hours	38.2	41.5	36.5	41.9	38.1	41.6
	Number of observations	2,335	201	679	249	3,014	450
2004	Average weekly hours	38.0	41.7	37.0	43.0	37.9	42.1
	Number of observations	1,591	151	447	194	2,038	345
2005	Average weekly hours	38.4	43.5	36.2	43.6	38.2	43.5
	Number of observations	1,523	131	393	169	1,916	300
2006	Average weekly hours	38.4	42.5	35.4	43.5	38.1	42.8
	Number of observations	1,469	134	432	185	1,901	319

Note: F-test results for differences in means are all significant at the 5 percent level.

Using the CPS supplement data, we also find that those who bring work home have statistically significantly higher average weekly hours (20–21 percent higher) than those who do no work from home (Table 8–11). We also report separate estimates for those who work at home at least once a week because their hours worked at home should always be included in CPS average weekly hours reports whereas only some of the hours from workers who do infrequent work at home will be captured in CPS average weekly hours. The subgroup of employees who bring work home at least once a week have slightly higher average weekly hours in 2001 and 2004 than all employees who bring work home. We do not report results for the 1997 CPS Supplement since respondents were not asked for frequency of work at home but only whether they worked at home last week, which would capture those working at home at least once a week and some of those who work less than once a week at home.

T 8–11: Average Weekly Hours Worked for Nonfarm Business Employees (CPS Supplement)

		No Work at Home	Bring Work Home	Bring Work Home at Least Once a week
1997	Average weekly hours	36.9	44.6	–
	Number of observations	32,305	2,733	–
2001	Average weekly hours	36.8	44.5	45.1
	Number of observations	30,124	2,908	2,040
2004	Average weekly hours	36.5	43.8	44.3
	Number of observations	34,892	3,160	2,269

Note: F-test results for differences in means are all significant at the 5 percent level.

The general results from the two data sources are the same; those who bring work home do in fact work longer hours. In addition, both data sources show very little change in average weekly hours over time. We will show these results also hold for nonproduction/supervisory employees and production/nonsupervisory employees separately.[128]

Use of Hours Data in U.S. Productivity Measurement

Labor productivity measures the difference between output and hours growth, and reflects many sources, including increases in the quantities of nonlabor inputs (i.e., capital services, fuels, other intermediate materials, and purchased services), changes in technology, economies of scale, changes in management techniques, and changes in the skills of the labor force. The BLS calculates labor productivity for the nonfarm business sector by combining real output from the National Income and Product Accounts (NIPA) produced by the Bureau of Economic Analysis (BEA) with quarterly measures of hours worked for all persons prepared by the BLS Office of Productivity and Technology (OPT). The primary source of data used to construct hours worked measures for productivity purposes is the monthly payroll survey of establishments conducted by the BLS Current Employment Statistics program (CES).[129] The CES collects data monthly on employment for all employees and average weekly hours paid for production workers in goods industries and for nonsupervisory workers in service industries. The data represent employment and average hours paid for the pay period including the 12th day of the month.[130] CES average weekly hours paid are adjusted to hours at work using an hours-worked to hours-paid ratio estimated from the National Compensation Survey (NCS). This adjustment ensures that changes in vacation, holiday, and sick pay, which are viewed as changes in labor costs, do not affect hours growth.[131] Production/nonsupervisory hours worked are calculated as:

$$AWH_P^M * N_P * 52 \qquad (1)$$

128 In goods-producing industries, workers are divided into production and nonproduction workers. Nonproduction workers include professional specialty and technical workers; executive, administrative, and managerial workers; sales workers, and administrative support workers, including clerical. In service-producing industries, workers are divided into supervisory and nonsupervisory workers. Supervisory workers include all executives and administrative and managerial workers

129 The CES samples 400,000 nonfarm establishments, more than six times the 60,000 households sampled in the CPS. In addition, the CES is benchmarked annually to levels based on administrative records of employees covered by state unemployment insurance tax records. There is no direct benchmark for CPS employment data. Adjustments to the CPS underlying population base are made annually using intercensal estimates and every ten years using the decennial census. Also, establishment hours data are more consistent with the measures of output used to produce productivity measures; output data are based on data collected from establishments. In addition, establishment data provide reliable reporting and coding on industries and thus are well-suited for producing industry-level measures. Measures for industries based on household reports tend to produce industry estimates with considerable variance, even in a survey as large as the CPS. Thus, the BLS's official measures by industry come from establishment surveys wherever possible.

130 The CES program began collecting data on earnings and hours for all employees in September 2005. An experimental series including these new data is available at www.bls.gov/ces/cesaepp.htm.

131 Prior to 2000, the annual Hours at Work Survey was used.

where AWH_P^M represents measured average weekly hours for production/nonsupervisory workers obtained from CES hours, that are adjusted by the hours-worked to hours-paid ratio and adjusted to remove the hours of employees of nonprofit institutions, and N_P is the employment of nonfarm business production/nonsupervisory employees.

Because official hours estimates are not available from the CES, the BLS estimates average weekly hours of nonproduction/supervisory employees.[132] Data from the BLS' household survey, the CPS, are used to construct a ratio of the average weekly hours worked by nonproduction/supervisory employees relative to the average weekly hours worked by production/nonsupervisory employees. Together with CES hours and employment data, this ratio (referred to subsequently as the CPS ratio) is used to calculate the total hours worked by nonproduction/supervisory employees. Nonproduction/supervisory hours worked are calculated as:

$$AWH_{NP}^{M} = AWH_{P}^{M} * \frac{AWH_{NP}^{CPS}}{AWH_{P}^{CPS}} * N_{NP} * 52 \qquad (2)$$

where AWH_{NP}^{CPS} and AWH_P^{CPS} represent CPS measures of average weekly hours for nonproduction/supervisory and production/nonsupervisory employees respectively, and N_{NP} is the employment of nonfarm business nonproduction/supervisory employees. Average weekly hours for production/nonsupervisory employees and nonproduction/supervisory employees are constructed by OPT at the NAICS major industry group level and then aggregated. Total hours for all persons in the nonfarm business sector are the sum of production/nonsupervisory employee hours, nonproduction/supervisory employee hours, and hours worked by the unincorporated self-employed, unpaid family workers and employees of government enterprises. Average weekly hours for the unincorporated self-employed, unpaid family workers and employees of government enterprises are taken directly from the CPS; remaining data are obtained from various sources.[133]

Some critics of official productivity measures have suggested that IT innovations have allowed workers the flexibility to work outside the traditional workplace and that these hours are not properly captured in official BLS productivity measures.[134] This criticism is typically directed toward the quarterly labor productivity in the nonfarm business sector. It is important to note that an underestimation of hours worked affects measures of productivity growth only if unmeasured hours grow differently from measured hours and affect a significant portion of the working population. Eldridge (2004) found that a hypothetical hours series constructed by combining CPS average weekly hours and CES employment data produced slightly higher levels of hours, but hours showed a comparable trend from 2000–2003.

132 In August 2004, BLS introduced this new method of constructing estimates of hours for nonproduction and supervisory workers. See Eldridge, Manser, and Otto (2004).

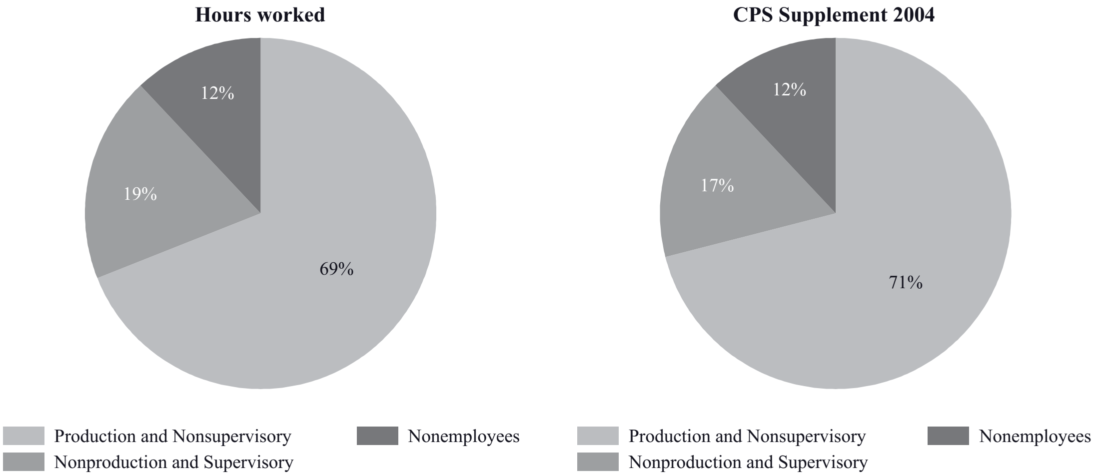
133 Employment counts for employees in agricultural services, forestry and fishing come from the BLS's 202 program, based on administrative records from the unemployment insurance system. The number of employees of government enterprises comes from the BEA.

134 Steven Roach (1998) argued that many white collar workers are working longer workdays than the official U.S. data show, as a result of the new portable technologies of the information age – laptops, cellular telephones, home fax machines, and beepers.

Are Hours of Work Brought Home Measured?

Hours worked are constructed separately for production/nonsupervisory employees, nonproduction/supervisory employees, and nonemployees.[135] Graph 8–2 shows each group's share of nonfarm business sector hours worked and employment. Production/nonsupervisory employees account for the majority of all nonfarm business sector hours (69 percent), while nonemployees account for the smallest share of hours (12 percent). As previously mentioned, an analysis of bringing work home among nonemployees is beyond the scope of this paper.

Percent of Nonfarm Business Sector Hours and Employment, by Type of Worker: 2004 G 8–2



Source: U.S. Labor Statistics

Production and Nonsupervisory Employees

Using the 2003–2006 ATUS data, we find that approximately 85–87 percent of production/ nonsupervisory employees who work on their diary day worked exclusively in the workplace, while 6 percent brought work home from the workplace in 2003, 8 percent brought work home in 2004, 7 percent brought work home in 2005, and 6 percent brought work home in 2006 (Table 8–12). We find that those who bring work home from their workplace report higher average weekly hours than those who work exclusively in a workplace; 4 percent higher in 2003, 9 percent higher in 2004, 13 percent higher in 2005, and 7 percent higher in 2006.

As mentioned before, the BLS constructs annual hours worked using hours paid data from the CES for production/nonsupervisory employees. If hours for production/ nonsupervisory employees are understated it is only to the extent that hours worked at home are not captured in reported hours paid.

135 We use the term nonemployees in this study to represent the unincorporated self-employed, unpaid family workers and government enterprise workers.

T8–12: Hours Worked for Production and Nonsupervisory Employees (ATUS)

		Workplace Only	Bring Work Home	Bring Work Home-Salaried
	Share of production/ nonsupervisory employees	86.5%	6.2%	4.1%
2003	Share of daily hours worked at home*	–	20.2%	19.1%
	Average weekly hours	37.2 (0.3)	38.6 (1.1)	39.8 (1.4)
	Number of observations	2,413	264	174
	Share of production/ nonsupervisory employees	85.5%	7.8%	3.9%
2004	Share of daily hours worked at home*	–	15.9%	16.5%
	Average weekly hours	36.7 (0.4)	39.9 (1.4)	42.7 (1.8)
	Number of observations	1,565	220	136
	Share of production/ nonsupervisory employees	85.7%	7.4%	4.4%
2005	Share of daily hours worked at home*	–	16.9%	15.3%
	Average weekly hours	37.2 (0.5)	42.2 (1.1)	42.9 (1.5)
	Number of observations	1,497	182	128
	Share of production/ nonsupervisory employees	85.4%	6.4%	3.7%
2006	Share of daily hours worked at home*	–	15.0%	13.8%
	Average weekly hours	37.5 (0.4)	40.0 (1.2)	42.4 (1.2)
	Number of observations	1,544	182	134

Note: Standard errors are in parentheses. F-test results for differences in means are all significant at the 5 percent level.

* weekday value used

** results for weekdays and weekends available upon request from the authors

The ATUS does not obtain information on whether work brought home is paid or unpaid. Therefore, to assess whether work that is brought home from the workplace is measured, we must make several assumptions. First, we assume that hours worked at the workplace are captured in reported hours paid and thus measured. Second, we assume that hourly workers are less likely to do unpaid work at home than salaried workers. The outgoing rotation cohort of the CPS Supplement indicates that over 81 percent of production/nonsupervisory workers who bring work home, without a formal arrangement to be paid, are not paid hourly. We find that approximately 4 percent of production/nonsupervisory workers were paid a salary and brought work home. Among these employees, we find that 14–19 percent of their weekday **daily** hours were worked at home. Among those who bring work home and are paid a salary, we find that average **weekly** hours were 7 percent greater than those who worked exclusively in a workplace in 2003, 16 percent greater in 2004, 15 percent greater in 2005, and 13 percent greater in 2006.

Recall that the CPS supplement specifically asked respondents whether they were paid to work at home or whether they just took work home. The CPS Supplement data indicate that approximately 91–92 percent of production/nonsupervisory employees report no work at home (Table 8–13), while 3 percent of production/nonsupervisory employees report some paid work at home and roughly 5–6 percent indicate they were just bringing work home. About 4 percent indicate that they bring work home at least once a week. Thus, in any given CPS week, somewhere between 4–6 percent bring work home. Comparing average weekly hours for those who bring work home with those who do no work at home, we find that those who bring work home have statistically significant higher average weekly hours (17–18 percent higher) than those who do no work from home. These findings suggest that there may exist unmeasured hours for production/nonsupervisory employees who work outside the workplace.

T 8–13: Hours Worked for Production and Nonsupervisory Employees
(CPS Supplement)

		NO WORK AT HOME	WORK AT HOME		
			Paid	Bring work home	Bring work home at least once a week
1997	Share of production/ nonsupervisory employees	92.4%	2.5%	5.0%	–
	Average weekly hours	36.1	38.1	42.6	–
		(0.09)	(0.71)	(0.45)	–
	Number of observations	27,060	754	1,453	–
2001	Share of production/ nonsupervisory employees	91.3%	2.9%	5.7%	4.0%
	Average weekly hours	36	37.8	42.5	42.9
		(0.09)	(0.64)	(0.40)	(0.49)
	Number of observations	25,057	802	1,570	1,118
2004	Share of production/ nonsupervisory employees	91.7%	2.8%	5.3%	3.9%
	Average weekly hours	35.8	37.5	41.9	42
		(0.10)	(0.67)	(0.44)	(0.55)
	Number of observations	29,540	941	1,766	1,296

Note: Standard errors are in parentheses F-test results for differences in means are all significant at the 5 percent level.

Nonproduction and Supervisory Employees

Among nonproduction/supervisory employees who worked on their diary day, roughly 72–77 percent worked exclusively in a workplace on their diary day, while 13–19 percent brought work home from the workplace on their diary day (Table 8–14).[136] As with the production/ nonsupervisory results, we find that those who bring work home from a workplace report

[136] Numbers do not sum to 100 since workers could work in other locations or exclusively at home. See footnote 9.

higher average weekly hours than those who work exclusively in a workplace – 9 percent higher in 2003, 11 percent higher in 2004, 9 percent higher in 2005, and 13 percent higher in 2006. The ATUS data indicate that 10–16 percent of salaried nonproduction/supervisory employees brought work home. We find that 12–16 percent of **daily** hours among salaried nonproduction/supervisory employees were worked at home. For these workers, we also find that average **weekly** hours were 13 percent greater than those who worked exclusively in a workplace in 2003, 12 percent greater in 2004, 12 percent greater in 2005, and 16 percent greater in 2006.

T8–14: Hours Worked for Nonproduction and Supervisory Employees (ATUS)

		Workplace Only	Bring Work Home	Bring Work Home-Salaried
	Share of nonproduction/ supervisors	73.6%	16.4%	13.5%
2003	Share of daily hours worked at home*	–	13.5%	14.1%
	Average weekly hours	41.9 (0.5)	45.8 (1.0)	47.2 (1.1)
	Number of observations	601	186	162
	Share of nonproduction/ supervisors	76.8%	12.6%	10.4%
2004	Share of daily hours worked at home*	–	15.4%	16.2%
	Average weekly hours	42.0 (0.6)	46.8 (1.1)	47.1 (1.2)
	Number of observations	473	125	111
	Share of nonproduction/ supervisors	72.0%	15.3%	12.4%
2005	Share of daily hours worked at home*	–	13.6%	11.5%
	Average weekly hours	42.2 (0.6)	45.8 (1.2)	47.2 (1.2)
	Number of observations	419	118	102
	Share of nonproduction/ supervisors	72.2%	19.3%	16.2%
2006	Share of daily hours worked at home*	–	13.8%	14.9%
	Average weekly hours	40.9 (0.8)	46.1 (1.4)	47.3 (1.4)
	Number of observations	357	131	118

* weekday value used

** results for weekdays and weekends available upon request from the authors

Note: Standard errors are in parentheses F-test results for differences in means are all significant at the 5 percent level.

Using the CPS supplement, we find that approximately 73–74 percent of nonproduction/supervisory employees reported no work done at home (Table 8–15). About 7 percent of nonproduction/supervisory employees reported doing some paid work at home and 19–20 percent reported that they bring work home. Comparing average weekly hours for those who bring work home with those who do no work at home, we find that those who bring work home have significantly higher average weekly hours than those who do no work from home – 15 percent greater in 1997 and 2001 and 13 percent greater in 2004. Although these findings suggest that there are hours that may not be reported as hours paid for nonproduction/supervisory employees who bring work home, it does not lead to the implication that hours are not measured since BLS hours for nonproduction/supervisory employees are not constructed using a series of hours paid for nonproduction/supervisory employees, but rather incorporate self-reported CPS hours.[137]

T 8–15: Hours Worked for Nonproduction and Supervisory Employees
(CPS Supplement)

		NO WORK AT HOME	WORK AT HOME		
			Paid	Bring work home	Bring work home at least once a week
1997	Share of nonproduction/supervisory employees	74.4%	6.6%	18.8%	–
	Average weekly hours	40.6	40.2	46.8	–
		(0.18)	(0.91)	(0.40)	–
	Number of observations	5,245	452	1,280	–
2001	Share of nonproduction/supervisory employees	72.8%	7.1%	19.7%	13.7%
	Average weekly hours	40.6	39.9	46.6	47.5
		(0.18)	(0.73)	(0.40)	(0.50)
	Number of observations	5,067	505	1,338	922
2004	Share of nonproduction/supervisory employees	72.9%	7.2%	19.6%	13.9%
	Average weekly hours	40.8	39.7	46.1	47
		(0.19)	(0.84)	(0.39)	(0.48)
	Number of observations	5,352	556	1,394	973

Note: Standard errors are in parentheses F-test results for differences in means are all significant at the 5 percent level.

Estimating the Percent of Unmeasured Hours

A. Assuming Accurate Response to the CPS

If we think of the measured average weekly hours series as capturing a weighted average of the average weekly hours of those who do not bring work home and the average weekly hours worked in a **workplace** of those who bring work home, then the measured series can be written as:

137 See equation (2).

$$AWH_P^M = \left(w_P^{\sim bwh} AWH_P^{\sim bwh} + w_P^{bwh} AWH_P^{bwh} \gamma_P^{workplace} \right) \quad (3)$$

where $w_P^{\sim bwh}$ and $AWH_P^{\sim bwh}$ represent the share of workers who do not bring work home and their average weekly hours respectively, and w_P^{bwh} and AWH_P^{bwh} represent the share of workers who bring work home and their average weekly hours respectively. By construction, $w_P^{\sim bwh}$ and w_P^{bwh} sum to one. Also, $\gamma_P^{workplace}$ represents the percent of hours worked at a workplace by those who bring work home.

Unmeasured hours worked per week for production/nonsupervisory employees are the hours worked at home by those who bring work home, or:

$$w^{bwh} \; AWH^{bwh} \; * \; \gamma_P^{home} \quad (4)$$

where γ_P^{home} represents the percent of hours worked at home by those who bring work home, or 1- $\gamma_P^{workplace}$. Dividing equation (4) by equation (3) and rearranging terms gives the unmeasured hours worked at home as a percent of measured hours for production/nonsupervisory employees:

$$\theta_P = \frac{\gamma_P^{home}}{\dfrac{w_P^{\sim bwh} AWH_P^{\sim bwh}}{w_P^{bwh} AWH_P^{bwh}} + \gamma_P^{workplace}} \quad (5)$$

If we assume that average weekly hours are accurately reported to the CPS or that CPS reporting errors are similar among those who bring work home and those who do not, we can estimate the percent of unmeasured hours for production/nonsupervisory employees using equation (5). Table 8–16 presents the estimates of the percentage of unmeasured hours for production/ nonsupervisory employees in each year, as well as the estimates for the components of equation (5).

The measured average weekly hours for nonproduction/supervisory employees are calculated by OPT as:

$$AWH_P^M \; * \; \left[\frac{AWH_{NP}^{CPS}}{AWH_P^{CPS}} \right] \quad (6)$$

Assuming accurate reporting to the CPS by those who bring work home, the percent of unmeasured hours for nonproduction/supervisory employees will be the same as that of production/supervisory employees.[138] According to ATUS data, approximately 0.6–0.8 percent of average weekly hours of nonfarm business employees are unmeasured due to work brought home (Table 8–16). According to the CPS supplement, the percent of unmeasured hours is a bit larger (0.9–1.1 percent); although when we focus on those who bring work home at least once a week, the percent of unmeasured hours is 0.8 percent.[139]

138 CPS average weekly hours should include all hours worked regardless of location for both production/ nonsupervisory employees and nonproduction/supervisory employees. Because this is a ratio, any survey effects will cancel out.

139 However, the quality of these additional hours at home may not be of the same quality as those worked in the workplace, especially if workers are doing secondary childcare while working at home.

T 8–16: Percent of Unmeasured Hours for Employees in the Nonfarm Business Sector
(No Reporting Bias)

		Production/nonsupervisory Employees					Percent of unmeasured hours
		Those who do not bring work home		Those who do bring work home			
		Share of production/ nonsupervisory employees	AWH_p	Percent of hours at home	Share of production/ nonsupervisory employees	AWH_p	
ATUS	2003	95.9%	37.2	19.1%	4.1%	39.8	0.84%
	2004	96.1%	36.7	16.5%	3.9%	42.7	0.76%
	2005	95.7%	37.2	15.3%	4.4%	42.9	0.77%
	2006	96.3%	37.5	13.8%	3.7%	42.4	0.58%
CPS Supplement	1997	95.0%	36.1	18.5%	5.0%	42.6	1.09%
	2001	94.3%	36.0	13.3%	5.7%	42.5	0.89%
	2004	94.7%	35.8	14.6%	5.3%	41.9	0.91%
CPS Supplement (at least once a week)	2001	96.0%	36.0	15.7%	4.0%	42.9	0.75%
	2004	96.1%	35.8	17.1%	3.9%	42.0	0.78%

B. Assuming Reporting Bias by Those Who Bring Work Home

CPS respondents who bring work home may differ from those who do not bring work home in their ability to accurately report their hours worked at home. We have shown that those who bring work home work longer hours. Much of the previous research finds that those who work longer hours tend to over report hours worked compared to those who work `normal' hours, while the popular press tends to suggest that work brought home from the office is going unreported. To address this latter concern, we estimate an upper bound on the percent of unmeasured hours worked by assuming that those who bring work home are not reporting their hours worked at home to the CPS.

Because survey respondents should be better able to accurately recall events of the previous day than the previous week, we use ATUS data on the percent of hours worked at home by those who bring work home on their diary day to estimate a modified average weekly hours.[140] Recall that measured average weekly hours from equation (3) include only average weekly hours worked in a workplace. Given the assumption that hours worked at home are not reported to the CPS, reported average weekly hours will also include only average weekly hours worked in the workplace. Thus, we re-estimate the percent of unmeasured hours worked for production/ nonsupervisory employees by dividing equation (4) by total reported CPS hours and rearranging terms to get:

140 Information from the CPS Supplement is not used because respondents were directly asked how many hours they usually work at home and how many hours they usually work in total in the same survey; therefore, these responses should be consistent and we would be unable to determine the correct percentage of hours worked at home if there is a recall bias.

$$\theta_P^r = \frac{\gamma_P^{home}}{\dfrac{\tilde{w}_P^{bwh}\,A\tilde{W}H_P^{bwh}}{w_P^{bwh}\,AWH_P^{bwh}} + 1} \tag{7}$$

Assuming that hours worked at home are not reported, the percent of unmeasured hours for nonproduction/supervisory employees is no longer equal to the percent of unmeasured hours for production/nonsupervisory employees. As we observed, nonproduction/supervisory employees are more likely to bring work home than production/supervisory employees. Therefore, if those who bring work home are not reporting the hours worked at home, then the nonproduction/supervisory to production/nonsupervisory hours ratio may be biased downward. Unmeasured hours for nonproduction/supervisory employees can be rewritten as:

$$AWH_P^M \left(1+ \theta_P^r\right) \left[\frac{AWH_{NP}^{CPS} + w_{NP}^{bwh}\ AWH_{NP}^{bwh}\left(\gamma_{NP}^{home}\right)}{AWH_P^{CPS} + w_P^{bwh}\ AWH_P^{bwh}\left(\gamma_P^{home}\right)}\right] \tag{8}$$

Dividing equation (8) by equation (6) and rearranging terms gives the percent of unmeasured hours for nonproduction/supervisory employees assuming all hours worked at home go unreported to the CPS as:

$$\theta_{NP} = \left\{ \left(1+\theta_P^r\right) \left[\frac{1 + \left(w_{NP}^{bwh}\ \gamma_{NP}^{home}\ AWH_{NP}^{bwh} \big/ AWH_{NP}^{CPS}\right)}{1 + \left(w_P^{bwh}\ \gamma_P^{home}\ AWH_P^{bwh} \big/ AWH_P^{CPS}\right)}\right]\right\} - 1 \tag{9}$$

Table 8–17 presents the estimates of the percent of unmeasured average weekly hours assuming hours worked at home by those who bring work home are not reported .[141] The percentage of unmeasured hours for production/nonsupervisory employees is virtually the same under either reporting assumption. However, the percent of unmeasured hours for nonproduction/supervisory employees are significantly higher (1.6–2.7 percent) than those of production/nonsupervisory employees. Total measured employee hours are the sum of the weighted share of hours of production/nonsupervisory employees and nonproduction/supervisory employees. From Graph 8–2, we know that production/nonsupervisory employees account for the majority of all hours worked, thus unmeasured hours by this group will be more heavily weighted. Assuming that CPS respondents who bring work home do not report their hours worked at home, we find that 0.9–1.1 percent of hours of all nonfarm business employees may be missed.

Our analysis using both the ATUS and the CPS supplement suggests unmeasured hours of nonfarm business employees may range from 0.6 to 1.1 percent of measured hours. We next examine whether unmeasured hours are increasing over time.

141 For the 1997 CPS Supplement, we use actual hours worked last week and all hours worked at home last week to calculate the percent of hours worked at home. Due to questionnaire differences, we use usual hours worked at home and usual hours worked in total for those respondents who do not report that their hours vary for the 2001 and 2004 CPS Supplement.

T 8–17: Percent of Unmeasured Employee Hours in the Nonfarm Business Sector Assuming Reporting Bias Among Those Who Bring Work Home
by Employee Status (ATUS)

	Share who bring work home	Percent of hours at home	AWH of those who bring work home	AWH those who do not bring work home	Percent of unmeasured hours
Production/nonsupervisory Employees					
2003	4.1%	0.19	39.8	37.2	0.83%
2004	3.9%	0.16	42.7	36.7	0.75%
2005	4.4%	0.15	42.9	37.2	0.76%
2006	3.7%	0.14	42.4	37.5	0.58%
Nonproduction/supervisory Employees					
2003	13.5%	0.14	47.2	41.9	2.10%
2004	10.4%	0.16	47.1	42.0	1.88%
2005	12.4%	0.11	47.2	42.2	1.57%
2006	16.2%	0.15	47.3	40.9	2.73%

All Employees

	Production/Nonsupervisory Employees		Nonproduction/Supervisory Employees		Percent of Unmeasured Total Hours
	Share of total hours worked	Percent of unmeasured hours	Share of total hours worked	Percent of unmeasured hours	
2003	0.78	0.83%	0.22	2.10%	1.11%
2004	0.78	0.75%	0.22	1.88%	1.00%
2005	0.79	0.76%	0.21	1.57%	0.93%
2006	0.79	0.58%	0.21	2.73%	1.03%

Unmeasured Hours Growth

Using the percent of unmeasured hours estimated above, we construct an hours series for all employees in the nonfarm business sector and add to this the hours worked by the unincorporated self-employed, unpaid family workers and employees of government enterprises, as measured by BLS-OPT. Table 8–18 compares the growth in measured hours worked for all persons in the nonfarm business sector with the growth in each of our adjusted series (assuming first no reporting bias in the CPS and then a downward reporting bias among those who bring work home). Official productivity growth statistics are published to the first decimal place. We find a small upward bias in measured hours growth over the 2003–2006 period; the ATUS-adjusted series grows 0.03–0.08 percent per year slower than the official BLS measured hours series. Because hours and productivity trends are reported at the one decimal level, this difference would not affect the measured data. Year to year fluctuations are always more volatile. For the year to year changes, measured hours grow the same or faster than adjusted hours in most years, except from 2004 to 2005 when assuming no reporting bias and from 2005 to 2006 when assuming reporting bias. Assuming reporting bias, the year to year trends are the same trends at the one decimal level for 2003–2004 and 2004–2005. However, over the 2005–2006 period, the adjusted hours series would produce a 0.2 percent reduction in hours growth if no reporting bias is assumed. Assuming reporting bias, the 2003–2004 and 2004–2005 trends would appear 0.1 percent slower than measured hours growth, while the 2005–2006 hours trend would be 0.1 percent faster if hours at home are assumed to be unreported. The CPS Supplement-adjusted series from 1997 to 2001, and over the longer period 1997–2004, grows slightly slower than the BLS measured series. Over the 2001–2004 period we find very little difference between the measured and adjusted series. Over all years the differences are too small to affect the official productivity growth statistics.

The potential bias in hours levels resulting from unmeasured hours worked at home does not lead to any conclusive finding that the growth in hours is biased. We find that over most time periods hours growth is not being understated as critics have suggested. Over the longer time periods hours would actually be growing slower than measured series if adjustments to incorporate hours worked at home are made; this would lead to an understatement of productivity growth. Therefore, we conclude that productivity estimates are not overstated due to any misreporting in hours.

T 8–18: Annual Average Growth in Hours of all Persons in the Nonfarm Business Sector

		OPT series	No reporting bias		Hours at home not reported	
			Adjusted	Difference	Adjusted Series	Difference
ATUS	2003–2004	1.34%	1.27%	-0.07%	1.24%	-0.10%
	2004–2005	1.66%	1.67%	0.01%	1.60%	-0.06%
	2005–2006	2.17%	2.00%	-0.17%	2.25%	0.08%
	2003–2006	1.72%	1.65%	-0.08%	1.70%	-0.03%
CPS SUPPLEMENT	1997–2001	0.81%	0.76%	-0.04%		
	2001–2004	-0.62%	-0.62%	0.01%		
	1997–2004	0.19%	0.17%	-0.02%		
CPS Supplement (at least once a week)	2001–2004	-0.62%	-0.61%	0.01%		

Conclusion

In this paper, we used both the ATUS and May CPS Work Schedules and Work at Home Supplements to determine whether hours worked by nonfarm business employees were understated and increased between 1997 and 2006 because of unreported hours worked at home. The main advantage of using the CPS Supplement is that we can determine whether work done at home is paid. The main advantages of the ATUS are that we can observe when during the day the work is being performed at home and get a more accurate measure of the number of hours worked at home.

According to the 2003–2006 ATUS data and the CPS Supplement, 8–9 percent of nonfarm business employees brought some of their work home from their primary workplace. A majority of CPS supplement respondents indicated that they did work at home in order to finish or catch up on work. We find evidence that suggests workers bring work home at least in part to better balance work and family responsibilities. We find that men and women of young children are more likely to bring work home than those without children. In addition, 17 percent of parents who brought work home reported a child in their care while working at home in 2003. Five percent of respondents to the CPS supplement directly indicated that they do work at home to better balance work and family responsibilities. Results from a multinomial logit model also indicate that highly-educated, salaried workers are much more likely to bring work home than their less-educated, hourly counterparts.

From both data sets we find that those who bring work home have higher average weekly hours than those who work exclusively in a workplace. From the ATUS data, we find that total daily hours at the workplace are lower for those who bring work home than for those who work exclusively in the workplace. Thus, it does appear that those who bring work home shift some work from their workplace to their home, yet work more hours overall.

The data suggests that there may exist a 0.6–1.1 percent downward bias in hours worked for the nonfarm business sector employees. However, when the official indexes of hours for all persons are augmented to include these unmeasured hours for employees we find little change in the **growth** of hours over the period 2003–2006. Our findings indicate that hours trends would actually be growing slightly slower if our estimates of hours worked were adopted, thus productivity would grow slightly faster. We find no conclusive evidence that productivity trends are overstated for the 1997–2006 period due to work brought home from the workplace.

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Part 3:

The Measure of the Composition of Labour Input

9. MAIN SOURCES OF QUARTERLY LABOUR PRODUCTIVITY DATA FOR THE EURO AREA

By Wim Haine and Andrew Kanutin[142]
European Central Bank (ECB)

Introduction

Labour productivity and its measurement is an important issue for the European Central Bank (ECB). Growth in productivity is key for non-inflationary growth. In addition to structural (annual) data, the ECB requires relatively highly aggregated and timely data on productivity growth for short-term economic analysis. The ECB has for several years calculated euro area productivity estimates and published them in its Monthly Bulletin. The calculation used is GDP per person employed, taken from the European System of Accounts 1995 (ESA95) national accounts. While this calculation is acknowledged to be a less than perfect measurement, there is a scarcity of other suitable data for the euro area, especially data fulfilling the timeliness requirement. The ECB also uses a number of supplementary euro area productivity indicators from both quantitative and qualitative surveys, which are explained in this note.

The next section of this paper describes the current calculation of quarterly labour productivity data at the ECB. The third section describes the rationale underlying the choice of data. The fourth section gives an overview of some ancillary productivity data sources used by the ECB for short-term analysis. The concluding section explains some ongoing and expected improvements in data quality which will help to improve labour productivity estimates.[143]

Current calculation and results

The ECB currently calculates quarterly labour productivity data using national accounts series and the following formula:

Labour productivity = GDP at constant prices / Number of people in employment (domestic definition)[144]

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[142] Any views expressed are only those of the authors and do not necessarily represent the views of the ECB.

[143] For analysis of long-term productivity developments in the euro area see the article entitled “Labour productivity developments in the euro area: aggregate trends and sectoral patterns”, in the July 2004 issue of the ECB’s Monthly Bulletin.

[144] 3 Eurostat compiles national accounts for the euro area by converting the national data to a common currency and summing them. This common currency is the euro from 1999 onwards and the ECU prior to 1999. When the pre-1999 conversion is carried out, variations in exchange rates between the national currencies and the common currency may affect the growth rates of the individual components. The aggregated growth rate may therefore diverge from the average of the national growth rates expressed in national currency. To avoid this, a correction coefficient is applied to the growth rates published by Eurostat for periods before 1999.

While the quarterly GDP volume data are available from Eurostat for the euro area and for all euro area countries, the labour input data are not available with the timeliness required.[145] The ECB therefore calculates its own estimate of employment,[146] which becomes available about 75 days after the end of the reference quarter. This is about 30 days ahead of Eurostat's employment estimates, which are published as part of the second regular release of euro area and EU quarterly national accounts (QNA). The ECB's estimation process is described below.

Compiling euro area employment indices

The ECB compiles its euro area employment indices on the basis of quarterly employment data provided by the individual countries, insofar as they are available. Data are taken in the following order of preference according to availability:

5. quarterly, seasonally adjusted
6. quarterly, non-adjusted
7. interpolated annual data

For Portugal, only annual data are available; for Ireland, annual data supplement quarterly data (prior to 1997). Where data are not available from a particular Member State in a seasonally adjusted form, the ECB makes its own adjustment using the programme Census X-12 ARIMA.

T 9 – 1 Timeliness and availability of QNA employment estimates

	Timeliness Q1 2005[1]	Availability
Euro area	74	Q1 1991–Q1 2005
Belgium	160	Q1 1981–Q1 2005
Germany*	54	Q1 1991–Q2 2005
Greece	n/a	n/a
Spain	56	Q1 1980–Q2 2005
France	50	Q1 1978–Q2 2005
Ireland	126	Q1 1998–Q2 2005
Italy	71	Q1 1970–Q2 2005
Luxemburg	111	Q1 1995–Q1 2005
Netherlands	42	Q1 1987–Q2 2005
Austria	74	Q1 1988–Q1 2005
Portugal	n/a	n/a
Finland	70	Q1 1975–Q2 2005

Source: ECB and Eurostat; 1 Number of days after the end of the quarter when data became available to the ECB.

1* German employment data have also been extended historically using West German employment series and break-adjusting them in 1991. The historical series is created by applying the annual percentage changes of the West German series to the 1991 unified German data. The resultant series is also used to estimate historical euro area data back to 1980.

145 For an overview of the ECB's requirements in this field see also "Review of the requirements in the field of General Economic Statistics", ECB, December 2004.

146 Estimates are calculated for total employment, self-employment and employees, and broken down on the basis of NACE A6.

Euro area aggregates are then calculated using a country weighted average of quarter-on-quarter growth rates of individual countries. The weights used are calculated annually for each index series. At each observation the euro area weight is calculated as the sum of the weights of the countries for which data are available, and the index is calculated only for observations where this weight is above 80% (this is only a factor at the end of the series – most of the series is calculated using a weight in excess of 90%). For the latest two observations, the growth rate of the last available data is replicated for countries where data are missing, provided actual data coverage is higher than 80%. This admittedly simple extrapolation procedure has yielded satisfactory results, with employment growth rates tending to show little short-term volatility.

The aggregation is then performed as the sum of the (country quarterly growth rates * annually changing country weights) / total available euro area weight. From these aggregated growth rates an index is created on the basis of the latest year for which national data are available.

Deriving a euro area employment level series

An annual aggregate is calculated using the available country data, selected in the following order of preference:
1) average of the four quarters of non-adjusted quarterly data
2) average of the four quarters of seasonally adjusted quarterly data
3) annual data

The index created above is applied to the latest available annual average figure. Furthermore, as the aggregation is based on the available seasonally adjusted country data for each breakdown, the procedure above leaves some small accounting inconsistencies. To ensure accounting identities, a balancing procedure is used and the inconsistencies are allocated to the respective breakdowns in proportion to the size of the non-balanced data.

Results

Using the above calculations, per-head labour productivity figures are available around 75 days after the reference period, with a breakdown by six main economic activities. Table 9–2 provides an overview of the most recent euro area labour productivity growth figures as published in the ECB's Monthly Bulletin (October 2005).

Overview of the sources and methodology

a) Output component

For the output component, the ECB estimate draws on euro area aggregate QNAs published by Eurostat. National accounts data are compiled according to the accounting definitions and methodology adopted in the ESA95 Regulation[147]. Member States submit quarterly and

[147] Council Regulation (EC) No 2223/96 of 25 June 1996, published in the Official Journal of the European Union (OJ) L 310, 30.11.1996; Regulation (EC) No 1267/2003 of the European Parliament and of the Council of 16 June 2003, OJ L 180 18.7.2003.

T 9 – 2 Euro area labour productivity growth
annual percentage changes; seasonally adjusted data

By economic activity

	Total	Agriculture, hunting, forestry and fishing	Mining, manufacturing and energy	Construction	Trade, repairs, hotels and restaurants, transport and communica-tion	Financial, real estate, renting and business services	Public administration, education, health and other services
2001	0.3	-0.8	1.4	0.3	1.2	-1.4	0.4
2002	0.1	1.6	1.5	-0.2	0.6	-1.2	-0.1
2003	0.5	-2.2	2	0.3	0.1	0	-0.1
2004	1.2	8.6	3.4	0.1	0.8	-0.8	0.8
2004 Q2	1.6	8.9	4.8	0.8	1.1	-0.5	1.2
Q3	1.2	10.5	4	-1.3	0.5	-0.9	0.8
Q4	0.7	8.9	1.7	-0.7	1.3	-1	0.5
2005 Q1	0.6	2.6	2.2	-2.3	2	-0.4	-0.4
Q2	0.4	1.7	2.1	-0.8	1.2	-0.5	-0.7

Source: ECB calculations based on Eurostat data.

annual national accounts data to Eurostat, on which basis it estimates EU and euro area QNA aggregates.

The flash estimate gives figures for EU and euro area quarterly GDP volume growth within 45–48 days after the end of the reference quarter. The first release, which includes value added at constant prices and its A6 activity breakdown, is published 65 days after the end of the reference quarter and is used for the first productivity estimates. As not all euro area countries publish quarterly results with the same timeliness, Eurostat has to use an estimation procedure. Most countries comply or are close to complying with the legal deadline of t+70 days. The methodology is based on a temporal disaggregation technique, which assumes that the relationship valid on an annual level between the euro area total and the total of the countries for which data are available is also valid on a quarterly basis.

The principle for compiling the main QNA aggregates for the EU and the euro area is the same for all releases. The flash estimate and the first release cover approximately 96% of euro area GDP.

It should be noted that the ECB's headline figures refer to the whole economy, i.e. they include the government sector. As the latter represents a non-negligible part of the economy (around 12% of euro area value added), not including it could present a misleading picture. Ideally, the whole economy measure should be broken down into the business and government sectors, but in the absence of quarterly volume (and employment) data by institutional sector this is not possible[148].

148 Furthermore, unlike productivity estimates published for the US economy, euro area GDP (and productivity) figures are not adjusted for the implicit value added component of owner-occupied housing (for which no corresponding labour input measure is recorded in the accounts to reflect house owners' work on maintaining their houses). However, this effect is not likely to matter significantly for short-term analysis.

b) Labour input component

National accounts employment measures are considered the most exhaustive employment measures, as well as best suited for international comparisons. Moreover, their definition is consistent with the output data. Labour productivity is usually calculated in terms of either output per person employed or output per hour worked. The latter measure is considered more appropriate, since the development of output per person employed is also influenced by the number of hours worked. Over an extended period, given the increasing importance of part-time work, the use of output per person employed is likely to lead to a downward bias in euro area productivity growth and level figures. Chart 1 compares quarter-on-quarter labour productivity growth per hour worked and per person employed for Germany. It shows that, over the last three years, labour productivity per hour was on average 0.1 percentage points higher. This suggests that the difference between per-person and per-hour-based measures tends to be small in the short term. Nevertheless, per-hour-based measures are important for longer-term comparisons, as well as for a detailed analysis at industry level when contractual working arrangements are changed.

Germany q-o-q labour productivity growth
(whole economy, % change, s.a.) **G 9–1**

Source: ECB calculations based on Eurostat data.

An additional issue centres on the comparability of international data on hours worked. The harmonisation and revision of such data is foreseen in the forthcoming revisions of the System of National Accounts (SNA), ESA and ILO/ICLS resolutions. Harmonisation is particularly needed in the recording of, among other things, time spent on stand-by, education and training, travelling, home office work, on-call work, rest periods, and absences. Additionally, the need to accommodate labour market changes and to clarify borderline cases related to modern work arrangements (such as home office work and flexible working hours) will need to be examined.

There is a certain difference between the SNA93 definition of employment and that of the ESA95. The SNA seems to give priority to the concept of "jobs" rather than the concept of "persons", while the ESA recommends the use of persons and additionally gives more precise definitions. This has led to a situation where most European countries favour the persons concept, while countries such as the United States and Japan often present data in terms of the number of jobs[149]. This again supports the use of labour input data expressed as hours worked. To date, however, no official data exist for euro area total hours worked[150], although data should have been published by all Member States by end-2004 as a result of an amendment to the ESA Regulation[151].

In addition, an aspect that is not considered in the ECB quarterly estimate is the issue of labour quality. Labour quality is of concern in a more structural analysis of productivity development[152]. The quality of input of one employee differs from that of another, which is not captured in the current productivity data. Factors that will determine this input level include personal characteristics of employees, such as educational attainment and experience in the labour market. Labour quality evolves over time and in response to changing labour market conditions. As a result, the euro area stock of human capital and the associated returns to human capital also change over time, thus contributing to changes in labour productivity. Best practice in the area of productivity measurement suggests that changes in labour quality should be taken into account by using a quality-adjusted number of hours actually worked as a measure of labour input.

Other short-term productivity measures

While national accounts-based data are considered the main productivity indicators for the ECB, supplementary information is also used, particularly if the extra data are available with a higher frequency, better timeliness or more detail. There are two principal sets of these supplementary data: data which can be constructed from the variables collected under the Short-Term Statistics (STS) Regulation[153] and data produced by NTC Research, i.e. the purchasing managers' indices (PMI) on productivity.

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149 "Employment and hours worked data in the national accounts", François Lequiller, OECD - October 2004.

150 An important issue for this data, when it becomes available, will be the ESA requirement of data on hours actually worked. While data on hours remunerated is relatively simple to collect, the amount of unpaid overtime worked is much more difficult to capture.

151 Regulation (EC) No 1267/2003 of the European Parliament and of the Council of 16 June 2003, OJ L 180 18.7.2003.

152 See the box entitled "Developments in euro area labour quality and their implications for labour productivity growth", in the October 2005 issued of the ECB's Monthly Bulletin.

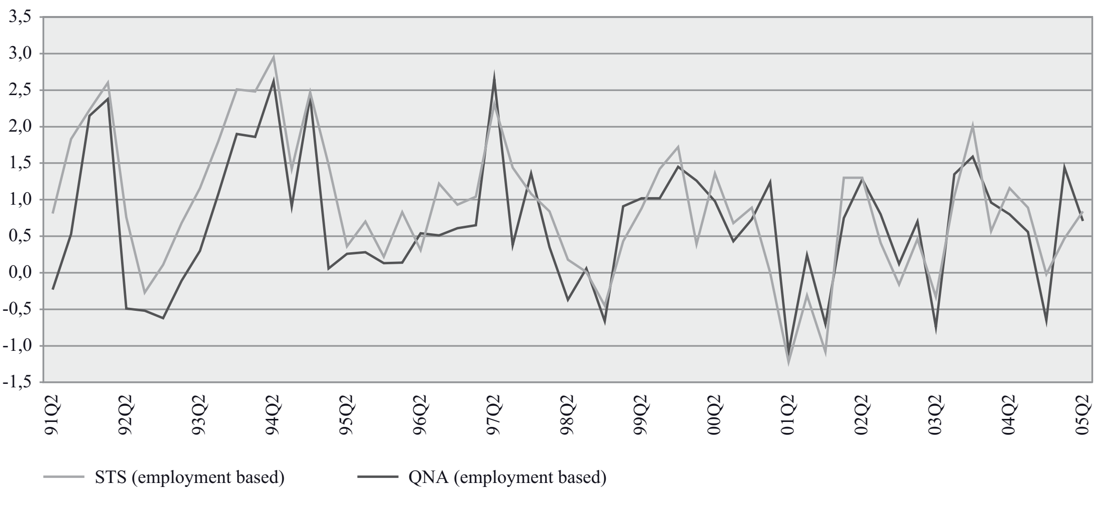
153 Council Regulation (EC) No 1165/98 of 19 May 1998, OJ L 162, 05/06/1998 pp. 0001–0015

a) STS-based results per person employed

STS data represent the timeliest and most detailed set of indicators for output, prices and the labour market for industrial activity. Labour productivity growth can be analysed on the basis of the industrial production index and the index of employment. These data are compiled using the methodology detailed in the STS Regulation, based on business surveys, and are available by Main Industrial Groupings (MIGs) and by NACE divisions. The euro area industrial production index has a monthly frequency and is released at about t+45 days. The index of employment is released at a monthly frequency for Belgium, Germany, Italy, Luxembourg, Austria, and Portugal, while the other euro area countries provide only quarterly information on employment. Consequently, euro area aggregates for employment are currently released only on a quarterly basis by Eurostat, after about t+48 days, i.e. as soon as the coverage of 60% is reached (as for other STS statistics).

Graph 9–2 shows a comparison of seasonally adjusted quarter-on-quarter euro area labour productivity growth in industry based on STS and QNA data[154]. It is clear from the chart that, at least for industry, STS-derived labour productivity data can serve as reasonable approximation of QNA-derived data. The average difference between the two series over the last three years is 0.1 percentage points, while over the last four quarters it is -0.1 percentage points (the average absolute differences are 0.4 percentage points and 0.6 percentage points, respectively).

Euro area q-o-q labour productivity growth QNA vs. STS estimates (s.a.) G 9–2



Source: ECB calculations based on Eurostat data.

[154] For more information on methodological differences, see "Benchmarking of short-term statistics with other sources: what is available and an empirical comparison with quarterly national account" R. Barcellan and E. Mazzucato (Eurostat).

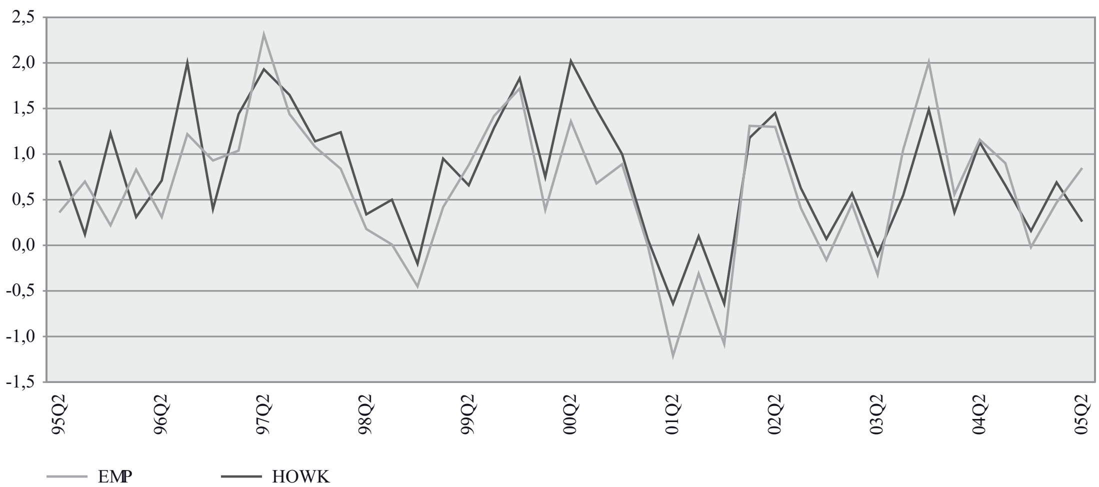
In order for STS data to provide really useful supplementary information on labour productivity, improvements are needed. In particular, the index of employment should ideally become a timely monthly indicator[155], which would also improve country coverage for the euro area aggregate. Furthermore, it should be noted that, while at the euro area aggregate level STS labour productivity data appear to be a good proxy of the corresponding QNA data, the story may be somewhat different at an individual country level. Some countries benchmark STS against national accounts data and consequently show no difference, while other countries benchmark STS against structural business statistics (SBS) or do not benchmark at all.

b) STS-based results per hour worked

In addition to the index of employment, STS data are also available as an index of hours worked. The latter is released by Eurostat for the euro area at quarterly frequency (again, since only Belgium, Germany, Italy, Luxembourg, Austria, and Portugal publish monthly information) after about t+48 days.

Graph 9–3 compares seasonally adjusted quarter-on-quarter euro area labour productivity growth in industry based on STS employment and STS hours-worked data. It is clear that both series describe largely the same evolution. Over the last three years, the average difference was approximately zero, while in the last four quarters it was 0.1 percentage points (the average absolute differences were 0.2 percentage points and 0.3 percentage points, respectively).

Euro area q-o-q Labour productivity growth (s.a.)
STS employment vs STS hours worked based **G 9–3**



Source: ECB calculations based on Eurostat data.

155 The amended STS Regulation (Regulation (EC) No 1158/2005 of 6 July 2005 amending Regulation (EC) No 1165/98) still has a reference period of at least a quarter. The delay in which countries have to deliver STS employment data to Eurostat has been reduced from three to two months (+15 days for Member States whose value added represents less than 3% of the EU total).

c) PMI productivity index

The NTC Research productivity index for the euro area is derived from data collected from panels of companies that participate in the PMI surveys of business conditions across Europe. It is the timeliest indicator for euro area productivity developments.

NTC analyses the output and employment data for each survey respondent to produce a single-figure measure of the rate of change in each company's productivity. The information for each company is then combined using a weighting system based on company size, and an overall "diffusion" index produced for each sector. These indices vary between 0 and 100, with levels of 50.0 signalling no change on the previous month. Readings above 50.0 signal an improvement on the previous month; readings below 50.0 signal deterioration. The greater the divergence from 50.0, the greater the rate of change signalled. The indices are seasonally adjusted. The national data are aggregated together with weights determined by GDP in order to form euro area and European Union indicators.

Data are available at a monthly frequency from January 1998 and are published around 15 days after the month in question. The series cover the manufacturing and service sectors, excluding the public sector. Services are further broken down into separate indices for financial services, business-to-business services, IT and computing, travel and transport, communications, hotels, restaurants and catering, and all consumer services. However, the available details for the manufacturing and services aggregates are not fully consistent with official statistics. For example, "diversified financial services" and the manufacturing of "luxury consumer goods" are not available from official statistics. For the euro area, the total and the split for manufacturing and services are available. Underlying data for manufacturing are collected from eight of the euro area countries (representing around 92% of euro area GDP); for services, five euro area countries are covered (around 80% of euro area GDP).

As graph 9–4 shows, the index has historically shown good leading indicator properties for euro area industrial productivity trends, although changes can sometimes be misleading (perhaps due to the relatively small sample) and therefore need to be interpreted with caution.

Future developments

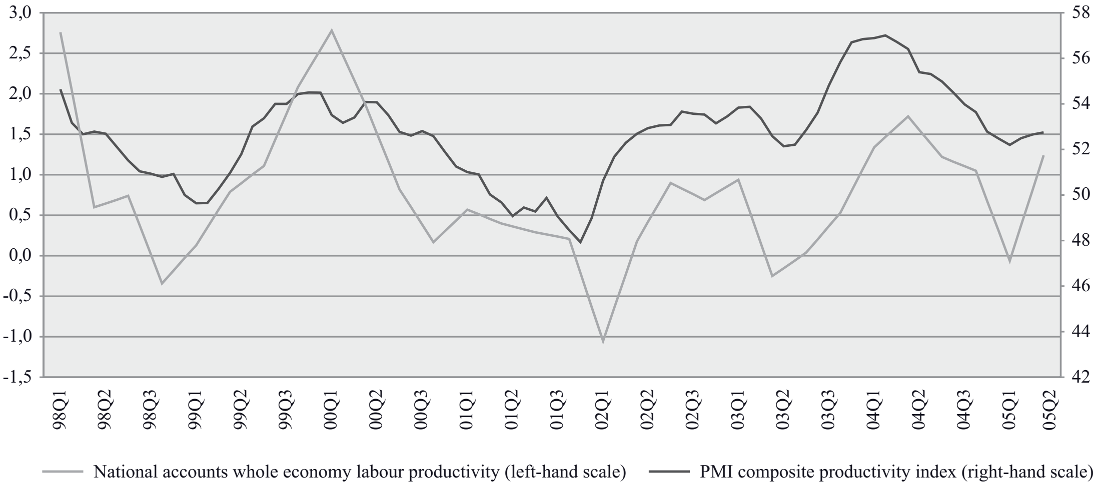
This section highlights the main ongoing and future developments in the source data that the ECB uses to calculate labour productivity. These are likely to allow higher quality estimates to be produced in the future.

National accounts output measures

In the course of 2005 and 2006 euro area and EU Member States' ESA95 national accounts data are undergoing major changes[156] as a result of the introduction of (i) chain-linking of annual and quarterly series at constant prices, (ii) a new treatment of financial services indirectly measured

156 For more information, see the box entitled "Major changes in euro area and Member States' national accounts" in the June 2005 issue of the ECB's Monthly Bulletin.

Euro area PMI composite productivity index and national accounts labour productivity
annual percentage change **G 9–4**



Source: ECB calculations based on Eurostat data.

(FISIM), and (iii) new methods for compiling government output, as well as benchmark revisions. These changes improve both the quality of the national accounts and their international comparability, particularly with the United States, where similar practices have been in place since the late 1990s. They will be introduced in Member States' national accounts on a staggered basis up to the end of 2006. Eurostat plans to begin presenting chain-linked volume measures for the annual and quarterly EU/euro area aggregates with the first regular release for the third quarter of 2005 on 30 November 2005, when it will have sufficient coverage of Member States' annual and quarterly national accounts. With the same release, Eurostat plans to implement the allocation of FISIM in both annual and quarterly European aggregates.

Improved availability of hours worked data

As mentioned in Section 3, a further expected improvement is the availability of a quarterly euro area aggregate of hours worked data. These data are presently only available from three euro area countries (Germany, the Netherlands and Finland); however, a full coverage of the euro area is one of the priorities for improving European statistics. Initial ECB investigations suggest that hours worked data taken from labour force surveys are not reliable proxies, as they tend to overestimate hours worked. The provision of hours worked data in the national accounts – an integrated system of factor input and output – is therefore crucial.

Short-term statistics

Our review of the available sources for short-term euro area labour productivity growth indicators has shown that STS-based euro area labour productivity indicators can complement the corresponding QNA-based indicators, providing valuable supplementary information.

However, there is still considerable room for improvement before these STS-based indicators meet ECB user requirements in full. Above all, both the index of employment and the index of hours worked for the euro area need to become monthly series with an improved timeliness and improved country coverage.

Improved timeliness of quarterly labour productivity data

Both quarterly GDP volume growth and quarterly employment estimates are Principal European Economic Indicators (PEEIs). PEEIs cover a broad range of (non-financial) macroeconomic statistics for which tight production deadlines are set out to reach standards of availability and timeliness comparable to those of the United States. At present, the timeliness standard of 45 days after the reference period has been met for euro area quarterly GDP volume growth. A similar objective for quarterly employment estimates has not yet been reached (the current delay for ECB-calculated data is 75 days). Eurostat plans to publish early employment estimates for the first time in 2006 with a timeliness of around t+72 days (and t+60 by end-2007), which would allow quarterly labour productivity growth estimates to be published within the same period.

Accounting for labour quality

In the longer term, it is hoped that more work will be possible on adjusting the estimates to account for labour quality. An ongoing source for these data in the euro area may be the continuous Labour Force Survey, which was released for the first time for euro area data for the first quarter of 2005. One problem that will need to be overcome is the integration of the data from this source with data from ESA national accounts sources. The ECB considers a regular compilation of annual national accounts including employment by educational level, age group, and gender (and by industry) to be an area for further work.

Conclusions

The ECB currently uses euro area productivity data from three sources. The main source is national accounts, with results per person employed. STS sources are also valuable as they provide more detailed and timely information – which has proven to be a reliable early indicator as regards the direction of productivity changes – but differences between the growth rates derived from these data and those calculated on the basis of national accounts may be sizeable. The most important improvements required by the ECB for euro area productivity estimates concern the availability of hours worked data from national accounts, and better timeliness of national accounts and STS data. Moreover, in the medium and longer term, more statistical information as regards the composition and quality of labour input is desirable in order to support structural analysis of productivity growth and levels.

10. U.S. QUARTERLY PRODUCTIVITY MEASURES
Uses and Methods

By Lucy P. Eldridge, Marilyn E. Manser and Phyllis Flohr Otto
U.S. Bureau of Labor Statistics

Introduction

Since 1967, the Bureau of Labor Statistics (BLS) has regularly published quarterly data on the change in labor productivity. Data on labor productivity and unit labor costs, together with related measures, are published on a very timely basis eight times per year in the form of a "Productivity and Costs" press release.[157] The initial data for a quarter are released shortly after publication of the advance gross domestic product (GDP) data by the Bureau of Economic Analysis (BEA) at the end of the month following the close of the quarter. Revised productivity and costs measures are released the following month after BEA's publication of the "preliminary" GDP data. There is no release in the third month because changes in the data usually are minimal. Historical data are made available on the BLS website and in other formats upon request.

The quarterly press release includes measures for six major U.S. sectors: business, nonfarm business, manufacturing, durable and nondurable goods manufacturing, and nonfinancial corporations. The measures for the broadest sector now published, the business sector, were introduced in 1976.[158] Business sector output excludes from GDP the output of general government, nonprofit institutions, and the household sector (including owner-occupied housing). The method of estimating output for these components of the economy is problematic for productivity measurement, as will be discussed below, and thus measures of productivity for the total economy are considered less reliable. Measures are produced for the total economy, however, and are made available by request. Most attention is given to the nonfarm business sector. Although the farm sector is small in the United States, it is highly volatile.

Multifactor productivity (MFP) data give a more comprehensive picture of productivity change over time, and they provide a decomposition of labor productivity change into sources

[157] The press release includes data on changes in labor productivity, output, hours, compensation per hour, and unit labor costs. See http://www.bls.gov/lpc/home.htm. Although the costs series are important economic measures, we do not discuss them in this paper.

[158] In 1967, BLS began publishing quarterly data on the change in labor productivity for the total economy excluding general government, but this measure was supplanted by the quarterly measures for the business sector. Measures for manufacturing also began in 1967.

of growth. However, due to the complexities associated with constructing MFP, these data are not available on a quarterly basis.[159]

The quarterly labor productivity and costs data are widely watched by the financial community, nonfinancial businesses, government policymakers, researchers, and many others. Two reasons for interest in quarterly productivity data stand out. First, they provide more current information than do the annual data. Second, they provide necessary information for analyzing economic behavior around recessions. A brief overview of trends and cyclical behavior, as well as volatility, of the quarterly labor productivity measures for the nonfarm business sector, the business sector and the total economy is provided in Section II. Section III presents procedures and measurement issues for constructing quarterly productivity and cost statistics for major sectors of the U.S. economy. Although various other industry productivity data are available on an annual basis, many users have requested additional industry productivity detail on a current, quarterly basis.[160] In the final section, we briefly discuss BLS's effort to develop prototype quarterly labor productivity and unit labor costs measures for retail trade and to assess their performance.

Trends and cycles in U.S. labor productivity

Labor productivity growth rates between selected business cycle peaks are presented in Table 10–1 for the total economy, the business and nonfarm business sectors, and total manufacturing. In every period, the nonfarm business and business sectors experienced the same or higher productivity growth than did the whole economy.[161] The speedup in labor productivity growth during the 1990s, which followed the slowdown that began around 1973, has generated widespread attention and analysis. Most focus has been on the nonfarm business sector, which accounts for approximately 77 percent of GDP. A strong productivity speedup is seen for the economy as a whole and for the business sector during the latter part of the 1990s,[162] but they experienced slightly lower productivity growth in the earlier part of the 1990s than in the previous decade.

Because of the conversion of our data from the Standard Industrial Classification system (SIC) to the North American Industry Classification system (NAICS), current figures for

159 Publication of annual multifactor productivity measures lags considerably behind the publication of the labor productivity data. In order to provide MFP information on a more current basis, BLS recently developed and published preliminary measures of MFP building on a method developed by Steve Oliner and Dan Sichel (2000) at the Federal Reserve Board. See the latest news release at www.bls.gov/news.release/pdf/prod3.pdf, and Meyer and Harper (2005).

160 We emphasize the importance of not inferring specific results for the nonmanufacturing sector from the business sector and manufacturing data, both because of differences in output concepts and because of concerns about some aspects of service sector measurement that are less important in broader measures.

161 As will be explained in Section III, the output measures for the excluded sectors have some built-in productivity assumptions.

162 In 2004, business sector output accounted for 77.1 percent of GDP output, and nonfarm business output accounted for 76.1 percent. The share of farm output has declined, primarily early in the period analyzed. In 1948, business sector output accounted for 84.5 percent of GDP, and nonfarm business sector output accounted for 76.3 percent of GDP.

manufacturing are not precisely comparable to data prior to 1987. Nonetheless, these figures are relatively similar for the period where data are available on both an SIC and a NAICS basis, 1987–2002, and a speedup appears for this sector as well.

T 10 – 1 Labor Productivity Growth, 1947–2004

average annual rates of change

	Total Economy	Business	Nonfarm Business	Manufacturing (SIC)	Manufacturing (NAICS)
1948–1973	2.6%	3.0%	2.7%	2.4%[a]	
1973–1979	1.1%	1.3%	1.2%	2.1%	
1979–1990	1.4%	1.6%	1.4%	2.6%	
1990–1995	1.1%	1.5%	1.6%	3.2%	3.4%
1995–2000	2.1%	2.7%	2.5%	4.4%	4.0%
2000–2004	2.8%	3.5%	3.4%		5.0%

[a] change for 1949–73

Source: U.S. Bureau of Labor Statistics

Data released August 9, 2005

Given the interest in productivity, the timeliness of the quarterly data is important both for business analysts and government policy makers. The quarterly data also are invaluable for studying economic behavior around recessions, as well as other changes in economic behavior that can not be observed in annual data.

We stress two things to users, however. The first is that the quarterly data are volatile, so that too much weight should not be placed on the precise movement for just one quarter, and changes for a few quarters should not be taken as an indicator of a change in trends.[163] Second, productivity movements should be analyzed with reference to the business cycle, because there are patterns of productivity change that appear around business cycles that should not be interpreted as a measure of trend.

Various theories have been put forth on how productivity varies just before, during, and shortly after recessions. For instance, the Wesley Mitchell story is that before a recession, productivity declines and this triggers an increase in unit labor costs and cutbacks by the weaker firms. The labor hoarding argument postulates that when demand starts dropping for whatever reasons, firms cut back on output but want to hold on to their workers because of recruitment and training costs, so productivity declines. A third story is a structural one in which deaths of inefficient firms, and births of efficient ones, raise productivity faster during periods of economic stress; see Caballero and Hammour (1994). In the United States, analyses of productivity behavior around recessions focus on the nonfarm business sector. Here, we first examine the change in nonfarm business productivity and hours around recessions, then compare movements in nonfarm business sector output per hour and GDP per hour for these periods.

163 The press release also presents the percent change from the corresponding quarter of the previous year. Analysts often use those data, which tend to be smoother than the quarter-to-quarter changes.

T 10 – 2 Comparison of quarterly movements in labor productivity (LP) and hours (H) around business cycle peaks: nonfarm business sector

average annual rates of change

PEAK	1948 IV		1953 II		1957 III		1960 II		1969 IV		1973 IV		1980 I		1981 III		1990 III		2001 I	
	LP	H	LP	H	LP	H	LP	H	LP	H	LP	H	LP	H	LP	H	LP	H	LP	H
-4	1.4	2.6	-1.8	2.9	4.1	2.2	0.0	-1.2	3.4	3.7	9.1	6.0	-1.1	1.6	4.4	4.9	0.6	0.0	7.1	0.2
-3	-0.3	-0.2	7.5	10.7	4.6	0.4	-0.7	0.1	-3.3	3.7	0.3	4.2	-0.5	3.4	6.1	2.2	3.7	0.9	-0.9	0.0
-2	0.8	2.8	2.9	4.1	-1.4	-0.9	9.1	2.5	0.1	1.9	-3.6	2.7	-0.5	0.8	-5.2	0.1	2.7	-2.1	3.9	-1.7
-1	2.6	-3.7	1.2	0.7	5.9	-1.9	-5.8	0.7	-1.9	-1.2	-2.5	2.0	1.6	-1.0	3.5	-0.1	1.6	-2.7	-0.4	-0.7
PEAK																				
+1	3.5	-6.7	2.1	-4.0	1.4	-8.3	1.0	-2.3	1.2	-1.6	-0.6	-1.7	-4.5	-7.0	-5.1	-1.5	-2.9	-2.0	5.5	-4.3
+2	4.3	-6.7	-1.5	-6.3	-6.2	-9.1	-5.2	-3.7	6.2	-5.3	-1.0	1.0	1.6	-1.8	-2.6	-6.5	0.9	-4.2	1.4	-4.3
+3	9.9	-4.2	0.5	-5.4	7.6	-5.7	4.9	-2.2	6.3	-2.0	-4.2	-1.4			0.8	1.6			6.3	-5.1
+4	-2.9	-1.6	2.8	-3.0					-3.5	-3.1	3.9	-6.6			0.7	-2.8				
+5											3.2	-12.5			3.4	-3.6				
Prior Peak to Peak			3.5	1.9	2.0	0.4	2.3	0.4	2.7	1.8	2.9	1.5	1.3	1.8	1.0	-0.3	1.6	1.9	2.0	1.6
-4 to Peak	1.1	0.4	2.4	4.6	3.3	-0.1	0.6	0.5	-0.4	2.0	0.8	3.7	-0.1	1.2	2.2	1.8	2.2	-1.0	2.4	-0.5
Peak to Trough	3.7	-4.8	0.9	-4.7	0.9	-7.7	0.2	-2.7	2.5	-3.0	0.3	-4.3	-1.5	-4.4	-0.6	-2.6	-1.0	-3.1	4.4	-4.6
Tough +4	7.0	7.3	5.1	3.8	5.0	6.5	6.9	2.0	3.3	1.9	4.2	3.3	2.2	1.8	5.0	5.5	4.4	-1.4	2.8	-0.8
Trough +8	4.7	4.4	2.1	3.4	2.8	3.5	4.6	1.5	4.0	2.7	3.0	2.7			3.0	4.9	3.1	0.4	3.8	-0.4
Trough +14	3.5	3.9	2.2	1.2			4.2	2.2			2.3	3.9			2.9	3.3	1.9	1.8	3.3	0.5

Source: U.S. Bureau of Labor Statistics

Data released August 9, 2005

For each recession, Table 10–2 presents the change in nonfarm business sector labor productivity and hours for each of the four quarters preceding the peak and for each quarter during the period between the peak and trough; notice that these are percent changes from the previous quarter at an annual rate. Table 10–2 also presents annual average movements over the complete cycle (peak to peak) and over the four quarters preceding the peak. Finally, it presents the average annual productivity change over the first 4, 8, and 14 quarters following the trough.

With the exception of the business cycle peak in 1990.III, there are productivity declines for at least one of the four quarters prior to each peak. For most periods prior to 1981, productivity changes tended to be smaller in the four quarters leading up to the peak than the productivity trend over the preceding cycle, but the reverse is true for the last three recessions. One difference in the economy over time has been the increasing size of the service economy. For 7 out of the 10 business cycle peaks, including the last four, we observe labor hours declining immediately preceding the peak quarter.

During recessions, productivity growth has tended to demonstrate some weakness. For all but the most recent recession, there was a decline in nonfarm business sector productivity in at least one quarter between the peak and trough. The three recessions between 1980 and 1990 demonstrated cumulative productivity change from peak to trough that was negative. In contrast, the recession of 2001 has the greatest cumulative positive productivity growth of all past U.S. recessions at 4.4 percent annual average growth. The last recession that demonstrated such strong productivity growth was the recession of 1948, with 3.7 percent annual growth. In addition, the average nonfarm business productivity change was lower between the peak and trough than the average for the preceding cycle for all the recessions except that in 2001. One recent factor is that because of just-in-time production processes and because of the dominance of the service sector where inventories are less important than in the goods sector, there now tend to be lower inventories; this may result in weaker productivity declines around recessions. Nonfarm business sector hours decline from peak to trough in all periods.

Once past the trough, nonfarm business productivity rebounds. In the 14 quarters since the business cycle peak in 2001, labor productivity has grown strongly, not only compared to past complete cycles, but also compared to other recoveries since 1973. The recession of 1991 was the first to be followed by cumulative negative nonfarm business sector hours growth through the second quarter following the trough. The recession of 2001 was the first to show a cumulative decline in nonfarm business sector hours through eight quarters following the trough; following the trough of 2001, these hours declined for 10 quarters before showing positive growth.

Because measures of the economic activity of general government, nonprofits, and the household sector may differ over time from that of the business sector, it is interesting to examine how the productivity story around recessions would differ if we looked instead at GDP per hour. Table 10–3 presents the comparison of nonfarm business and total economy productivity movements around the business sector peaks. Except for the two most recent recessions, the growth in labor productivity for nonfarm business was the same or lower over the 4 quarters prior to the peak than was the growth in labor productivity for the whole

T 10 – 3 Comparison of quarterly movements in labor productivity around business cycle peaks for the nonfarm business sector (NFB) and the total economy (GDP)

average annual rates of change

PEAK	1948 IV		1953 II		1957 III		1960 II		1969 IV		1973 IV		1980 I		1981 III		1990 III		2001 I	
	NFB	GDP	NFB	GDP	NFB	GDP	NFB	GDP	NFB	GDP	NFB	GDP	NFB	GDP	NFB	GDP	NFB	GDP	NFB	GDP
-4	1.4		-1.8	1.0	4.1	6.7	0.0	3.1	3.4	1.3	9.1	5.6	-1.1	0.9	4.4	3.1	0.6	-1.2	7.1	6.1
-3	-0.3	6.2	7.5	5.6	4.6	3.4	-0.7	0.8	-3.3	0.0	0.3	0.8	-0.5	-2.6	6.1	6.7	3.7	4.3	-0.9	0.0
-2	0.8	-2.1	2.9	6.1	-1.4	0.5	9.1	9.3	0.1	1.0	-3.6	-4.5	-0.5	0.0	-5.2	-1.0	2.7	3.1	3.9	3.6
-1	2.6	2.4	1.2	3.5	5.9	2.8	-5.8	-6.0	-1.9	-0.9	-2.5	2.6	1.6	2.6	3.5	6.6	1.6	-0.2	-0.4	-0.4
PEAK																				
+1	3.5	-1.4	2.1	0.2	1.4	3.7	1.0	0.0	1.2	2.4	-0.6	-4.1	-4.5	-3.3	-5.1	-7.1	-2.9	-2.0	5.5	4.1
+2	4.3	1.6	-1.5	-1.5	-6.2	-1.6	-5.2	-1.6	6.2	3.6	-1.0	2.8	1.6	0.5	-2.6	-0.3	0.9	0.9	1.4	0.3
+3	9.9	10.3	0.5	1.4	7.6	4.5	4.9	3.3	6.3	7.0	-4.2	-3.8			0.8	-0.8			6.3	4.6
+4	-2.9	-0.2	2.8	5.3					-3.5	-2.3	3.9	2.2			0.7	1.4				
+5											3.2	4.3			3.4	2.8				
Prior Peak to Peak			3.5	3.6	2.0	2.1	2.3	2.6	2.7	2.5	2.9	2.7	1.3	1.1	1.0	2.1	1.6	1.3	2.0	1.6
-4 to Peak	1.1		2.4	4.0	3.3	3.3	0.6	1.8	-0.4	0.3	0.8	1.1	-0.1	0.2	2.2	3.8	2.2	1.5	2.4	2.3
Peak to Trough	3.7	2.5	0.9	1.3	0.9	2.2	0.2	0.6	2.5	2.6	0.3	0.3	-1.5	-1.4	-0.6	-0.8	-1.0	-0.6	4.4	3.0
Tough +4	7.0	6.5	5.1	4.7	5.0	3.8	6.9	5.1	3.3	3.5	4.2	3.4	2.2	3.8	5.0	3.2	4.4	3.4	2.8	2.1
Trough +8	4.7	4.2	2.1	2.2	2.8	2.8	4.6	4.2	4.0	3.4	3.0	2.4			3.0	2.4	3.1	2.4	3.8	3.1
Trough +14	3.5	3.9	2.2	2.5			4.2	3.8			2.3	1.8			2.9	2.3	1.9	1.5	3.3	2.7

Source: U.S. Bureau of Labor Statistics

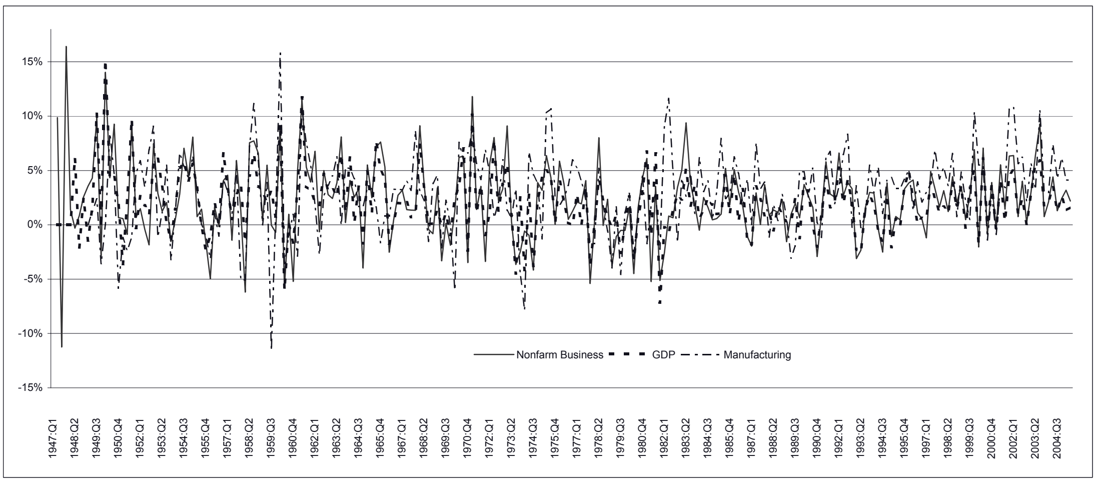
Data released August 9, 2005

economy; this is in contrast to the situation for whole cycles, where the total economy experiences lower productivity growth. For the recession periods from peak to trough, productivity growth for the nonfarm business and total economy sectors are often quite similar. However, in 2001 we observe stronger growth in nonfarm business productivity as compared to total economy productivity. For quarters following the trough, nonfarm output per hour growth usually exceeds the growth in GDP per hour.

Volatility comparisons

Analysts interested in the stability of the economy have studied the volatility of time series data. High-frequency data, such as quarterly series on productivity, although seasonally adjusted, show volatility throughout cycles that can be missed when analyzing only annual data. Graph 10–1 shows quarterly productivity changes from 1947 to the present for the whole economy, nonfarm business, and manufacturing.

Graph 10-1:
U.S. Major Sector Productivity
percent change from previous quarter at an annual rate



Source: U. S. Bureau of Labor Statistics
Data released August 9,2005

One method of precisely measuring the volatility of a series is to look at the variance of the quarter-to-quarter changes in the series over time. For the period 1949–2003, the variances of quarterly productivity fluctuations for the total economy, the nonfarm business sector and the manufacturing sector are quite similar, with the total economy series (0.09) being slightly more stable than the nonfarm business (0.13) and manufacturing (0.14) sectors.[164]

[164] The time period of 1949–2003 was selected in order to have a consistent time period for all 3 sectors. Manufacturing data are available on an SIC basis from 1949–2003.

T10–4 Volatility of quarterly changes in major sector output, hours and productivity

	1949–2003	Pre-1984	Post-1983	Change
Total Economy				
Variance(output)	0.16	0.23	0.05	-0.19
Variance(hours)	0.10	0.13	0.05	-0.08
Variance(labor Productivity)	0.09	0.11	0.04	-0.07
2* Cov(hours, labor productivity)	-0.03	-0.01	-0.05	-0.03
Nonfarm Business Sector				
Variance(output)	0.29	0.41	0.08	-0.33
Variance(hours)	0.13	0.17	0.07	-0.10
Variance(labor Productivity)	0.13	0.16	0.07	-0.10
2* Cov(hours, labor productivity)	0.02	0.06	-0.06	-0.12
Manufacturing				
Variance(output)	0.68	0.98	0.17	-0.82
Variance(hours)	0.46	0.65	0.13	-0.52
Variance(labor Productivity)	0.14	0.17	0.07	-0.11
2* Cov(hours, labor productivity)	0.07	0.14	-0.03	-0.17

Source: U.S. Bureau of Labor Statistics

Data released August 9,2005

Output in the United States has been more stable since the mid-1980s than previously, and there exists a literature that seeks to explain the phenomenon. This body of research postulates several possibilities for the decreased volatility such as: a shift to a service economy which is less volatile than manufacturing; improvement in inventory management that stabilizes the gap between production and sales; a reduction in external economic shocks; and improvements in monetary policy.[165] [166] McConnell and Perez-Quiros (2000) identify a structural break in the volatility of U.S. output growth in the first quarter of 1984.

A recent study by Stiroh contributes to this body of research, examining the declining volatility of output growth from a production perspective. He decomposes output volatility into the influences of hours, labor productivity and the correlation between the two as follows: *Var(output) = Var(hours) + Var(labor productivity) + 2* Cov(hours, labor productivity).*

He finds that, for the nonfarm business sector, the dramatic decline in output volatility after 1983 can be attributed equally to modest declines in the volatility of hours and labor productivity and an increasingly negative correlation between hours and labor productivity.[167] In the manufacturing sector, he finds that the significant stabilization of output is primarily

165 A detailed discussion of this issue can be found in Stock and Watson (2002) and Ramey and Vine (2004). There is no consensus on which of these factors is primarily responsible for the stabilization of output in the past two decades.

166 The variance of a series also will be affected by characteristics of the underlying survey data.

167 This decreased volatility of productivity can be seen in figure 1.

attributed to declining hours volatility with smaller contributions from labor productivity stabilization and the negative correlation between hours and productivity.[168] We have replicated Stiroh's findings for the nonfarm business and manufacturing sectors; see Table 10–4. Using data for the entire economy, we find that GDP per hour and hours for the total economy similarly became less volatile in the post-1983 period, and that the correlation between productivity and hours became more negative. In addition, we see that the total economy demonstrated a smaller decline in output volatility after 1983 as compared to the nonfarm business sector and that the correlation between hours and labor productivity played a smaller role in this decline.

Current procedures and major measurement issues

Output data for GDP, the business and nonfarm business sectors, and nonfinancial corporations, as well as compensation data come from the national income and product accounts constructed by the Bureau of Economic Analysis (BEA). Output data for manufacturing industries come from the Federal Reserve Board of Governors and the Census Bureau. Labor hours are constructed using various BLS data series, as well as other source data.

Business sector output

As we have noted earlier, our featured quarterly productivity measures are for the business and nonfarm business sectors, where productivity can most meaningfully be measured. This is because the portions of the total economy that have been excluded from the business sector are either measured using input costs such as employee compensation or are activities for which our data system has no corresponding hours.

The largest sector to be excluded is general government. Since the "output" of the sector is not sold on the market, it is evaluated in the national accounts as the sum of employee compensation in the sector and the general government consumption of fixed capital (economic depreciation). By far the largest proportion of this is employee compensation[169] and since this is tied closely to the hours worked by government employees, a no-growth productivity assumption is incorporated into the output measure.

The second sector to be excluded from the business sector is private households, which includes the compensation of employees in private households and owner-occupied housing. The first part, compensation of employees of private households, incorporates a no-growth productivity assumption. For the value of owner-occupied housing, on the other hand, there is no measure of the hours that homeowners put into maintaining their own housing.

Nonprofit organizations serving individuals – in the United States, these are primarily hospitals and universities – also are excluded from the definition of the business sector. Here we come closest to defining what we mean by "business" sector which excludes goods and

168 McConnell and Perez-Quiros (2000) and Stiroh evaluated industry effects on stability and both studies find that there is a substantial difference in volatility across industries. Both agree that durable goods manufacturing is a source of aggregate output volatility.

169 Employee compensation in general government accounts for about 85 percent of output.

services with "prices" that may not reflect market pricing because of donated money and time as well as the tax-exempt status of much of the organizational income. Many charities and religious organizations may not even offer a good or service that can be quantified, so national accounts must value them in terms of input costs.

BEA constructs quarterly estimates of nominal and real output for detailed components of GDP from various data sources. Where necessary, BEA adjusts the data for seasonal change. The detailed data then are aggregated to the GDP level using a Fisher-Ideal index. BEA also calculates the measure of business sector output by removing from GDP the gross product of general government, private households (including owner-occupied housing) and nonprofit institutions.

The measurement of business sector hours

For productivity and cost measurement, the ideal measure of undifferentiated labor input is hours at work allocated to the industry in which it is worked. In addition, the production of quarterly labor productivity measures requires high-frequency data that are produced very soon after the end of the reference quarter. The BLS publishes monthly data on employment and hours from two surveys – the Current Establishment Statistics (CES) program and a labor force survey of households, the Current Population Survey (CPS) – that meet these criteria. Both surveys are conducted monthly and the data are released on the same day, usually the first Friday of the following month.

Because the data are monthly, all of the employment and hours data used for the productivity measures have to be adjusted to remove the effects of normal seasonal variation. Without seasonal adjustment, it is hard to distinguish the trend and cyclical movements in the data. Most of the data that we use in productivity measurement are seasonally adjusted by the office that produces them. We produce quarterly series by averaging three months of seasonally adjusted data.

The U.S. establishment survey is not perfect for our needs, however. Historically, only the paid hours of production and nonsupervisory workers in private, nonagricultural industries have been collected.[170] In addition, the establishment survey only covers wage and salary workers and excludes those working in private households.[171] For the business sector measures, therefore, we require a way to adjust paid hours to hours at work; we need hours measures for nonproduction and supervisory workers; we need employment and hours measures for the wage and salary workers in agriculture, forestry, fishing, and hunting and in government enterprises and all workers who are self-employed or working without pay in a family business; and we also need estimates of the number of wage and salary workers in nonprofit organizations serving individuals.

170 The CES survey began collecting all employee payroll and hours data in September 2005. Publication of the first all employee hours and earnings series, on an experimental basis, began in April 2007. Publication of official series is scheduled for early 2010. Once several years of data are available, the Office of Productivity and Technology will begin studying the new series to see if and how they can be used for productivity and cost measurement.

171 Private household employees are excluded from the business sector measures. However, the hours of these employees are included in our unpublished total economy measure.

The U.S. labor force survey, called the Current Population Survey (CPS), was designed as a very current indicator of economic performance and is closely watched by persons studying trends in employment and the unemployment rate. Early each month, usually on the first Friday, BLS reports the employment rate for the preceding month. Because it was designed to cover employment trends for the entire economy, the labor force survey is the only monthly survey collecting data on the employment and hours of the self-employed and unpaid family workers and persons working on farms.

However, because of the emphasis on measuring employment and unemployment, the survey is collected using data for a specific period, the week containing the 12th of the month, a week that contains very few U.S. holidays. Having a reference week that is consistent from month to month facilitates the analysis of employment and unemployment trends. However, seven of the ten Federal holidays are never in the labor force reference week and two more are only included occasionally. Thus, using hours levels from the labor force survey to construct monthly hours levels is expected to lead to monthly estimates that are biased upward.[172]

In addition, more than one out of every twenty workers in the United States holds more than one job, and in the labor force survey all hours worked are allocated to the primary job of the worker. Beginning in 1994, the outgoing rotation group in the CPS, about 15,000 households, now are asked questions about their second job (but not any third or fourth jobs) if they work at more than one activity. Prior to 1994, information about the activities of multiple-jobholders was collected no more than once a year.

Since June, the BLS has been using the limited information on second jobs to more properly count the hours of farm workers and persons working in their own or the family unincorporated business.[173] This method, which looks at hours worked in primary and secondary jobs separately, allows us to allocate the hours to the proper industry. The employment measure used for these workers now corresponds more closely to a job count, similar to the CES.

As mentioned above, the CES collects the hours for which production workers are paid. We prefer hours at work to hours paid as the proper measure for labor productivity. We consider that changes in vacation, holiday, and sick pay accounted for in hours paid are best viewed as changes in labor costs, which should be attributed to differences in average hourly compensation. However, hours at work, even unproductive ones, should be counted toward the labor input available to the employer for production of goods and services.

To calculate hours at work for the production workers and nonsupervisory workers, the BLS productivity office uses supplementary information to adjust paid hours to hours at work. [174] From 1983 through 2000, BLS collected information on the hours worked and hours paid of production and nonsupervisory workers in the Hours at Work Survey (HAWS). These data, collected for broad sectors of the economy, were used to directly convert the CES hours data

172 See Eldridge, Manser, and Otto (2004) for further discussion of CES and CPS hours and some empirical comparisons.

173 See "Productivity and Costs: First quarter 2005, Revised", 2 June 2005 at ftp://ftp.bls.gov/pub/news.release/History/prod2.06022005.news

174 See http://www.bls.gov/lpc/lprhws/lprhwhp.pdf .

to hours at work. However, this survey was discontinued following collection of 2000 data and replaced with information from the BLS Employment Cost Index program on normal work schedules and employer practices concerning vacation, holidays, and paid sick leave.

To cover all employees, data for nonproduction and supervisory workers are added by calculating average weekly hours at work for these workers relative to the average weekly hours at work of production and nonsupervisory workers in the same industry. Furthermore, we account for hours at work in all jobs. These data are from the CPS. We then apply the final average weekly hours per job ratios for all employees to job employment counts of production workers from the CES. Because the data are from the labor force survey and reflect hours at work rather than hours paid, it must be applied to average weekly hours for production and nonsupervisory workers that have already been adjusted to hours at work, as above.[175]

To measure hours for the business sector, we also need a way to estimate the number of employees of nonprofit organizations serving individuals.[176] In the United States, nonprofit status is designated by the Internal Revenue Service (IRS) which determines which organizations exhibit the required charitable, religious, educational, scientific, and other qualities that make them deserving of tax-exempt status.

Although salaries, compensation, and professional fees are included in the data reported by the IRS, employment is not. However, in the quinquennial censuses of many service-producing industry groups, the Census Bureau publishes separate employment counts for establishments subject to income tax and tax-exempt establishments. This employment information is used to establish the relative proportions of nonprofit employment in those industries for which the information is collected. For inter-censal years and other industries, we supplement the employment counts using information on compensation by legal form of organization from the Bureau of Economic Analysis.[177],[178] These relative proportions are applied to the hours data we derive from the CES to calculate hours of nonprofit organizations.

Possible enhancements

Users often ask for quarterly productivity data for additional industry sectors. Quarterly revenue and price data exist for certain sectors outside of manufacturing. Available labor hours data cover the economy. We recently have been exploring possibilities for publishing quarterly productivity measures for an additional sector, namely, retail trade. The primary

175 For information on how the hours of nonproduction and nonsupervisory workers are computed, see http://www.bls.gov/lpc/lprswawhtech.pdf

176 Nonprofit organizations serving businesses are considered to be part of the business sector.

177 Where employment information is not directly available, we have to make the assumption that employees of nonprofit organizations are compensated at the same rate as employees of for-profit establishments. Although we believe that this assumption is weak, it applies only to a small percentage of the nonprofit employment we calculate. In all cases, however, we make the assumption that employees of nonprofit and for-profit organizations work similar hours.

178 BEA breaks out employee compensation by industry group into four types of organizations, for-profit corporations, nonprofit corporations (which also includes private households), proprietorships and partnerships, and other types of business.

issues concern substantial volatility in the measures, how this might be handled, and whether the resulting measures would be informative and valuable for users. Because of the switch from SIC to NAICS, long, consistent time series cannot be developed, which hampers the effort to seasonally adjust or otherwise smooth the data at this time.

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11. LABOUR INPUT PRODUCTIVITY
Comparative Measures and Quality Issues

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Introduction

In the second half of the 1990s, Italy has had a relevant increase of the labour utilisation but the intensity of the growth rates differ in relation to the labour input measure chosen. In particular, the growth rates of the persons employed go faster that those ones of the full-time equivalent units, that represent a proxy of the amount of hours worked. At the same time, data shows that production trend follows the employment time profile only in some years.

Since 2005, the National Statistical Office of Italy (Istat) has began to produce information on hours actually worked that represent a more appropriate measure to quantify the labour participation to the productive process and to analyse labour productivity growth. The time series of hours actually worked seems to approach well the fluctuations of the production values.

The paper presents all the different measures of labour currently produced by Istat. A detailed description of the method for estimating hours actually worked is presented, as a description of the results obtained for the period from 1993 to 2005. The results enable, in particular, to understand the impact of the labour input trend on the productivity, which is firstly calculated without considering differentiated types of hours actually worked.

A new method that takes into account variables that correct the traditional method of estimating labour productivity is presented too; the new approach introduces factors of differentiation of workforce that measure changes in quality over time.

The next section describes all the different measures of labour input produced by Istat. The third section describes the methodology used for estimating hours actually worked. The fourth section presents the new approach to taking into account the adjustment for labour quality and the results obtained. Finally, the last section reports some conclusions and possible future developments of the method proposed.

Labour input measures

Labour input can be measured in terms of total hours worked, number of persons employed and/or number of full-time equivalent unit, a unit of analysis obtained transforming part-time jobs in terms of full-time job. For productivity and GDP growth analysis, it is preferable to measure labour input in terms of hours actually worked.

179 The views expressed are those of the authors and do not necessarily reflect those of the National Statistical Office of Italy (Istat).

Total hours actually worked produced by the National Statistical Office of Italy are consistent with national accounts. Some uncertainty remains regarding the comparability of data with the others European Union countries because the approaches used for annual estimates differ across them.

Total hours worked can be derived by combining estimates of annual hours worked per person employed with the average level of employment or per capita hours worked by each job multiplied for the corresponding number of jobs; according to the Istat approach, jobs represent the basic measure of labour input that is multiplied for per-capita hours data in order to obtain the total amount of hours worked or that is transformed in full-time equivalent unit.

The Italian measures of labour produced by national accountants are currently checked by the European Statistical Office (EUROSTAT) with the aim to ensure consistency within the framework of the System of national accounts (ESA95) and comparability among countries.

Estimates on hours worked

According to the System of national account, the hours actually worked represent the most adapted measure for quantifying the real use of labour in the income production process. In particular, the availability of the information would enable to fully consider brief-period fluctuations of the labour factor due to both economic factors and extra-economic factors. The problems associated to this estimate, nevertheless, are different and relate to the difficulties of integrating in a satisfying way the sources from the enterprises side and those from the household's side. Another difficulty lies in measuring the hours worked by self-employed workers and their relative remuneration.

In accordance with ESA95, the total amount of hours actually worked includes the hours worked, both remunerated and non-remunerated by employees and self-employed, as long as they are oriented to the production of income.

The estimates of the hours worked refer to the jobs according to a domestic concept: in other words, they include all the hours worked in productive units distributed nationally, apart from the residence and nationality of the person carrying out these hours. Moreover, the estimates meet an exhaustive concept of employment that takes into account both the hours worked in a first and multiple job regularly registered as well as those unregistered, that is not declared to the tax office or social security institutions and insurance companies.

The estimates are drawn by Istat for the period 1993–2005 and divided in 30 industries of the NACE-Rev 1.2 classification and by occupation (employee and self-employed); the estimates are regularly produced, together with the other employment measures estimated from the national accounts, that is the number of jobs, persons employed according to the domestic concept and the full-time equivalent units.

Total hours represents the whole amount of the hours worked, remunerated and/or partially remunerated; it includes the working hours performed in addition to the normal working hours and excludes the hours remunerated but not actually worked (such as holidays, sickness, reduction of working hours due to absenteeism, leaves and other), as well as all the hours worked in activities that, according to the national accounts, are not to be considered for the purposes of calculating the GDP (mainly homely work, productive service volunteering, *do-it-yourself* type of activities other than extraordinary house maintenance work).

For estimating the hours worked, the approach adopted consists in multiplying the number of jobs of specific typologies of employment by an annual per capita number of hours worked, the latter being directly taken from the statistical surveys that measure this phenomenon.

Jobs are differentiated per type of work in order to apply homogeneous working hours per capita in relation to the statistical unit of reference (enterprise, institution or household), the industry and the type of employment (registered, unregistered, main and multiple job).

Up until today, the full-time equivalent units have been considered as a *proxy* of the total of hours worked. They are computed by applying to the part-time jobs transformation coefficients obtained from the relation between the hours worked in part-time activities and those worked *full-time* in the same industry.

In reality, the full-time equivalent units slightly diverge from the total of hours worked not only as level but also as regards the trend, since they are mainly determined by the distribution of the jobs among full-time, part-time and multiple job-holders employment. On the other hand, the total of hours actually worked is identified not only from the composition of the above indicated jobs but also from other important components, such as overtime and absenteeism from work. If, for example, leaves due to illnesses or for some other motives grow over time, while the level and composition between part-time and multiple job-holder employment do not change, the total of hours actually worked will be reduced while the full-time equivalent units will remain unchanged.

In order to interpret correctly the diversity that characterises the full-time equivalent units and the total of hours worked, it is thus necessary to take into account the calculation differences associated to the different aggregates.

Sources of information used for the estimates

Information regarding the length of time of weekly and/or annual employment is obtained from the workers themselves through statistical surveys addressed to households or from employers, through surveys addressed to enterprises.

The main sources of information on the hours actually worked available are the following:

- The Labour Force Survey[180]
- The annual surveys on the private enterprises economic accounts
- The monthly survey on enterprises with over 500 employees
- The quadrennial survey on the labour cost conducted on a sample of enterprises with 10 employees and over

180 The Labour Force Survey has been completely reviewed since 2004. The new survey is a continuous-type survey and the reference weeks are uniformly distributed over the whole year. The data on the hours worked used for estimating the total of hours actually worked are those from the continuous survey estimated backward till the IV quarter of 1992.

It is important to highlight that one of the reason of differentiation between the enterprise surveys and the households surveys is that the first ones analyse the value per capita of the hours actually worked per job and the second ones study per capita of the hours worked by an employed person in the main job activity and distinctly in the second one.

Another difference is that the enterprise surveys gather information directly from the employers who, theoretically, provide more precise data than those declared by the households. Generally, though, the enterprise surveys do not register the hours worked by the self-employed workers, they do not cover all economic activity sectors (such as, for example, the agricultural sector, the general government sector and all non-market productive activities) and do not survey the employment of who is unrecorded for the tax-contribution institutions.

Another element to be taken into account when analysing the total of hours worked is that the respondent enterprises could show a certain tendency at declaring more frequently the per capita of hours remunerated rather than that of hours actually worked, even if adequately defined.

The household surveys provide complete information on the hours actually worked, both remunerated and non-remunerated, and on the working hours used unregistered in tax-contribution institutions; moreover, these surveys enable to obtain more detailed information divided per important demographic variables such as gender, age and study degree, all relevant for the purposes of the socio-economic analyses and international comparisons. The coverage of the survey interests the entire economy but, as regards the persons employed deriving from the enterprise surveys, it does not cover the workers present in the country but without residence who work in resident productive units, as they are not part of the survey sample selected from the population registers.

The data on the hours provided by respondents often result affected by non-systematic response errors. Moreover, the statistical practice pointed out that the information on the hours actually worked tends at approaching that on the usual hours; this is the case of the responses given by persons who are not remunerated per hour worked and who can take into consideration in the response given to the interviewer the overtime worked.

When estimating the total of hours produced by the national accounts, enterprises surveys provided information on the per capita of hours actually worked by employees for different *market industries* (divisions C-K and M,N,O of the Nace Rev.1.2 classification) and by size of enterprises; the labour force survey provided data for a detailed level of industries (4 digit of the Nace Rev. 1.1 classification) for employees and self-employed.

The total of hours worked has been obtained by applying the per capita of hours actually worked surveyed to the universe of jobs, distinguished into the different types of employment, and estimated coherently with the national accounts.

The estimate of the hours actually worked in the service sectors used also the information available on the per capita of hours actually worked deriving from the following informative sources:

- The General Accounts Department, which enabled to survey the direct and indirect data on the hours worked in the General Government sector (as defined in the national accounts framework);

- The ABI (Italian Bank Association), which provided specific data on the workable hours in the finance industry.

The estimation procedure of the total of hours worked

The estimation on the total of hours worked was carried out using the so-called *account approach*: data on the per capita of hours worked deriving from the surveys and adequately detailed have been applied to the different types of jobs estimated from the national accounts.

Working on a long time period has entailed the need of harmonising the data of a same survey over time, taking into account the changes that have regarded the statistical units of reference, the survey techniques and the industry coverage.

For the purposes of estimating the annual hours worked by employees, it was possible to use all information on the per capita of hours worked deriving from the above-indicated enterprise surveys and available from 1992. In particular, the annual surveys on the enterprise' economic accounts include, since 1998, all companies with 100 employees and over as well as a sample of companies with a lower number of employees. For the year 2000, it has been possible to make use of the detailed data on the number of hours worked obtained from the quadrennial survey on the labour cost structure addressed to companies with 10 employees and over.

The analysis of the enterprises data pointed out to a tendency (which is even more accentuated as regards smaller enterprises) at providing data on the hours remunerated rather than that relatively to the hours actually worked. Thus, a statistical method has been applied which, based on the number of hours worked and on the remunerated hours, both surveyed by means of the quadrennial labour cost survey, has enabled to reduce the distortion due to this over-estimation.

The data on the per capita of hours actually worked in the industries that are not covered by the enterprise surveys, those relative to the multiple jobs and the per capita of self-employed workers are directly surveyed by means of the labour force survey on a continue base. Starting from the first quarter of 2004, the above survey is conducted each week of the year even if the results are reliable at a quarter level.[181]

The *approach per component* method has been only used to calculate the annual per capita of hours worked in the General Government and in the finance industries, and consists in estimating the components that imply a variation of the working time compared to a *norm* considered equal to the working hours established by national agreements. In this case too, the total of hours worked has been obtained multiplying the per capita estimated for the whole of the registered jobs of employees estimated from the national accounts in the competent industries.

181 Before of the above date, the survey was done every three month four weeks a year during which there were no holidays, in the months of January, April, July and October. It caused two main problems in terms of hours worked analysis: 1) the possible distortion of the seasonal profile considering the fact that the reference week of the interview was distant from the usual holiday periods; 2) the consequent possible annual over-estimation of the hours actually worked.

International comparability of the estimates

The use of statistics on labour input is being promoted on an international level in order to improve the comparability of the estimates as regards labour productivity. The definition of labour productivity that is generally accepted is that of Gross Domestic Product per hour worked, even though it is being acknowledged that this measure might not be able to gather the differences of productivity among the various countries because influenced by different factors, such as the composition of labour force (high or low specialisation).

Numerous problems need yet to be overcome in order to reach the above objective. A factor that affects the quality of international comparisons relatively to the hours worked is represented, as mentioned in previous paragraphs, by the reference measure of the hour per capita indicator that, in some countries, is the person employed and in other countries, such as in Italy, the job.

Another important aspect is linked to the different concepts and definitions used in the statistical surveys, as well as to the sources of information available and to the different coverage degree of the surveys.

International comparisons make necessary to identify an indicator that takes into account some other factors, such as the different weight of the active population and the participation degree of the labour force in order to provide a more accurate framework of the working hours and their effects on the entire economy.

Even in front of evident problems of comparability, the OECD (Organisation for Economic Co-operation and Development) publishes some annual estimates on the hours actually worked on a per capita level for 29 countries. The national institutes of statistics provide these estimates; nevertheless, only for some of them, the results are coherent with the concepts and the coverage degree of the national accounts. To produce these estimates, some countries use the hours actually worked drawn from the enterprises surveys, which generally regard only employees, while other countries use the data from the labour force survey that enables to measure the working hours of self-employed workers.

The series that the OECD has made available up until now represent only the first step towards the harmonization and a greater international comparability of the estimates. The problems linked to the study and the adjusting of the international definitions on the hours worked, as well as the improvement of the quality of information have been object of discussion since a few years within the *Paris Group*, a workgroup that brings together the different national institutes of statistics as well as some important international institutions such as OECD and ILO (International Organisation of Labour). The objectives the Paris Group has set, include to promote the development of statistical information regarding the hours worked, recognizing their importance for estimating the total of hours to be put in relation to the national accounts economical aggregates, for estimating correctly the productivity of the labour factor and for measuring the impact of the social policies, such as that of reducing the working hours.

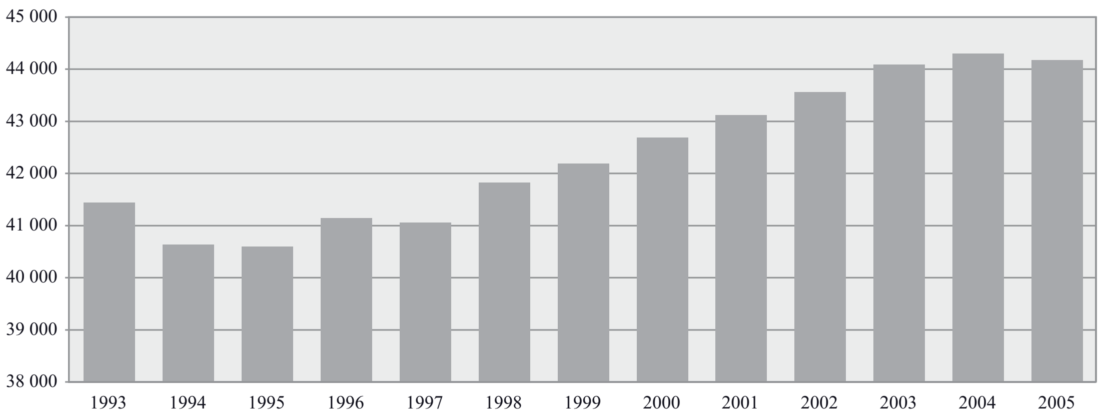
Istat has already started since a few years an intense work of developing information on the hours worked and is, on an international level, involved in the activities promoted by the Paris Group and by some other important institutions (EUROSTAT and OECD); nationally, it aims at promoting mainly the development of concepts, definitions, verification and correction procedures of the information gathered during the various statistical surveys.

The estimates produced by the national accounts will thus evolve in relation to the development of the study and promotion activities of statistical information on the hours worked started by the Institute and which involve various statistical contexts (surveys on enterprises, agricultural farms, households and administrative sources).

The analysis of the results obtained

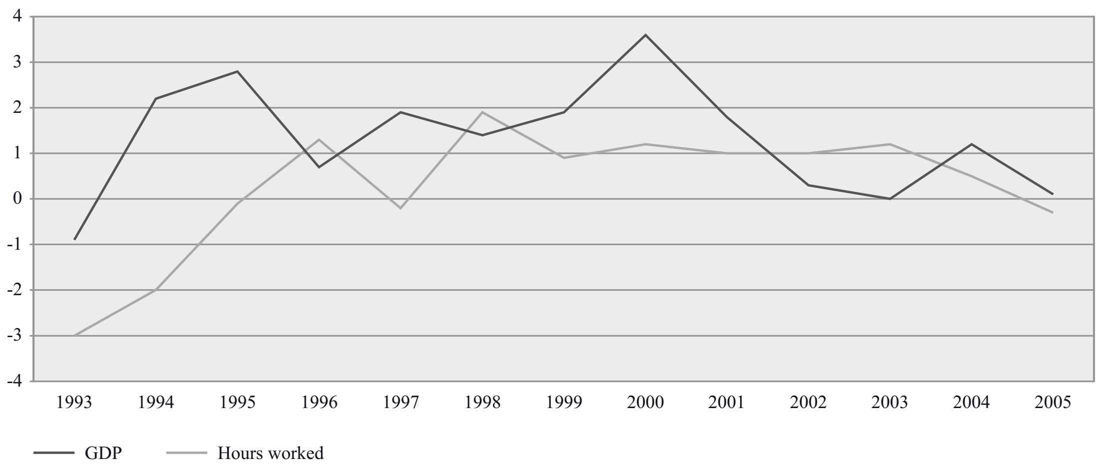
In this paragraph, we present data on hours worked in the period 1993–2005 that are analysed taking into consideration three different periods (Graph 11–1). The first period (from 1993 to 1995) is characterised by a decrease of the hours worked; in this period, the employment registered an unprecedented drop compared to the trend of the previous decade. The second period (the two-year period from 1996 to 1997) saw the expansion and subsequent reduction of the hours worked, together with a slow recovery of the employment. Finally, in the third period (from 1998 to 2005) the hours worked grew at a more sustained rhythm, encouraged by the important increase of employment, just interrupted at the end of the period (in 2005).

Hours actually worked between 1993 and 2005
(absolute data in millions) **G 11–1**



The availability of the data on the hours worked, together with the GDP estimations (seasonally and calendar adjusted, chain-linked volumes 2000=100), enables to analyse better the contribution of the labour factor in the growth of the output (Graph 11–2). In this case, two distinct phases can be distinguished: one that goes from 1993 to 2001 and the other that goes from 2002 to 2005. The first phase registered a growth of the product almost always superior to that of the hours worked necessary for realising it (except for years 1996 and 1998); the second phase, though, saw a change in the relation between hours worked and product with the approaching of the two series at the end of the period (years 2004 and 2005) to such an extent that the trend of the total of hours worked appeared to reflect the trend of the GDP due to its intensity and signal with the exception of the 2003 result.

Total hours worked and GDP between 1993 and 2005
(changes rates in percentage) **G 11–2**



In 1993, the total of hours worked amounted to about 41,446 millions of hours, while the subsequent years registered a drop following the reduction of jobs; a recovery of the work intensity was registered as from 1998, when the hours worked exceeded, even though to a modest extent, the levels registered at the beginning of the period. In 1998, the hours worked amounted to about 41,828 millions. Since that year, they have registered a quite regular positive trend, even reaching 44,172 millions of hours in 2005.

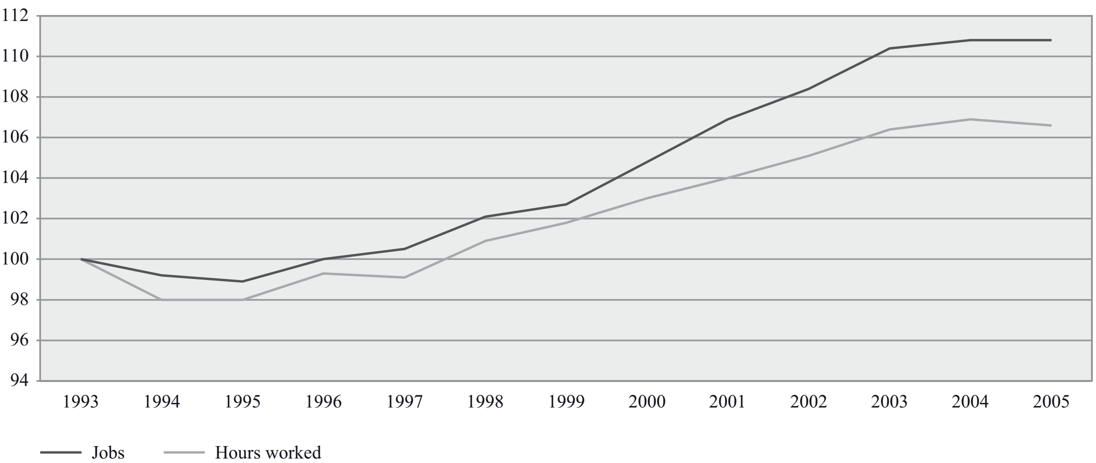
The whole period, object of observation, enables to study the different growth rhythm of the full-time equivalent units (obtained by transforming the jobs at reduced time and multiple jobs in full-time jobs) compared to the trend of the total of hours worked (Table 11–1). The comparison between the two employment measures points out to the differences in the intensity of growth rather than to a contraposition in the increase rates; nevertheless, the two measures differ as the full-time equivalent units do not take into account the overtime and absenteeism and do not reflect, as closely as does the total of hours worked, the trend of the jobs and that of the per capita of hours used for the purpose of the estimation.

T 11–1 Growth rates of persons employed, full-time equivalent units, jobs and hours worked (% values)

Years	Persons employed	full-time equiva-lent units	Jobs	Hours worked
1993	-2.7	-3.2	-2.7	-3.0
1994	-1.6	-1.1	-0.8	-2.0
1995	-0.2	-0.0	-0.2	-0.1
1996	0.6	0.3	1.1	1.3
1997	0.3	0.4	0.5	-0.2
1998	1.0	0.9	1.6	1.9
1999	1.1	0.5	0.6	0.9
2000	1.9	1.8	2.1	1.2
2001	2.0	1.8	2.1	1.0
2002	1.7	1.3	1.4	1.0
2003	1.5	0.6	1.8	1.2
2004	0.4	0.4	0.4	0.5
2005	0.3	-0.2	-0.0	-0.3

All through the reference period, the trend of the hours worked was influenced by both the trend of the jobs and by the changes in the average annual working hours; the years following 1993, the base year=100, registered a drop of the hours worked and jobs up until 1996, a subsequent increase of both employment measures (characterised by a higher dynamism of the hours worked between 1997 and 2003) and, finally, an interruption of this tendency only in 2005 when the stability of the jobs corresponded to a modest decrease of the hours (Graph 11–3).

Total hours worked and jobs
Index numbers 1993=100 **G 11–3**



In the period 1993–2005, different trends of the hours worked have been registered at an industry level. Data shows a reduction of the hours worked in agriculture and industry sectors, accompanied by a strong increase of the hours worked in the service sector.

In 2005, the service industry accounts for 67,2% of the total of hours worked, the industry sector 27,2% and agriculture 5,6%; in terms of jobs, these sectors employed around 69%, 24,7% and 6,4% respectively.

These results enable us to see how the productive system (especially in the sector of services) has been using more flexible work contracts and diversified working hours regimes, even as regards full-time workers. Ever since the nineties, companies and public institutions seem not to search anymore, as in the past, regularisation forms of working hours but, on the contrary, tend to accept the changes in the weekly working hours regimes that are reflected in the total estimation of the total of hours worked.

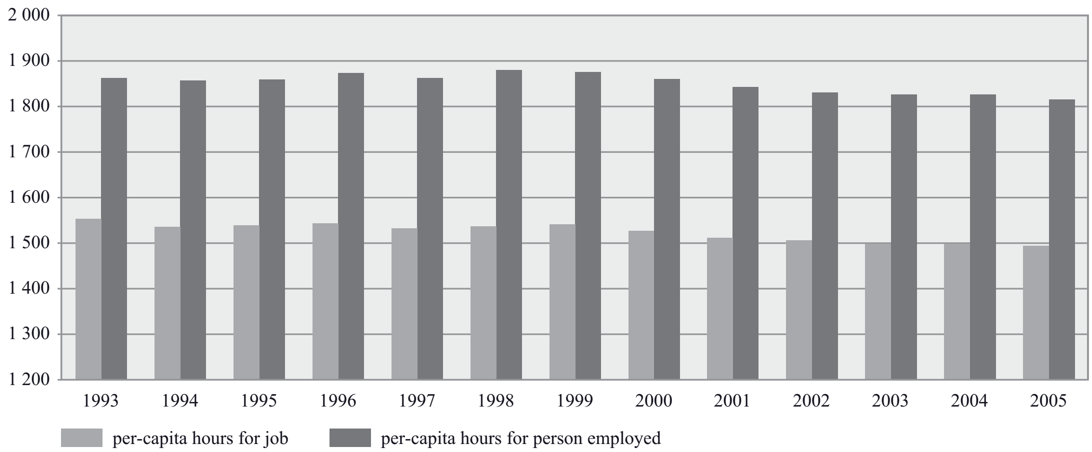
As told before, the total of hours worked is obtained by multiplying the average annual number of hours worked in a job (per capita) per the total of corresponding jobs. This means that the average annual working hours used for the purposes of the estimation do not refer to the number of physical persons employed but to the total of the jobs that each employed person can carry out, even in different industries and different status in employment (for example, a first job as employee and a second job as self-employed).

From the national accounting point of view, to calculate the average per capita number of hours worked per job is considered as more correct than to measure the working hours of each person employed. The latter indicator, unlike the previous one, is significant only if measured for the entire economy; it provides no information at an industry level as there is no certainty as to whether the employed persons surveyed in the same sector are the only ones who have contributed in the total of hours worked, estimated in a given industry or in a specific job position.

As highlighted in Graph 11–4, the average annual per capita of hours worked calculated per employed person appears definitively superior to that estimated per job. In 2005, each employed person worked on average 1,815 hours while the hours corresponding to each job was of 1,495 hours. In 1993, the per capita numbers were of 1,863 hours and 1,554 hours respectively. The results obtained are influenced by the effect of multiple jobs that in 2005 weight for 7,4% on the total amount of hours actually worked (the 5,7% in 1993).

The integrated approach used for the purposes of estimating the labour input of the national accounts enables to measure the volume of labour in terms of jobs and, consequently, to use better the sources available on the hours worked, in some case, in terms of hours worked per employed person distinguished between first and second job (the surveys addressed to households) and, in other cases, in terms of hours worked per job (surveys addressed to enterprises).

Annual per capita of hours actually worked calculated per employed person and per job G 11–4



Labour quality

The methodology here applied to measure quality-adjusted labour input is the one proposed by the OECD productivity manual.[182] Data are referred to hours worked by individuals and their hourly income. Hours worked have been disaggregated according to their different

182 OECD (2001).

characteristics in order to account for quality; in this way, indeed, is possible to consider substitution between the different inputs for identifying properly productivity growth.

The data analysed permits to cross-classify individuals by gender, age and types of educational attainment.

Several are the approaches proposed by the literature and the practical experience to explicit differentiation of labour input. Differences are related to the measurement used for taking into account individuals skills.

Starting from the application of existing methodologies,[183] we have measured labour services in terms of the growth rate of hours worked by each individual labour category weighted with its compensation share in total labour compensation.

We have considered three characteristics (gender, age, education) to cross-classify labour input for the whole economy. Because the different characteristics are correlated, the corresponding labour compensation measure reflects both the direct contributions of these characteristics to output growth as interaction effects between them. In our approach the interaction effects are reduced because no differentiation by industry is considered and this because of the lack of data.

According to the method applied and the neo-classic theory, each labour category is weighted by its compensation share: labour is compensated at marginal productivity. The above considerations produce that women and young workers would be less compensated than men or older workers on productivity account.

The approach permits to produce and analyse three different results: 1) the time profile of the simple sum of hours worked, that is the quantity of labour input; 2) the time profile of the quality-adjusted measure of hours worked, that is the quality of labour input; 3) the time profile of the differential effect between the total and the quality of labour input.[184]

In conclusion, an increase in the average quality of labour implies that the quality-adjusted measure of hours worked rises faster than the unadjusted measure of labour input.

Sources of data and methodological approach

The National Statistical Office of Italy doesn't currently produce detailed data on employment (hours worked and labour compensation per different types of employment) by the same sources of data. In order to reach the goal of measuring labour quality, we have used more that one sources of data.

Data on total hours worked detailed by gender, age and education have been provided by the Labour Force Survey, a quarterly survey on a continue base; then, shares of each types of labour on the total amount of hours worked surveyed have been estimates. The above shares have been applied to the national accounts figures on the total hours worked in order to detail the exhaustive level of hours worked (coherent with the GDP level) for a quite good level of employment characteristics.

183 Jorgenson (1987).

184 Fosgerau and others (2000).

Istat compiles a wide range of annual and infra-annual statistics using different sources in the area of wages, earnings, compensation and labour cost. Each of the above statistics represents a part of the phenomenon because based on different definitions and different aims of representing it. In particular, hourly labour compensation by type is available from the Istat survey on Structure of Earning that provides information every four years but, at the moment, it is possible to use only 2002 data.

Data on hourly wage compensation by types of labour have been produced using micro data of the Bank of Italy's Survey of Households' income and wealth in the period 1992–2004. The survey is compiled every two years; values for missing years have been here obtained by interpolation.

In this approach, we take into account only labour compensation of employees. The treatment of income generated by self-employed persons has been not faced. We have assumed that the average compensation per hour of a self-employed person of each type equals that of an employee of the same type.

In the final database of hours actually worked and hourly compensation the information are separated by two gender groups (men, women), four age classes (<25 years old, 25–34, 35–54, >54) and four level of education (elementary school or none, low secondary school, high secondary school and university degree). We have obtained 32 characteristics (2*4*4 cells). No breakdown by industry has been considered because the number of cases in each cell weren't significant.

The value attributed to hours worked is represented by the average compensation per hour; this corresponds to the wage rate from a producer's point of view and it includes all supplements to wages and salaries. We take into account only labour compensation of employees assuming that the average compensation per hour of a self-employed person of each type equals that of an employee of the same type.

The labour index proposed in the paper is a weighted average of the growth rate of hours worked according to the above labour characteristics. In particular, three first-order indexes have been computed for each characteristic of the workforce (gender, age and education) combining hours worked with the corresponding compensation; then other three second-order indexes have been obtained through the interaction of each characteristic with the others. The last order represents the total labour services adding the weighted growth rates of each characteristic.

The ratio of labour services obtained using different orders can measure the labour input quality. The labour index in this way is represented by a quantity factor, the volume of hours worked, and a quality factor with the aim of measuring the substitution between the above two factors. The quality index increases when components generating the most labour services grow faster than the other characteristics, or decreases if the least efficient hours worked grow faster than the others.

In order to reach the goal, the growth rate of labour input (indicated in Equation 1) is measured on the base of the following formulation (*Tornqvist index*).[185]

185 The Tornqvist index is based on the logarithmic differences of the growth rates weighted with the influence of each input cost on the total cost.

$$\ln\left(\frac{L_t}{L_{t-1}}\right) = \sum_{i=1}^{n} \frac{1}{2}(v_t^i + v_{t-1}^i)\ln\left(\frac{H_t^i}{H_{t-1}^i}\right) \qquad (1)$$

where H_t^i represents hours worked by each type of employment considered (i = 1,…,n)

and where v_t^i is the rate of remuneration associated to it compared to the whole labour cost formulated as:

$$v_t^i = \frac{(w_t^i H_t^i)}{\sum_{i=1}^{n} w_t^i H_t^i} \qquad (2)$$

where w^i is the price of labour input of type *i*. The above equation expresses the *volume of labour input* as a translog index of the individual components.

To quantify the impact of labour services among different types of labour input, we have adopted the methodology proposed by Jorgenson to assume that labour input for each category L_i is proportional to hours worked H_i. In particular, a measure of the contribution of substitution between components of the labour input respect to the volume of hours worked can be expressed as follows:

$L_i = Q_i * H_i$

where L_i represent labour services in cell i, Q_i represent constants of proportionality of labour input and H_i the non-weighted hours worked. The contribution of substitution among the components of labour input to the volume obtained from a given number of hours is expressed by the following equation:

$$Qi = \frac{Li}{Hi}$$

where the unweighted sum of hours actually worked is the following:

$H = \Sigma H_i$

The quality of labour can be also expressed as follows:

$$\Delta \ln Q = \Sigma \bar{v} \Delta \ln H - \Delta \ln H \qquad (3)$$

In this way, the ratio of labour services measured on the different orders respect to the growth rate of unweighted hours worked measures the *labour quality index* and it represents the labour-augmentation factor calculated as residual between a constant quality labour input index and an index of the quality of hours worked as a measure of changes in the components of labour input.

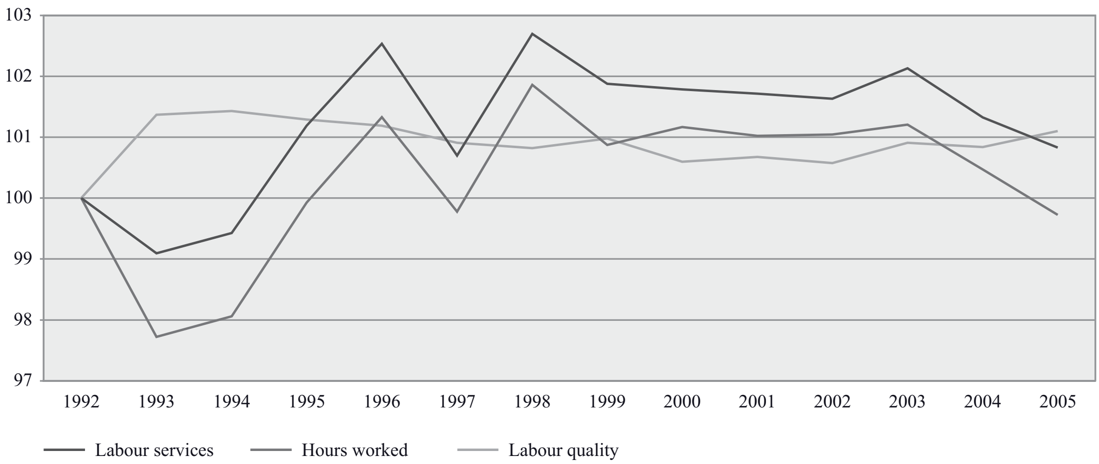
Final results will be shown on labour productivity adjusted and non-adjusted for quality for the period 1992–2005. In the two cases, the measure of labour input is represented by hours actually worked.

Quality adjusted labour input results

The approach here proposed is based on the methodology described by Ho and Jorgenson (1999) and applied by Melka and Nyman for France.[186] It outlines the compositional change in the use of labour and the contributions of various factors (gender, age and education) to labour quality over the period 1992–2005. Hours worked have been disaggregated according to this three different characteristics in order to account the labour quality and to provide a measure of labour services. Labour services are obtained by aggregation of the growth rate of hours worked, classified by gender, education and age, with weights determined by the compensation share of each type of labour; labour quality is indicated by the difference between labour services and the growth rate of hours worked. Moreover, the decomposition of overall quality index to the contributions of its determinants provides some insight on the factors explaining changes in labour quality growth.

The overall contribution of the three factors to labour quality growth has been calculated and the results are shown in Graph 11–5.

Labour services, hours worked and labour quality
(1992=100) **G 11–5**



According to the exercise proposed, hours worked register a positive trend in all the period and labour services follows the positive time profile of hours worked; labour quality shows a quite steady time profile.

[186] See "Growth accounting and labour quality in France, 1982–2001" in Growth, Capital and New Technologies by Matilde Mas and Paul Schreyer, Fundation BBVA, 2005.

The above results can be well understood analysing the decomposition of the quality index to the contributions of its determinants. The first order indexes indicate the contributions of each factor to labour quality growth and Table 11–2 presents the results obtained.

T 11–2 Contribution to Italian labour quality (% values)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Quality	**1.37**	**1.41**	**1.27**	**1.18**	**0.90**	**0.81**	**0.97**	**0.59**	**0.67**	**0.57**	**0.90**	**0.83**	**1.09**
Gender	-0.02	-0.02	-0.02	-0.04	-0.01	-0.02	-0.03	-0.05	-0.05	-0.01	-0.03	-0.03	-0.00
Education	0.87	0.87	0.86	0.77	0.72	0.77	0.80	0.55	0.50	0.38	0.76	0.70	0.57
Age	0.28	0.29	0.23	0.25	0.22	0.12	0.27	0.24	0.29	0.18	0.17	0.16	0.40
Sum of interactions	0.24	0.26	0.21	0.20	-0.03	-0.05	-0.07	-0.15	-0.07	0.02	0.00	-0.00	0.12
Non-weighted hours	**-2.28**	**-1.99**	**-0.08**	**1.33**	**-0.22**	**1.87**	**0.86**	**1.16**	**1.01**	**1.04**	**1.19**	**0.47**	**-0.27**
Weighted hours (labour services)	**-0.90**	**-0.58**	**1.20**	**2.51**	**0.68**	**2.68**	**1.83**	**1.75**	**1.69**	**1.61**	**2.10**	**1.30**	**0.82**

Note: quality is the difference between weighted hours and non weighted hours.

The contribution of education is relevant as that one of age; both plays an important role in labour quality increase.

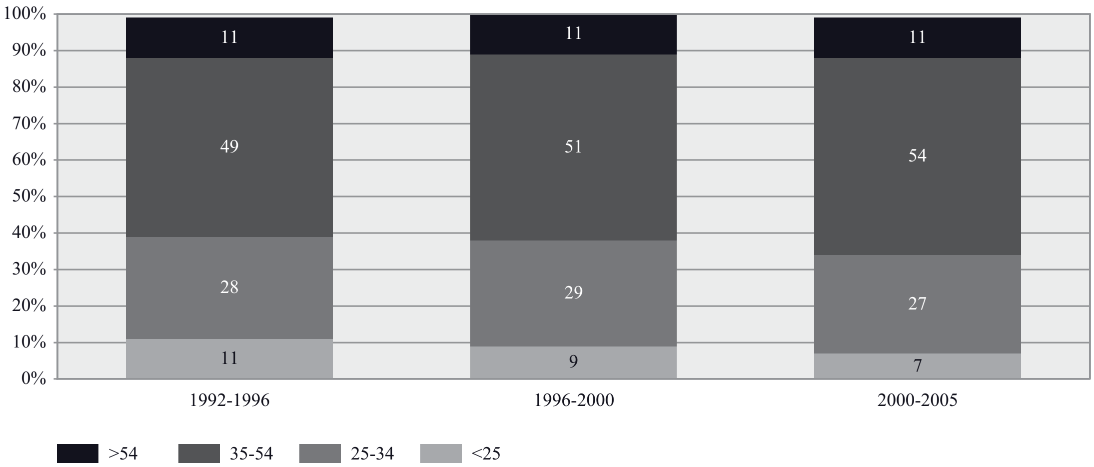
Contribution of education follows a different trend all over the period: it decreases till 2002, growing up again till 2005. The decrease has been determined by the spreading of atypical works (part-time workers, persons employed by temporary employment agencies and temporary workers) that encourages the participation to labour market of unskilled workers.

The age contribution to labour quality is still significant. The age is a proxy for labour market experience but this factor is strongly related to demographic developments. According to our results, the contribution to quality given by the age is almost steady until 2001 then it decreases in the years 2002–2004 and increases again in 2005.

The above trends can be explained by different factors. Working population over the last 30 years is characterized by the movement of so called baby–boom cohort (those born in the 1950s and 1960s) and this trend is confirmed in the Euro area.[187] In particular, the upper age (35–54 year) has a relevant role in terms of hours worked (Graph 11–6) and, at the same time, their hourly wages increase. An increase in hours of more experienced workers has contributed to an increase in labour quality that is more relevant in the years 1993–2001 than in following years.

[187] See G. Schwerdt and J. Turunen "Growth in euro area labour quality" , Working paper series n.575-January 2006, European Central Bank.

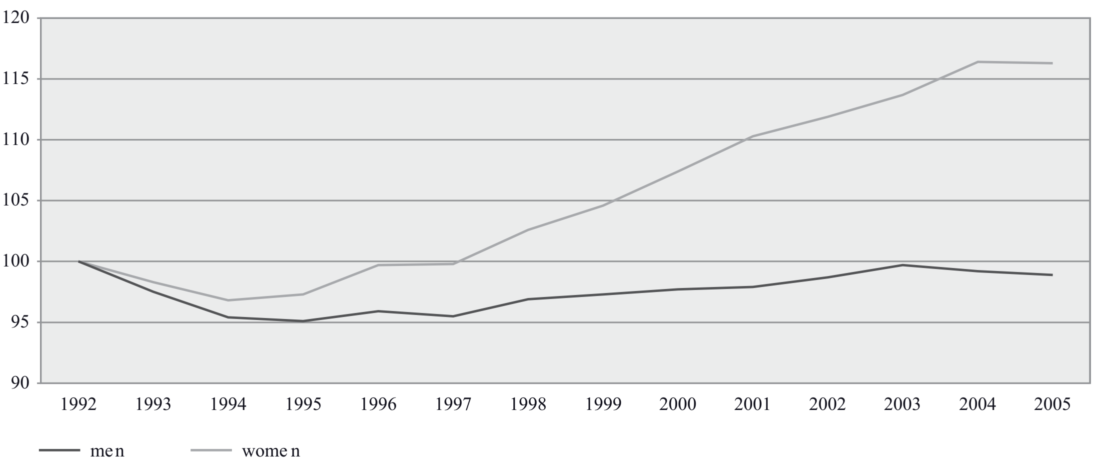
Composition of hours worked by age bracket (%) **G 11–6**



The relevant growth of the age contribution in 2005 is due to upward trend of the 35–54 age bracket's hours while labour below age 25 goes down. This could reflect the impact on the Labour Force Survey of the foreign resident population afterwards the amnesty on illegal foreigner worker in 2002.

Graph 11–7 shows the growth rates of hours worked by gender. The hours worked by women have increased more than those of men and the higher contribution has been reached by skilled women.

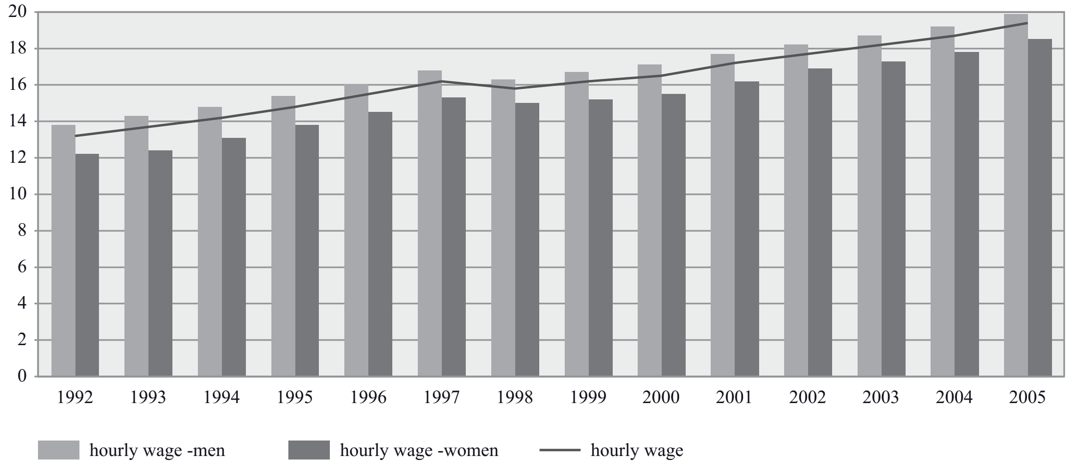
Growth rates of hours worked by gender
(1992=100) **G 11–7**



In the same period, the differential between hourly wage of men and women has decreased (see Graph 11–8) but not in a relevant way: men are still better paid than woman.

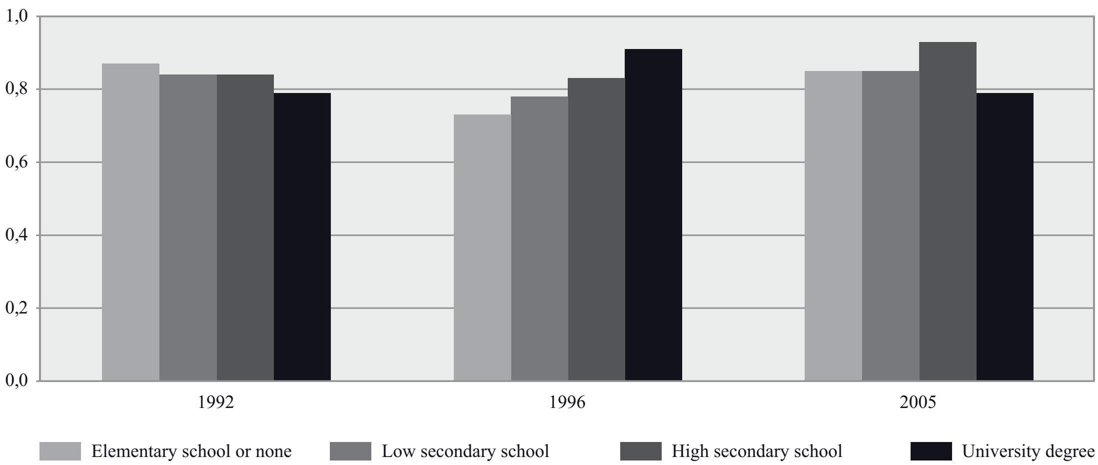
Hourly wage by gender
(absolute value in euro)

G 11–8



Graph 11–9 shows that differential hourly wage of women relative to men is increased in a negative way, especially for women with the university degree whose hours worked are increased significantly over time. In comparison women with low level of education are better paid; among the four categories, women with high secondary school increased more than the others their hourly wage while hourly wage of graduated women is getting worst in the last ten years.

Hourly wage of women/men by education **G 11–9**



In conclusion, the compensation weighting scheme has a crucial role in labour quality assessment and our results show that the quality has received impulse by the categories of employment whose compensation share decrease.

The findings of our exercise need to be better analysed also in relation to the quality of data sources. Firstly, hours worked estimated in the national accounts framework have been split by gender and other characteristics using data of the quarterly Labour Force Survey from 1992 till 2003, the new survey on a continue base is available since 2004. The lack of backward calculation series on hours worked by gender, age and education causes a structural break in the figures.

Secondly, the annual Bank of Italy survey on households' balances presents some discontinuities due to the small sample size for guaranteeing reliable estimates and to the lake of survey in some years.

Conclusions

This paper describes all the developments done in the last years by the National Statistical Office of Italy on labour input and labour productivity measurement.

In particular, a methodology to currently produce annual estimates on persons employed, jobs and hours actually worked has been adopted. The comparability of the results with the GDP growth rates is assured because of the consistency of the all aggregates produced in the context of national accounts.

We have also presented some first evidences of changes in labour quality in Italy by constructing a quality-adjusted index of labour input covering the period 1993–2005. The index is the result of a procedure that combines data on wages from micro data of the Bank of Italy's Survey of Households' income and wealth and on hours worked from micro data of Quarterly Labour Force Survey .

The results show that during the overall period the main contribution to the Italian labour quality is driven by the education but this contribution is decreasing over time. Even though the share of hours worked by people with university degree has been increased over time, their hourly wages have been rising but with a negative marginal growth rate and this results reflect two considerations: the first issue is that the share of women with university degree is increased in terms of quantity but not in value due to their low wages; the second consideration is that data reflect a specific problem of the Italian labour market where high level of attainment workers are under-assigning.

The findings of our exercise need to be better analysed also in relation to the quality of data sources. In particular, the quality and the availability of statistical and/or administrative data on hourly wages detailed by quality aspects of labour force remain uncertain. The results obtained in terms of quality adjusted measure of labour input are fragile, in particular considering the difficulties regarding the measurement of hourly labour cost. Nevertheless, Istat is highly interests to promoting convergence on statistical methodologies on hours actually worked and to provide a better statistical base for labour productivity analysis.

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12. CHANGES IN HUMAN CAPITAL
Implications for Productivity Growth in the Euro Area

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Introduction

Productivity growth is the main source of increases in economic welfare, as measured by real output per capita, in the long run. In this respect, the recent evolution of euro area productivity growth has been disappointing. In particular, the euro area has experienced a sustained decline in labour productivity growth since the 1980s. Existing analysis of the causes of this decline suggests that lower productivity growth has been due to both a decline in capital deepening and lower total factor productivity (TFP) growth over this time period (see for example Gomez-Salvador et al., 2006). However, the same analysis suggests that over the last ten years, the observed slowdown in capital deepening appears to be linked mainly to stronger employment growth. Robust euro area employment growth in the late 1990's together with economic policies aimed at encouraging employment of lower skilled workers in many euro area countries may also have resulted in a shift in the composition of the workforce towards workers with lower human capital. If this were the case, the sustained decline in euro area labour productivity growth could, in part, also reflect a lower contribution of labour quality growth to labour productivity growth. Standard unadjusted measures of labour input used so far in analysing euro area productivity growth ignore changes in human capital – changes in average labour quality – leading to an underestimation of the contribution of the labour input to economic growth. Best practise in the area of productivity measurement suggests instead that changes in labour quality should be taken into account by using a quality-adjusted number of hours actually worked as a measure of labour input (OECD, 2001).

We present evidence of changes in labour quality in the euro area and a number of euro area countries and evaluate the significance of changes in human capital for recent developments in productivity growth. We do this by constructing a quality-adjusted index of labour input in the euro area covering the period 1983–2004. In particular, we use averages of the relative returns across different human capital characteristics within euro area countries

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over the time period 1994 to 2001 to construct appropriate weights for different types of labour input. Changes in human capital are therefore captured completely by changes in total hours worked by workers with different levels of education and labour market experience. We illustrate the usefulness of the index of quality adjusted labour input based on fixed relative returns by documenting the macroeconomic importance of changes in labour quality in various dimensions. In particular, we use the series to illustrate the impact of changes in quality on labour productivity growth. We also use calculate a quality adjusted measure of the total labour force (i.e. including the unemployed).

We find that euro area labour quality has increased continuously since the early 1980s and that improvements in human capital have accounted for an increasing share of euro area labour productivity growth. Country results show some variation in labour quality growth across euro area countries. In line with the view that stronger employment growth may have resulted in the entry of workers with lower human capital in the late 1990s, we find that growth in labour quality moderated again towards the end of the 1990's. While these results suggest that lower labour quality growth has contributed to the decline in labour productivity growth in the late 1990s, the impact is small compared to the overall decline in capital deepening and total factor productivity growth.

The rest of this paper is organised as follows. In the next section we survey the existing literature on calculating measures of labour quality and the methodological issues involved. In the third section we describe the data sources and methodology that we use to construct a quality-adjusted index of labour input in the euro area covering the period 1983–2004. In the fourth section we discuss the main results for the euro area and a number of euro area countries. In the fifth section we provide descriptive evidence about the composition of total hours worked in the euro area labour force by worker groups with different human capital and estimate the contribution of changes in labour quality to the labour productivity growth over this time period. Finally, we conclude in the last section with a summary and implications for economic policies.

Survey of literature

Human capital has a prominent role in modern growth theory. Endogenous growth models suggest that human capital may generate economic growth in the long term (see Barro and Sala-i-Martin, 2004). These theories interpret capital broadly to include human capital and incorporate mechanisms such as innovation and learning-by-doing that can generate non-diminishing returns to capital and thus a positive contribution to long-term growth. Nevertheless, empirical evidence from aggregate data on the role of human capital in explaining growth is somewhat mixed. For example, Bils and Klenow (2000) argue that schooling may have only a limited impact on growth. Other studies, focussing on alternative measures of education such as test scores, suggest that differences in the quality of education are likely to have a significant role in explaining cross-country differences in growth (see Hanushek and Kimko, 2000). In contrast, a large body of evidence using microdata has shown that investment in education does result in increased individual earnings, suggesting that the social return to schooling is also positive (Krueger and Lindahl, 2001).

The literature on measuring labour quality is based in disaggregate measures of returns to individual characteristics and hours worked by worker groups. First estimates of labour input holding labour quality constant were constructed by Denison (1962) and Jorgenson and Griliches (1967) using US data. A seminal study in this literature, Jorgenson *et al.* (1987) contains a detailed examination and estimates of labour quality for the US. This work has been recently updated by Ho and Jorgenson (1999). Ho and Jorgenson construct a quality-adjusted measure of labour input for the US based on a cross-classification of hours worked into a number of cells by observed worker characteristics (sex, age groups, education and self-employment status). They then compute changes in the aggregate labour input as a weighted average of the change in hours worked for each cell and time period, where the weights are given by the average share of compensation attributable to each cell in two adjacent years. Finally, Ho and Jorgenson calculate growth in labour quality as the difference between growth in this aggregate labour input and growth in a raw measure of hours worked.

Ho and Jorgenson (1999) find that in 1948–1995 labour quality grew on average by 0.6% per year in the US. Furthermore, they identify three different periods in the evolution of labour quality in the US: first a continuous robust increase until the late 1960s, followed by a period of stagnation between late 1968 to 1980, and finally resumed growth from 1980 onwards, albeit at a lower rate than in the early period (on average 0.4% per year). In terms of the determinants of labour quality growth Ho and Jorgenson find that the rise in average level of educational attainment is the main driver of the increase in quality. Furthermore, according to Ho and Jorgenson the period of stagnation in the 1970s is explained by the entry of a large inexperienced cohort (the "baby boomers") into the labour force.

While the results in Ho and Jorgenson still provide the benchmark methodology and results for the US, recent studies have expanded this work. The Bureau of Labor Statistics (BLS) uses a slightly modified version of the Ho and Jorgenson method to estimate labour quality in the United States (see BLS, 1993). The method differs mainly in the estimation of the weights. In particular, instead of calculating simple averages of compensation for each cell, the BLS uses a regression approach to estimate cell means. This involves using microdata to estimate earnings equations with a number of individual characteristics, including education and work experience, as explanatory variables, and using the predicted wages obtained from these regressions for each worker group as the weights to calculate aggregate labour input. Compared to the approach in Ho and Jorgenson (1999), the BLS approach allows for estimating the weights using a larger number of observations, thus improving the robustness of the results. Furthermore, the BLS uses more detailed information about actual work histories provided by matching the Current Population Survey with data from the Social Security Administration. This allows the BLS to estimate actual work experience, instead of relying on a proxy of potential work experience (BLS, 1993).

Aaronson and Sullivan (2001) calculate a labour quality measure for the US using microdata of individuals only. Similar to the BLS, they obtain predicted wages for each individual using a regression approach. However, instead of using the predicted wages and hours data for each aggregate worker group, Aaronson and Sullivan combine predicted wages with actual individual data on hours worked. Compared to the Ho and Jorgenson and BLS methods this allows for more flexibility in the measurement of changes in skills, effectively extending the number of cells to equal the number of individuals that are observed in the microdata. However, this approach also requires good quality microdata of individuals for an extended time period.

Estimates of labour quality growth differ somewhat between these studies. In particular, BLS (1993) finds a lower average growth rate of labour quality since the late 1940s in the US than those presented in Ho and Jorgenson (1999). However, since the 1980s the results in the two studies are similar. The results in Aaronson and Sullivan (2001) confirm the decline in labour quality growth in the last two decades. In terms of the determinants of quality growth they also confirm earlier results, but additionally find that the business cycle has a significant impact on labour quality growth through the entry and exit of low education and low experience workers. Furthermore, using projections for demographic developments they forecast a significant decline in labour quality growth in the US.

Recent studies using more detailed data have tended to find that the contribution of human capital on labour productivity growth may go beyond previous estimates. In particular, changes in labour quality growth figure prominently in the recent discussion of the increase in US labour productivity growth in the late 1990's. In particular, Jorgenson *et al.* (2005) find that the increase in the employment of college-educated workers contributed significantly to the increase in US productivity growth since 1995. Taking a different methodological approach Abowd *et al.* (2005) also derive measures of human capital. Their methodology relies on a novel and data intensive combination of comprehensive firm level and household level data sources for the US. Their results suggest that compared to measures derived in Jorgenson *et al.* (2005) average growth in human capital in all industries has been significantly higher in the late 1990's period.

Some limited evidence of labour quality growth exists for other countries. Jorgenson (2004) provides evidence of labour quality in G7 countries, including estimates for three large euro area countries, i.e. France, Germany and Italy. The results are based on the method used in Ho and Jorgenson (1999) and use a number of different data sources. His estimates for these three countries suggest that labour quality growth in the euro area has been positive between 1980–2001, ranging from approximately 0.45% annual growth in Germany to 0.86% in France (Table 12, Jorgenson, 2004). For the euro area as a whole this suggests that labour quality grew on average by approximately 0.57% per year.[189] The results also suggest that growth in labour quality was strongest in the period 1989–1995, mainly due to robust improvement in labour quality in France. Furthermore, growth in labour quality declined somewhat in all three countries in 1995–2001. While the contribution of labour quality to labour productivity growth is smaller than the contribution of the other two components of labour productivity growth, i.e. capital deepening and total factor productivity growth, it is significant. For the euro area aggregate based on France, Germany and Italy the results suggest that the contribution of labour quality growth was always positive and accounted for just below one fifth of the growth in labour productivity (Jorgenson, 2004). In addition, Melka and Nayman (2004) estimate labour quality growth in France, Card and Freeman (2004) in Germany and Brandolini and Cipollone (2001) in Italy. O'Mahony and van Ark

[189] This rough estimate is based on a weighted average of the country estimates using labour force weights.

(2003) calculate sectoral measures of labour quality for France, the Netherlands and Germany. While the estimates in O'Mahony and van Ark (2003) are based on relatively limited data sources and thus are only indicative of developments in labour quality growth, they provide some additional insight into sectoral diversity. Their findings suggest that labour quality growth has been larger in sectors that produce information and communication technology (ICT). In addition, the slowdown in labour quality growth in 1995–2000 appears to have been most relevant in non-ICT sectors. Scarpetta et al. (2000) also construct very crude measures of labour quality growth for some euro area countries.

Measuring labour quality growth relies on a number of important assumptions. In particular, all labour quality studies assume that individual characteristics reflect differences in productivity and that relative wages are a good proxy of relative productivities. In the empirical exercises surveyed here, a number of individual characteristics are used to control for the composition of the aggregate workforce. These include education, age or labour market experience, sex and other individual characteristics (such as employment status). The choice of these individual characteristics is largely determined by economic theory on human capital as well as empirical results that document the impact of these variables on individual wages. In some cases, data limitations result in the use of proxy variables for capturing the impact of an underlying characteristic that matters for human capital.

Education is the key determinant of human capital. In terms of economic theory, formal education is the main source of general human capital (as opposed to job-specific human capital), with the basic proposition that investment in education results in higher human capital and productivity (see Becker, 1993). This assumption is confirmed by an extensive literature on returns to education that documents gains to education in terms of higher individual earnings (for surveys see Card, 1999 and Ashenfelter *et al.*, 1999). Empirical work at the aggregate level is largely based on educational attainment (such as the share of those with tertiary or university level education) as a proxy for the stock of human capital obtained through schooling (see OECD, 2004 and Barro and Lee, 2001). This is also the case for the studies of labour quality surveyed above that decompose the work force into those with different levels educational attainment. The international classification of education (ISCED) allows for constructing internationally comparable categories of educational attainment based on three levels of education: lower secondary, upper secondary and tertiary education. A detailed description of national educational systems and the ISCED classification can be found in Annex 3 of OECD, 2004. The specific education categories used in this study are shown in the Appendix. Country differences in educational systems complicate complete harmonisation of the measurement of educational attainment at a more detailed level. Generally, internationally comparable data on more detailed classifications are not available for longer time periods. Fosgerau et al. (2002) study the impact of extending the number of educational categories on measures of human capital in Denmark. Their results suggest that a relatively small set of educational categories is sufficient for measuring aggrerate labour quality.

It should be noted that the level of education is a limited proxy for general human capital. For example, the level of education does not take into account the impact of possible differences in the quality of schooling or the type of education (see Barro and Lee, 2001).

Alternative measures of general human capital have been derived recently, e.g. using data on internationally comparable test scores (see Hanushek and Kimko, 2000 and Barro and Lee, 2001).

In addition to formal education, workers gain human capital after finishing school through increased labour market experience and on-the-job training. Some of this human capital is likely to be specific to the job or industry where the worker has gained experience. Again, substantial evidence exists to suggest that general labour market experience and job-specific experience contribute positively to individual wages and productivity (see e.g. Katz and Murphy, 1992). However, compared to education, measuring experience is significantly more complicated and the empirical literature largely relies on incomplete proxies. The BLS is the only labour quality study to measure actual labour market experience. They use detailed information obtained from matching work histories from the Current Population Survey and data from the Social Security Administration to construct a measure of actual work actual experience (BLS, 1993). When data on actual work histories are not available, a common approach to measure experience used extensively in the labour literature is to approximate labour market experience with age minus years spent in schooling (minus the school starting age). This approach is adopted in several studies of labour quality (for example in Ho and Jorgenson, 1999 and Aaronson and Sullivan, 2001). An alternative approach is to acknowledge that experience can not be measured accurately and to use age as a proxy for human capital gained after school. In fact, by construction, measures of estimated experience and age are strongly correlated. Furthermore, a large body of empirical evidence suggests that similar to experience, earnings are a concave function of age, i.e. earnings increase but at a diminishing rate with age (see Murphy and Welch, 1990). Part of the explanation for this profile lies in the tendency for the young to invest more in human capital, while at the same time foregoing some current earnings. Older workers invest less, and thus forego less current earnings, but earn returns from previous investment in human capital.

Other individual characteristics that are commonly included in the estimation of labour quality include sex, employment status (such as part-time employment) and industry. The inclusion of these variables largely reflects empirical findings that they matter for individual wages. In general, different labour market experiences for men and women result in significant differences in the accumulation of human capital and their returns between sexes. For example, it is likely that using estimated experience or age as a proxy for actual labour market experience results in different experience-earnings profiles for men and women. Finally it should be noted that a number of unobserved human capital characteristics of workers are likely to matter for their productivity.

As mentioned above, estimation of labour quality relies on wages as a measure of worker productivity. The underlying assumption, based on a model of competitive labour markets, is that relative wages are equal to the relative marginal products of labour. Various characteristics of actual labour markets, such as discrimination, union bargaining, signalling and mismatch, may result in violations of this assumption (for a more detailed discussion see Ho and Jorgenson, 1999). Furthermore, some of these characteristics, such as the relative importance of union bargaining, may be more relevant in the European context than is the case in the US. However, due to lack of more direct measures, wages remain the best available proxy of worker productivity. For reasons of data availability we also assume here that the relative returns to individual characteristics, such as education and labour market experience within each country remain unchanged at their average level for the 1994 to 2001 period. At first sight, this may seem like a relatively strong assumption. However, empirical evidence for European countries suggests that returns to skills may indeed be more stable in the euro area than in other economic areas. For example, in their review of the literature on returns to education Ashenfelter et al. (2000) find that while there has been a significant upward shift in returns to education in the US, studies for non-US countries do not show such a shift. Similarly, Brunello and Lauer (2004) find a statistically significant, but modest effect of cohort size on the earnings of different worker groups. These results suggest that relative wages (between groups of workers) may be relatively rigid in European countries and necessary adjustments take place mainly in terms of the quantities. This conjecture is supported by empirical evidence on group-specific unemployment rates in Europe.For example, Biagi and Lucifora (2005) find that changes in the age and education structures (such as the increase in middle-aged and more educated workers) have different implications for unemployment rates for different age and education groups.

Data and methodology

We largely follow previous literature in calculating our estimates for changes in labour quality in the euro area and in euro area countries. As mentioned above, however, for reasons of data availability we assume that the relative returns to individual characteristics, such as education and labour market experience within each country remain unchanged at their average level for the 1994 to 2001 period. Our measure of quality adjusted labour input is constructed as follows. First, using available microdata for individual workers (see below), we estimate wage equations separately for each country and for males and females:

$$\mathrm{W}_{\mathrm{it}} = \alpha_{\mathrm{it}} + \mathrm{EDU}_{\mathrm{it}}\beta_{\mathrm{e}} + \mathrm{AGE}_{\mathrm{it}}\beta_{\mathrm{a}} + \varepsilon_{it} \tag{1}$$

Where the subscript *i* refers to the individual and *t* to time. These equations are estimated using weighted OLS, using sample weights provided with the microdata. The dependent variable is measured as the gross real wage in PPP units. We use the PPP conversion rates based on consumer goods prices provided by Eurostat to do the conversion across countries. The right hand side variables include two education categories EDU (with secondary education as the omitted category) and five age categories AGE (with those between 34 and 45 as the omitted category). The education categories are constructed using the ISCED97 classification (see the Appendix for more details). Note that this combination of classifications results in 36 times 12 worker-country groups.

The European Community Household Panel (ECHP) provides detailed information on individuals, including their wages and human capital characteristics. The ECHP is a survey of households in all EU countries that includes detailed information about individual characteristics, including earnings. Wages are originally reported in the ECHP as net wages (including bonuses) in the previous month in national currency.[190] From this information gross wages are constructed using the gross/net ratio provided by the survey. The use of gross wages is motivated by the use of the labour quality estimate primarily as an input to productivity analysis within a growth accounting framework (see OECD, 2001). Finally, in order to derive hourly wages we divide the monthly wage by monthly hours worked.

We use the predicted wages $\widetilde{W}_j$ based on coefficient estimates from equation (1) to construct weights for each worker-country group *j* as the average of the share of each worker group in total compensation in adjacent years:

$$\bar{s}_{j,t} = \frac{1}{2}\left(s_{j,t} + s_{j,t-1}\right) \tag{2}$$

Where the share $s_{j,t}$ is given by:

$$s_{j,t} = \frac{\widetilde{W}_j H_{j,t}}{\sum_j \widetilde{W}_j H_{j,t}} \tag{3}$$

Where *H* refers to total hours worked.

We use data from the European Labour Force Survey (LFS) to construct measures of hours worked for worker groups.[191] Eurostat collects data from national labour force surveys and provides estimates for aggregate indicators, such as hours worked cross-classified for different age-gender-education groups for each euro area country. Total hours worked have been calculated from the LFS source data using information on employment and usual weekly hours.[192] The time span of these data varies somewhat across euro area countries, but with the exception of data on educational attainment, the cross-classifications are currently available for most countries from 1983 until 2004.[193] In the years when LFS data is not available for

190 Except for France and Finland where wages are reported as gross wages.

191 The LFS data used in this paper were extracted in July 2005.

192 Total hours usually worked were utilised for data availability reasons. Only for the post 1992 period complete information is available on usual as well as on actual hours worked. Results for this period do not differ significantly when actual hours are used instead of usual hours.

193 Lack of education data in the LFS prior to 1992 requires the use of additional data sources to estimate the full cross-classification of total hours worked for the pre 1992 period. We use information from the Luxembourg Income Study (LIS) and the German Socio-Economic Panel (GSOEP) to fill this gap. LIS is a non-profit organisation that collects and provides access to cross section data from household income surveys from a number of countries. The GSOEP is a large longitudinal survey of German households that is available from the early 1980s onwards. Both LIS and GSOEP provide information that is similar to the ECHP. We combine LFS hours data for the less complete age times sex cross classifications with data on hours for the complete age times sex times education cross-classifications from LIS to extrapolate education shares for a number of euro area countries. Furthermore, we use information from the GSOEP to interpolate the pattern of hours worked between LIS data points. While we have information on hours worked cross-classified by gender and age, no information is available along the educational dimension for several data points prior to 1992. For example, total hours worked by 35–44 years old males are known, but information on what

all countries, growth rates for the euro area are computed using information on the available countries. [194]

Using these data the change in aggregate labour input in the euro area is then calculated as:

$$\ln\left(L_t / L_{t-1}\right) = \sum_j \bar{s}_{j,t} \ln\left(H_{j,t} / H_{j,t-1}\right) \tag{4}$$

Growth in labour quality is equal to growth in aggregate labour input and growth in the raw measure of hours worked:

$$\Delta \ln Q = \Delta \ln L - \Delta \ln H \tag{5}$$

Results

The results from estimating equation (1) for each country, separately for men and women, aggregated to the euro area are shown in Table 12–1.[195] Note that the aggregated results are shown for illustrative purpose only, and weights derived from regressions at the country level are used in the actual calculations (see below). These results illustrate that in the calculation of labour quality, the hours of those with tertiary education are given a larger weight than the hours of those with only secondary and/or primary education. In addition to this impact of education, the results show that in line with previous evidence earnings generally increase with age and more so for men than women. These results should also not be interpreted e.g. as providing an exact measure of the causal effect of education on earnings in the euro area. For example, the equation does not take into account the possible impact of unobservable individual characteristics on the returns to education. However, for the measurement of average labour quality the exact causal effect of education on individual earnings is less relevant than arriving at a good proxy for the aggregate impact of increased education on human capital. See Card (1999) for a survey of this literature and a discussion of the measurement difficulties related to measuring the causal effect of education.

T 12–1 Aggregated coefficient estimates

	Female	Male
Age 15–24	-0.44	-0.53
Age 25–34	-0.14	-0.16
Age 45–54	0.06	0.09
Age 55–64	0.03	0.07
Age 65–	-0.12	-0.09
Primary education	-0.24	-0.18
Tertiary education	0.28	0.27
Constant	4.38	4.49

Source: authors' calculation. Note: age 35–44 and secondary education are the omitted categories. Wages are in logs

share of these hours can be attributed to either of the three educational categories is missing. We fill in the missing data points using predicted values for the respective shares stemming from weighted regressions for each worker-country group. All regression equations include time trends as well as information from the complete GSOEP series.

194 LFS data for Portugal and Spain is available from 1986 onwards and for Austria and Finland from 1995 onwards.

195 The results from estimating equation (1) directly with euro area data are not identical, but broadly similar to those shown in Table A.

For the euro area our estimates of labour quality based on fixed returns indicate a continuous increase in quality in the last 20 years (see Table 12–2). The estimated average growth rate of euro area labour quality in the 1984–2004 period is 0.62% year-on-year. The estimated growth rate for the euro area is higher than a simple aggregation of previous results for Germany, France and Italy presented in Jorgenson (2004) would suggest (averaging 0.40% in 1984–2001). This difference is likely to reflect a number of factors, including differences in data and methods used. Furthermore, in addition to including data from all euro area countries, we also allow changes in the composition of the euro area workforce across countries to influence growth in euro area labour quality. Beyond the average increase in labour quality, our estimate of labour quality shows some variation in labour quality growth over time (see Table 12–2). In broad terms the data point to three different time periods in terms of longer-term developments in euro area labour quality. The 1980s were characterised by relatively low growth in labour quality, followed by particularly strong growth in the early 1990s. Average labour quality growth appears to have moderated again somewhat towards the end of the 1990's and during the recent slow growth period. Some of this variation may be associated with the business cycle. Previous evidence suggests that labour quality is likely to be counter-cyclical showing periods of "down-skilling" in upturns and "up-skilling" in downturns as workers with different skills move in and out of the labour force (Aaronson and Sullivan, 2001 and Solon *et al.*,1994). In particular, the share of workers with lower skills tends to increase during periods of stronger growth as firms lower their skill requirements to expand production and more low-skilled workers, faced with a higher likelihood of finding a job and possibly higher wages, are encouraged to enter the labour market. Recent developments, such as the significant increase in labour quality growth in the early 1990's and the subsequent decline in the course of the 1990's – a period of particularly strong employment growth – is consistent with the interpretation of countercyclical quality growth.[196]

Combining the estimated series of labour quality with data on total hours worked results in a measure of labour quality adjusted labour input. Consistent with previous work on labour productivity in the euro area the estimate of total hours is taken from the Groningen Growth and Development Center (GGDC) database.[197] Due to continuous increases in quality, labour quality adjusted labour input has increased faster than unadjusted labour input in the last 20 years (see Table 12–3 and Graph 12–1). The stronger increase in quality in the early 1990s is also clearly reflected in a significant widening of the gap between the adjusted and unadjusted labour input series.

196 For more detailed evidence, see Schwerdt and Turunen (2006).

197 Timmer, Ypma and van Ark (2003), University of Groningen, Appendix Tables, updated June 2005.

T 12 – 2 Complete results

index: 1983=100

Total		First order indices			Second order indices			
		S	A	E	SA	SE	AE	SAE
1983	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1984	100.27	99.92	100.23	100.13	100.01	100.06	99.98	99.94
1985	100.94	99.88	100.37	100.62	100.02	100.11	100.02	99.92
1986	101.35	99.83	100.20	101.19	100.05	100.15	100.02	99.92
1987	101.81	99.80	100.18	101.67	100.05	100.16	100.03	99.91
1988	102.66	99.76	100.26	102.45	100.05	100.17	100.05	99.90
1989	103.40	99.73	100.37	103.11	100.06	100.16	100.05	99.90
1990	104.47	99.66	100.44	104.23	100.07	100.12	100.04	99.89
1991	105.70	99.48	100.64	105.46	100.08	100.10	100.04	99.89
1992	105.83	99.47	100.66	105.61	100.08	100.09	100.02	99.90
1993	106.87	99.45	101.12	106.27	100.05	100.03	100.01	99.91
1994	108.14	99.42	101.51	107.17	100.04	100.04	100.01	99.89
1995	108.84	99.40	101.77	107.68	100.01	100.01	100.00	99.90
1996	109.34	99.37	102.10	107.92	99.99	99.98	100.00	99.90
1997	110.16	99.37	102.30	108.55	99.98	99.98	99.99	99.91
1998	110.24	99.36	102.28	108.70	99.98	99.95	99.96	99.91
1999	110.66	99.31	102.26	109.20	99.98	99.95	99.96	99.91
2000	111.33	99.26	102.34	109.82	99.98	99.96	99.95	99.91
2001	111.76	99.22	102.56	110.07	99.97	99.96	99.94	99.92
2002	112.09	99.17	102.74	110.27	99.96	99.97	99.91	99.93
2003	112.81	99.13	103.02	110.72	99.95	99.99	99.91	99.93
2004	113.87	99.13	103.23	111.55	99.94	99.98	99.91	99.93

Source: authors' calculation. Note: S refers to sex, A to age and E to education.
SA is the second order contribution of sex and age.

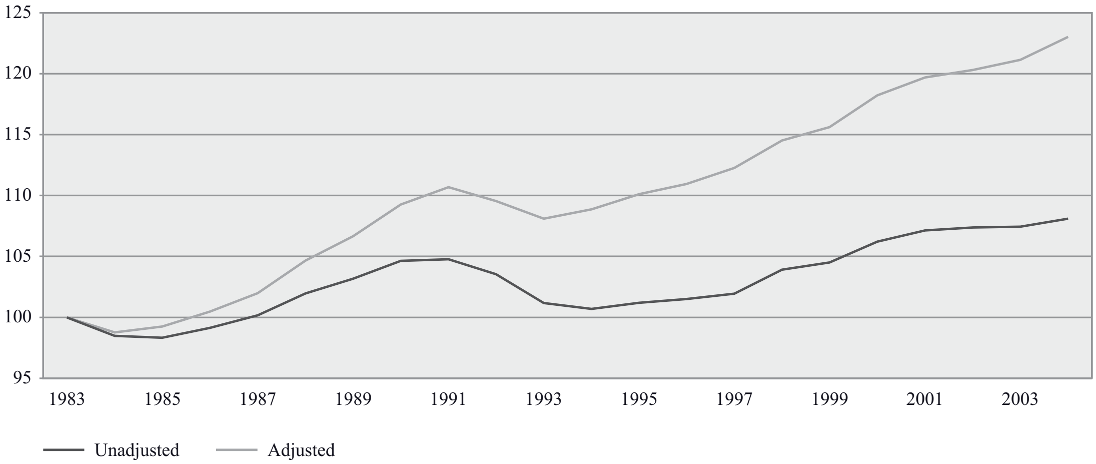
T 12 – 3 Growth in euro area labour quality and labour inputs

average annual growth rate

	1984–89	1990–94	1995–99	2000–04	1984–2004
Labour quality	0.56	0.90	0.46	0.57	0.62
Unadjusted labour input	0.53	-0.48	0.75	0.68	0.38
Quality adjusted labour input	1.09	0.42	1.21	1.25	1.00

Source: authors' calculation. Unadjusted labour input refers to total hours worded from the Groningen Growth and Development Center growth accounting database.

Labour quality adjusted labour input
Index points: 1983=100 **G 12–1**



Source: authors' calculation. Unadjusted labour input refers to total hours worked from the Groningen Growth and Development Center growth accounting database.

We have also estimated labour quality indices for each euro area country separately (see Table 12–4). The results suggest that the average annual growth in labour quality for the 1984–2004 period was lowest in Germany and strongest in France, Ireland and Luxembourg. Labour quality grew strongly also in Spain and Austria. All other euro area countries have moderate growth rates at around 0.5%. While the contribution of changes in the workforce composition along the gender dimension was negligible in all countries, the first order index of age grew steadily at modest rates in all euro area countries and with little variation across countries. The big gap in average growth rates of labour quality between low- and high-performers can almost entirely be attributed to different developments in the share of total hours worked by education groups. Germany, for example, showed average growth rates of 0.19% for the first order index of age and 0.22% for the first order index of education. France and Ireland, on other hand, have a comparable growth in the first order index of age (both 0.21%) for the 1984–2004 period, but the first order index for education grew at average annual rates of 0.6% and 0.67%, respectively. This strong growth reflects the significant increase in the share of total hours worked by workers with upper secondary and tertiary schooling in France and Ireland.

T 12 – 4 Growth in labour quality: country estimates
average annual growth rate

	1984 – 1989	1990 – 1994	1995 – 1999	2000 – 2004	1984 – 2004
Germany	0.13	0.44	0.15	0.33	0.26
France	1.25	1.35	0.63	0.48	0.94
Italy	0.32	0.35	0.69	0.54	0.47
Spain	n.a.	1.09	0.80	0.79	0.79*
Portugal	n.a.	0.90	-0.56	1.70	0.48*
Netherlands	0.17	0.90	0.38	0.60	0.50
Belgium	0.25	0.47	0.47	0.56	0.43
Greece	0.43	0.70	0.39	0.88	0.58
Ireland	1.28	1.18	0.48	1.24	1.09
Luxembourg	0.67	2.67	0.55	1.69	1.36
Austria	*n.a.*	*n.a.*	*0.68*	*0.76*	0.73**
Finland	*n.a.*	*n.a.*	*-0.09*	*0.39*	0.21**

Note: * 1987 – 2004, ** 1995 – 2004.
Source: authors' calculation.

The estimates for labour quality growth on the country level also allow a comparison with existing country results. Comparing the results reveals that our country results for the three largest euro area countries, Germany, France and Italy, are broadly in line with results in Jorgenson (2004).[198] Both the overall average growth rates and the pattern of average growth rates over time are roughly consistent with results in Jorgenson (2004), with the exception of a somewhat lower estimated growth rate for Germany. However, our lower estimate for Germany is similar to the estimated growth rate of 0.21% for the post 1980 period in Card and Freeman (2004). Overall, the comparison with existing country results supports the robustness of our estimates.

We have also explored using alternative determinants of human capital (not shown). In particular, we constructed an alternative labour quality index including two additional characteristics: part-time versus full-time work and sectors of economic activity (agriculture, industry and services). Both characteristics are potentially important determinants of wages. However, it is not a priori clear what their impact is on human capital. For example, the group of part time workers is likely to be relatively heterogeneous, including workers with both relatively low and high human capital. At the same time, the increase in part time work has generally been associated with the increase in employment of workers with lower skills. Results from including these characteristics increase average labour quality growth slightly, to 0.53% for this time period. The increase is entirely due to a positive contribution from changes in the sectoral composition. Again however, the difference between the alternative results and the benchmark calculation is small.

[198] Jorgenson (2004) reports average growth rates for the 1984–2001 period for Germany of 0.52%, for France of 0.86% and for Italy of 0.51%.

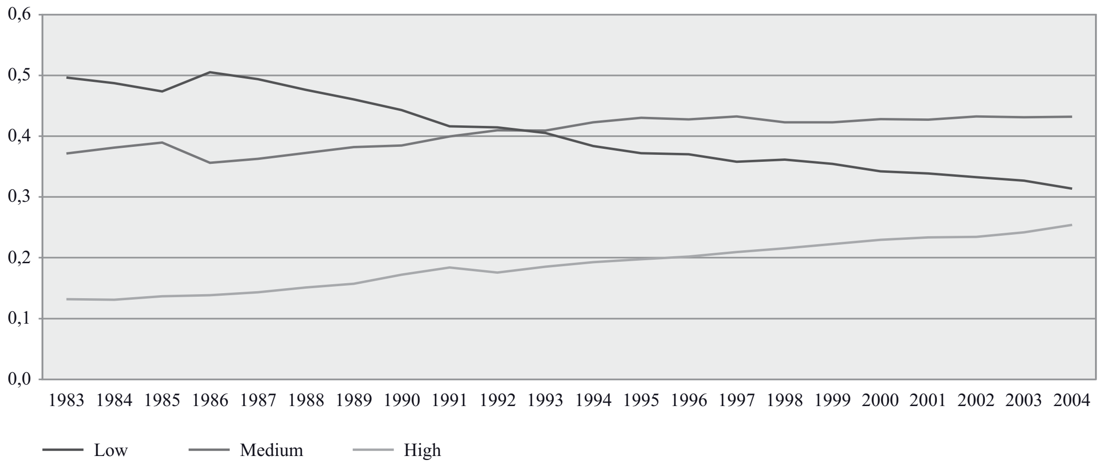
Growth in the quality of labour force
annual growth rates **G 12–2**

Source: authors' calculation

Similar to estimating the impact of changes in the composition of those employed, it is possible to estimate growth in the quality of the labour force (see Aaronson and Sullivan, 2001 for a similar exercise for the US). We use LFS data of unemployed by age, sex and education for the 1992–2003 time period to extend our benchmark index of labour quality of the employed to cover the whole labour force.[199] The extended measure is informative about the quality of the available labour force. The results show that the growth rates of labour quality of employed and the total labour force have been very similar (see graph 12–3). This result largely reflects the fact that the employed form a major part of the labour force. Nevertheless, the growth in labour quality of the unemployed has been on average somewhat higher than that of the employed, with a particularly marked difference in the growth rates in the late 1990s to early 2000s period. Assuming that the average level of labour quality of unemployed workers is lower, the higher growth rate thus represents narrowing of the skill differential between workers and the unemployed over the whole time period. At the same time, the larger difference in quality growth between the two groups of workers in the late 1990s may also reflect cyclical factors.

199 Complete data for 2004 was not yet available. For this exercise, the data for employed and unemployed excludes those over 64 years of age (maximum age for Eurostat definition of labour force). Data for Luxembourg is excluded due to missing data.

Hours worked by educational attainment
(shares) **G 12–3**



Source: authors' calculation based on the Labour Force Survey.
The shift in 1985 reflects the inclusion of Portugal and Spain for whith data on hours is not available before 1985.
The calculation of the labour quality index takes into account changes in the country composition.

Changes in euro area human capital and implications for labour productivity growth

A decomposition of the overall quality index to the contributions of its determinants provides some insight on the factors underlying changes in labour quality growth. We calculate the first order contributions of sex, age and education following the method described in Ho and Jorgenson (1999)[200]. The results show that, as expected, education has been the main driving force of labour quality growth (see Table 12–1).[201] The contribution of education to labour quality growth was particularly strong in the late 1980s and early 1990s, consistent with an increase in the share of those with tertiary education of total hours worked in the euro area during this time period. Longer term developments in educational attainment in the euro area has been characterised by a secular increase in years spent in schooling. Data on total hours worked from the LFS illustrates the significant increase in average educational attainment over the last 20 years (see Figure 3). The share of those with primary education or less has declined significantly, whereas the share of those with secondary and tertiary qualifications has increased. The recent increase in the share of the population that has tertiary (university level) qualifications has been particularly striking. Overall, the increase in educational attainment amounts to a significant increase in the supply of general skills in the euro area.

200 First order indices are constructed analogously to the main index described before. The only difference compared to the full index consists in the choice of worker-country groups, which is determined by the respective cross-classification. For example, the first order contribution of sex requires only a cross-classification along one dimension with two possible worker groups (males and females). Hence, the corresponding index for sex is calculated based on 2 times 12 worker-country groups.

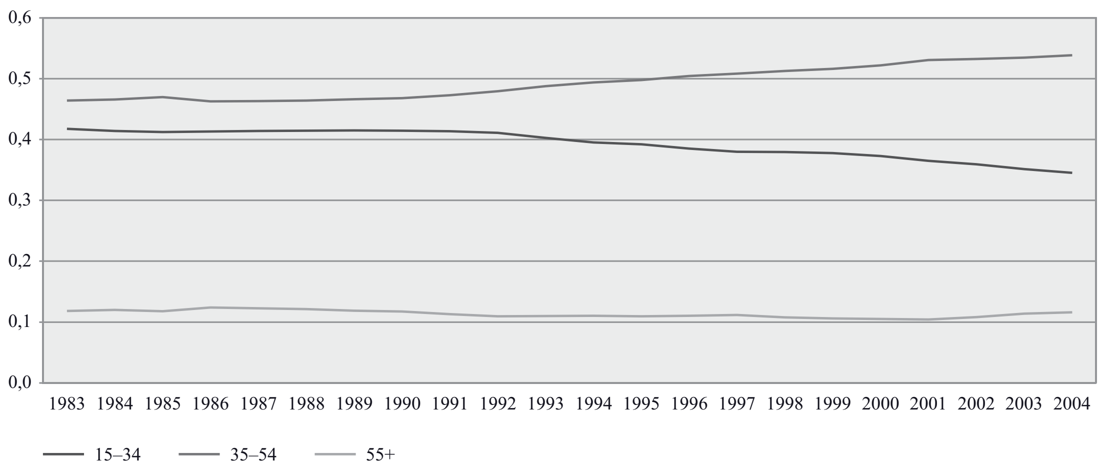
201 This conclusion is robust to the inclusion of other determinants. In particular, the contributions of sector and fulltime versus part-time status for the period 1992 onwards are negligible.

The contribution of age to the index of labour quality was also particular strong in the early 1990s. This coincides with an increased share of workers in prime age (aged between 35 and 54). Thereafter the contributions of both characteristics declined in the late 1990s possibly reflecting the impact of continued robust growth in employment and the entry of marginal workers with lower human capital both in terms of education and labour market experience. Most recently, an increase in hours of more educated and experienced workers has contributed to an increase in labour quality in 2003 and 2004.

While acting as proxy for labour market experience, the contribution of age to labour quality changes is largely driven by demographic developments. Overall trends in the euro area working age population over the last 30 years are characterized by the movement of the so-called baby boom cohort (those born in the 1950s and 1960s) through the age distribution (see graph 12–4). In particular, the shares of those in prime age, i.e. between 35–54 years of age have been steadily increasing since the early 1990's, whereas the share of younger, less experienced workers, i.e. those between 15 and 34 years of age has declined over the same time period. The increase in the share of hours worked by prime-aged workers and the decline in the share of younger workers is likely to have resulted in an increase in average labour market experience over this time period, as well as lower contemporaneous human capital investment. Compared to the changing contribution of workers below 55, the share of older workers has been relatively steady over this time period. However, the ageing of the baby-boom generation is likely to result in an increased share of total hours worked for this age group in the near future. Finally, the first order contribution of sex to the labour quality index has been quantitatively negligible. The negative contribution reflects the increased share of total hours worked by women (see Genre and Gomez-Salvador, 2002).

Hours worked by age groups
(shares)

G 12–4



Source :authors' calculation based on the Labour Force Survey.

Previous growth accounting exercises for the euro area have ignored the role of changes in human capital, thus estimating TFP growth as a residual item including the contribution of labour quality growth (see Gomez-Salvador et al, 2006 and Vijselaar and Albers, 2004). With positive growth in labour quality, this omission results in larger estimates of TFP growth and a possible misinterpretation of the determinants of the sustained decline in labour productivity growth. The results of a more complete decomposition of labour productivity growth, i.e. separating out the impact of labour quality growth from TFP growth point to a significant and increasing role for changes in labour quality in explaining labour productivity growth in the past 20 years (see graph 12–5). While in the early 1980's the contribution of labour quality growth accounted for only 15 percent of productivity growth, this share has increased to 35 percent in the early 2000's. However, as discussed above lower labour quality growth in the second half of the 1990s appears to have also contributed somewhat to the decline in labour productivity growth over the same time period. In particular, adjusting for labour quality results in significantly lower estimates of euro area TFP growth than previously estimated. As TFP growth is estimated as a residual, these estimates should be interpreted with some caution. With this caveat in mind, the results suggest that while TFP growth has been slower in the 1990s compared to the 1980s, a significant further slowdown in TFP growth took place during the recent period of slow growth in the euro area.

Decomposition of labour productivity growth
(contributions) **G 12–5**

Source: authors' calculation. Except for the estimate of labour quality data are from the Groningen Growth and Development Centre growth accounting database.

Conclusions

The results presented in this paper suggest a continuous increase in the human capital composition of the euro area workforce in the last 20 years. Country results show some variation in labour quality growth across euro area countries. In line with the view that stronger employment growth may have resulted in the entry of workers with lower human capital in the late 1990s, we find that growth in labour quality moderated again towards the end of the 1990's. We have illustrated the usefulness of the index in better understanding macroeconomic developments in the euro area. The results of an accounting exercise point to a significant and increasing role for changes in labour quality in explaining labour productivity growth. Accounting for positive labour quality growth lowers estimates of total factor productivity growth in the euro area and points to a possible decline in the contribution of technological progress to growth in the euro area.

The central role of human capital in contributing to productivity growth has been acknowledged in key European economic policy recommendations. Indeed further improving knowledge and innovation remain as one of the key areas for further progress as identified in the mid-term review of the Lisbon agenda.[202] In this context a key indicator of progress is the percentage of the population aged from 20 to 24 who have completed at least an upper secondary education. This share remains well below the 85% target, suggesting that further progress in encouraging higher educational attainment is needed. In this regard, the results in this paper show that higher educational attainment can contribute positively to labour productivity growth. While it is important to recognise that other (not measured) factors, such as quality and type of education are likely to also matter, the results suggest that economic policies designed to promote growth in euro area human capital should be geared towards an increase in educational attainment and increased on-the-job training. Needless to say both education and training should be geared towards the needs of the job market.

In this context, technological progress and other factors, such as globalisation and the ageing of the euro area workforce, are likely to present additional challenges. The results of the accounting exercise in this paper points to a decline in euro area total factor productivity growth. This decline argues for stronger emphasis on economic policies that promote innovation and the use of productivity enhancing technologies, as well as an increased focus on understanding the interactions between human capital and technological progress. In particular, some commentators have noted that type of schooling may matter for explaining cross country differences in the adoption of new technologies. For example Krueger and Kumar (2005) argue that compared to the more general education in the US, European education systems are focussed on specialised vocational training. Wasmer (2003) argues that the structure of European labour markets favours more investment in job-specific versus general human capital. Both arguments suggest that European educational systems may not provide sufficient flexibility for workers in periods of significant structural changes. Looking forward, changing demographics are likely to have a strong impact on growth in labour quality in the future. While ageing of the working age population (until prime-age) generally increases average labour quality due to larger return to previous investment in human capital, it may result in lower incentives for current investment in human capital. Ageing is thus likely to result in downward pressure on the contribution of labour quality to aggregate productivity growth.

202 See europa.eu.int/growthandjobs/pdf/COM2005_024_en.pdf and ECB (2005).

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Appendix I: Reclassification based on ISCED97.

Lower secondary education = Low
ISCED 0 Pre-primary level of education Initial stage of organised instruction, designed primarily to introduce very young children to a school-type environment. ISCED 1 Primary level of education Programmes normally designed to give students a sound basic education in reading, writing and mathematics. ISCED 2 Lower secondary level of education (2A, 2B, 2C) The lower secondary level of education generally continues the basic programmes of the primary level, although teaching is typically more subject-focused, often employing more specialised teachers who conduct classes in their field of specialisation.
Upper secondary education = Medium
ISCED 3 Upper secondary level of education (3A, 3B, 3C) The final stage of secondary education in most countries. Instruction is often more organised along subject-matter lines than at ISCED level 2 and teachers typically need to have a higher level, or more subject-specific, qualification that at ISCED 2. There are substantial differences in the typical duration of ISCED 3 programmes both across and between countries, typically ranging from 2 to 5 years of schooling. ISCED 4 Post-secondary, non-tertiary education (4A, 4B, 4C) These programmes straddle the boundary between upper secondary and post-secondary education from an international point of view, even though they might clearly be considered as upper secondary or post-secondary programmes in a national context. These programmes are often not significantly more advanced than programmes at ISCED 3 but they serve to broaden the knowledge of participants who have already completed a programme at level 3. The students are typically older than those in ISCED 3 programmes. They typically have a full-time equivalent duration of between 6 months and 2 years.

Tertiary education = High
ISCED 5   First stage of tertiary education (5A, 5B) Programmes with an educational content more advanced than those offered at levels 3 and 4. ISCED 6   Second stage of tertiary education (leading to an advanced research qualification) This level is reserved for tertiary programmes that lead to the award of an advanced research qualification. The programmes are devoted to advanced study and original research.

Source: Eurostat

Part 4:

The Measure of Capital Input

13. INTERNATIONAL COMPARISONS OF LEVELS OF CAPITAL INPUT AND MULTI-FACTOR PRODUCTIVITY

By Paul Schreyer[203]
Organisation for Economic Co-operation and Development

Introduction

International comparisons of levels of labour and capital inputs, outputs and productivity tend to receive a great deal of attention because they respond directly to policy-makers' and analysts' interest in measuring competitiveness, economic well-being of countries' inhabitants and the intensity by which resources are used. Generally, such level comparisons are more difficult to put in place than comparisons of growth rates: data sources are more susceptible to problems of international comparability (Ahmad et al. 2004), and spatial price indices are required to account for differences in the levels of input or output prices.

While the OECD has a long tradition of measuring comparative levels of GDP and labour productivity by way of its purchasing power parity programme (PPP) (see OECD 2004), there has been much less work to compare levels of capital input, levels of capital productivity and capital intensity. Some recent developments have changed this picture: (i) the OECD Productivity Database[204] now features a set of capital service measures for 18 OECD countries that are as comparable internationally as possible; (ii) in some countries, measures of capital input and capital intensity are followed closely in the policy debate. This is, for example, the case for New Zealand where questions have been posed about the 'hollowing-out' of the New Zealand economy (Black et al 2003) and where comparative measures of capital input are of significant interest to analysts to make an informed statement about the capital intensity of the New Zealand economy; (iii) additional methodological work has been undertaken on comparisons of productivity levels in a number of places, including at the OECD with a forthcoming handbook on the subject (van Ark forthcoming); (iv) several studies with level comparisons of productivity and capital have been published in recent years, in particular Inklaar et al. (2006), Jorgenson (2003), O'Mahony and de Boer (2002) and more results will be forthcoming by way of the EU-KLEMS project[205]

[203] Views expressed in the paper are those of the author and not necessarily those of the OECD or its member countries.

[204] See data and descriptions of the OECD Productivity Database under http://www.oecd.org/statistics/productivity.

[205] The CES samples 400,000 nonfarm establishments, more than six times the 60,000 households sampled in the CPS. In addition, the CES is benchmarked annually to levels based on administrative records of employees covered by state unemployment insurance tax records. There is no direct benchmark for CPS

The present paper is a contribution to these efforts. It pursues several objectives: (i) deriving point estimates of relative productivity and capital services, based on the OECD Productivity Database. As a first step, the comparison relates to seven countries from all OECD regions; (ii) decomposing GDP per capita differences into productivity differences and differences in labour utilisation and identifying the contribution of ICT capital to labour productivity differences; (iii) discussing the statistical uncertainties surrounding level comparisons and determination of likely error margins by way of a simple Monte-Carlo simulation. Overall, the paper is statistical in nature and focuses on the measurement issues rather than on the economic analysis of productivity differences.

Bilateral and multilateral comparisons: concepts for comparisons

There is a large body of literature on the international comparison of volumes and prices of output and GDP. The international comparison of the levels of capital input has been less prominent in the methodological literature and partly this is because the principles that apply to the output side are directly transferable to the input side, so there seemed to be little need for extra elaboration. Also, data availability often forces the analyst to use highly simplified assumptions by which conceptual questions about international comparisons are more or less defined away. For example, when labour inputs are measured as undifferentiated hours worked, it is straight forward to compare them across countries. Such an easy comparison is, however, only possible because it is assumed that every hour worked has exactly the same productive properties, independent of the experience, the educational attainment or the skill of workers, and independent of the country or the industry where it is delivered. O'Mahony and de Boer (2002), Jorgenson (2003), Inklaar et al. (2006) are exceptions to this rule – they derive international comparisons of labour input measures that take account of the compositional change of the labour force.

Comparisons of capital input suffer sometimes from a deficiency similar to comparisons of labour input when no account is taken of the composition of capital inputs. The following section describes how such compositional effects can be incorporated into level comparisons of capital input.

A quantity index of capital services

We start by re-stating the measurement of capital services over time within a country or within an industry. Capital services are the flow of services by which capital goods contribute to production. It is typically assumed that, for each type of capital goods, the flow of capital services is proportional to the productive stock of the same type of capital

employment data. Adjustments to the CPS underlying population base are made annually using intercensal estimates and every ten years using the decennial census. Also, establishment hours data are more consistent with the measures of output used to produce productivity measures; output data are based on data collected from establishments. In addition, establishment data provide reliable reporting and coding on industries and thus are well-suited for producing industry-level measures. Measures for industries based on household reports tend to produce industry estimates with considerable variance, even in a survey as large as the CPS. Thus, the BLS's official measures by industry come from establishment surveys wherever possible.

good. The productive stock reflects the productive capacity embodied in the available stock. Proportionality between the productive stock and the flow of capital services implies that the rate of change of capital services equals the rate of change of the productive stock of each asset. An overall index of capital services is derived by weighting the flow of each asset's capital services by its marginal productivity. Marginal productivity cannot be observed directly, but the theory of production tell us that the marginal productivity of an asset relative to the overall marginal productivity of capital equals each asset's share in the overall user costs of capital. The latter can be measured as the price that the owner of a capital good would charge for renting it out during one period. This provides a handle for the derivation of conceptually correct weights in a capital services index. The theoretical foundations of capital services measures are largely due to Jorgenson (1963, 1965, 1967) and Jorgenson and Griliches (1967). The necessary theory of index numbers and aggregation has been developed by Diewert (1978, 1980) and this literature forms the basis for most empirical studies in capital measurement.

Capital measures in the OECD Productivity Database are also based on these theoretical foundations and time series of capital input between period t and period t-1 in country j are derived as a Törnqvist index:

$$\ln\left(\frac{K_t^j}{K_{t-1}^j}\right) = \sum_s^M \overline{w}_s \ln\left(\frac{K_{s,t}^j}{K_{s,t-1}^j}\right) \qquad (1)$$

$$\overline{w}_{s,t} = \tfrac{1}{2}\left(w_{s,t}^j + w_{s,t-1}^j\right)$$

$$w_{s,t}^j \equiv \frac{u_{s,t}^j K_{s,t}^j}{\sum_s^M u_{s,t}^j K_{s,t}^j};$$

In (1), $K_{s,t}^j$ stands for the productive stock of asset type s=1,2,…M in country j=1,2,…N at the beginning of period t, $u_{s,t}^j$ is period t user cost per unit of the productive stock of type s. $K_{s,t}^j$ is itself constructed with the perpetual inventory method, i.e., by aggregating across volumes of investment in past periods and by weighting each of these investment flows with a factor that reflects productive efficiency and retirements. A full description of data and concepts can be found in Schreyer et al. (2003).

Bilateral comparisons

The temporal Törnqvist index of capital input above has a strong theoretical basis[206] and one can directly build on these properties to develop a similar index for spatial comparisons of capital input. In principle, all that needs to be done is to substitute the time periods t and t-1

206 The Törnqvist index is a superlative index number formula (Diewert 1976), i.e., an exact representation of a flexible aggregator function. In the present case, the underlying aggregator function is a cost function and the above index of capital input will be exact if we assume that the cost function is of the translog form, that capital markets are competitive and that producers minimise costs.

with country indices A and B in expression (1). This is the **translog bilateral input index** γ_t^{AB} as derived by Christensen et al. (1981) and by Caves et al. (1982):

$$\ln\gamma_t^{AB} = \sum_s^M \overline{w}_{s,t}^{AB} \ln\left(\frac{K_{s,t}^A}{K_{s,t}^B}\right) \quad (2)$$

$$\overline{w}_{s,t}^{AB} = \tfrac{1}{2}\left(w_{s,t}^A + w_{s,t}^B\right)$$

$$w_{s,t}^j \equiv \frac{u_{s,t}^j K_{s,t}^j}{\sum_s^M u_{s,t}^j K_{s,t}^j};\ j = A, B.$$

The theoretical formulation in (2) implicitly assumes that at the level of individual assets, inputs are measured in physical units and that they can therefore be directly compared across countries. In practice, this is not the case and stocks of asset groups are expressed in national currency units of some base year such as 'constant 1995 dollars', reflecting the fact that individual asset types are aggregations across similar sub-types of assets rather than truly homogenous investment goods that could be expressed in physical units. Thus, country A's productive stock of asset type s $K_{s,t}^A$ is measured in currency units of country A and consequently not comparable to $K_{s,t}^B$, expressed in currency units of country B. More specifically, the underlying valuation is in terms of investment goods prices of a base period. This base period for the underlying investment goods price index may or may not coincide with the year of the spatial comparison. We use the asset-specific price index and express each asset's productive stock at replacement costs of the comparison period. Finally, to make the productive stocks of countries A and B comparable, the purchasing power parity for investment good of type s, $q_{s,t}^A / q_{s,t}^B$ has to be applied to (2) to obtain:

$$\ln\gamma_t^{AB} = \sum_s^M \overline{w}_{s,t}^{AB} \ln\left(\frac{K_{s,t}^A}{K_{s,t}^B}\frac{q_{s,t}^B}{q_{s,t}^A}\right). \quad (3)$$

The extension to an index of capital productivity is straightforward. We define a ***bilateral Törnqvist index of capital productivity***[207] as

$$\ln\theta^{AB} = \ln\lambda^{AB} - \ln\gamma^{AB} \quad (4)$$

where λ^{AB} is the volume of output in country A relative to country B. We skip the presentation of a theoretical Törnqvist quantity index of output here because in our applications we use a readily-available indirect quantity index of GDP, obtained by dividing money values of GDP in the various countries by the OECD/Eurostat PPPs, i.e., by a spatial price index. This spatial deflation yields comparable volume indices of GDP.

207 The time subscript t has been dropped here to facilitate notation.

The index of capital productivity in (4) can be compared with an index of labour productivity. In principle, labour input should be gauged with a method that is exactly parallel to the measure of capital input, i.e., by aggregating across different types of labour taking into account the relative skills, qualifications and educational attainment of the labour force. Presently, the necessary data for such a differentiation is, however, not available and we have to content ourselves with a measure of labour input that reflects total but undifferentiated hours worked. Letting H_t^A be the number of total hours in country A and period t and letting H_t^B be the number of total hours in country B and period t, a ***bilateral index of labour input*** and a ***bilateral index of labour productivity*** are defined as:

$$\ln h^{AB} = \ln\left(\frac{H^A}{H^B}\right) \tag{5}$$

$$\ln \pi^{AB} = \ln \lambda^{AB} - \ln h^{AB}. \tag{6}$$

It is now a small step towards deriving an index of multifactor productivity (MFP). A bilateral index of MFP shows the difference in output between two countries that cannot be attributed to differences in the number of hours worked or to differences in capital input. Akin to the computation over time, MFP is a residual, obtained by weighting relative labour and capital inputs and adjusting relative outputs for relative inputs. Alternatively, MFP can be described as a weighted average of labour and capital productivity, where each of the two partial productivity measures are weighted by the respective share of labour and capital in total costs. For the purpose at hand, we shall choose the latter avenue and define a ***bilateral index of multifactor productivity*** μ^{AB} as:

$$\begin{aligned} &\ln \mu^{AB} = \bar{v}^{AB} \ln \pi^{AB} + (1-\bar{v}^{AB}) \ln \theta^{AB} \\ &\quad \bar{v}^{AB} = \tfrac{1}{2}\left(v^A + v^B\right). \\ &\quad v^j = p_w^j H^j \Big/ \left(p_w^j H^j + \textstyle\sum_{s=1}^{M} u_s^j K_s^j\right) \;\; j = A, B. \end{aligned} \tag{7}$$

In (7), v^A is the share of labour compensation $p_w^A H^A$ in the total compensation of labour and capital $p_w^A H^A + \sum_{s=1}^{M} u_s^A K_s^A$. Similarly, v^B is country B's labour share and $\bar{v}^{AB}$ is the average share between the two countries.

An alternative way of presenting equation (7) is as a de-composition of the labour productivity difference between the two countries. With a few transformations, one obtains

$$\ln \pi^{AB} = (1-\bar{v}^{AB})(\ln \gamma^{AB} - \ln h^{AB}) + \ln \mu^{AB}. \tag{8}$$

Expression (8) breaks the bilateral index of labour productivity into two parts: an index of relative capital intensity (the ratio between the index of capital services and the index of hours worked), weighted by the share of capital in total costs and the index of multi-factor productivity. This presentation is well known from the temporal equivalent to (8) in growth accounting exercises. The above de-composition can be carried further to identify the contribution of different asset types to labour productivity differences. In particular, we can distinguish between information and communication technology (ICT) assets and non-ICT assets. This is readily achieved by breaking the computation of the index of capital services (see equation (3) into an ICT and a non-ICT part:

$$\ln\gamma^{AB} = \ln\gamma^{AB}_{ICT} + \ln\gamma^{AB}_{non-ICT} \tag{9}$$

$$\text{with } \ln\gamma^{AB}_{ICT} = \sum\nolimits_{s\in ICT}\overline{w}^{AB}_{s,}\ln\left(\frac{K^A_s}{K^B_s}\frac{q^B_s}{q^A_s}\right),\ \ln\gamma^{AB}_{non-ICT} = \sum\nolimits_{s\in non-ICT}\overline{w}^{AB}_{s,}\ln\left(\frac{K^A_s}{K^B_s}\frac{q^B_s}{q^A_s}\right)$$

To put down the full bilateral de-composition of the index of labour productivity it remains to define ***the bilateral indices of total capital intensity,*** ς^{AB}***, of ICT capital intensity*** ς^{AB}_{ICT} ***and of non-ICT capital intensity,*** $\varsigma^{AB}_{non-ICT}$***:***

$$\ln\varsigma^{AB}_{ICT} = \sum\nolimits_{s\in ICT}\overline{w}^{AB}_{s,}\left[\ln\left(\frac{K^A_s}{K^B_s}\frac{q^B_s}{q^A_s}\right) - \ln h^{AB}\right] \tag{10}$$

$$\ln\varsigma^{AB}_{non-ICT} = \sum\nolimits_{s\in non-ICT}\overline{w}^{AB}_{s,}\left[\ln\left(\frac{K^A_s}{K^B_s}\frac{q^B_s}{q^A_s}\right) - \ln h^{AB}\right]$$

$$\ln\varsigma^{AB} = \ln\varsigma^{AB}_{ICT} + \ln\varsigma^{AB}_{non-ICT}$$

The ***de-composition of the bi-lateral labour productivity index*** with regards to the two asset groups and to multi-factor productivity is

$$\ln\pi^{AB} = (1-\overline{v}^{AB})(\ln\varsigma^{AB}_{ICT} + \ln\varsigma^{AB}_{non-ICT}) + \ln\mu^{AB}. \tag{11}$$

Multilateral comparisons

Bilateral comparisons, when applied to more than two countries, have the disadvantage of intransitivity, i.e., in general $\gamma^{AB} * \gamma^{BC} \neq \gamma^{AC}$. A number of techniques exist to obtain transitivity. For the purpose at hand, we apply the Caves et al. (1982) method: transitivity in a multilateral context is achieved by defining the capital input of country i relative to the capital input of all N countries as the geometric mean of the bilateral input comparisons between i and each of the countries:

$$\ln\overline{\gamma}^{i} = \tfrac{1}{N}\sum\nolimits_{k=1}^{N}\ln\gamma^{ik} \tag{12}$$

The ***multilateral Törnqvist index of capital inputs*** $\tilde{\gamma}^{ij}$ is defined as

$$\ln\tilde{\gamma}^{ij} = \ln\overline{\gamma}^{i} - \ln\overline{\gamma}^{j}. \tag{13}$$

It is not difficult to verify that this index is transitive. If a spatial index of outputs had been constructed in the present exercise, the same method would have been applied to achieve transitivity. There is no need for a particular adjustment here, however, because the OECD/Eurostat PPPs that enter the calculations have already been made transitive by a similar procedure[208] to the one described in (12) and (13).

The ***multilateral Törnqvist index of capital productivity*** $\tilde{\theta}^{ij}$ is defined as

$$\tilde{\theta}^{ij} = \ln \lambda^{ij} - \ln \tilde{\gamma}^{ij}. \tag{14}$$

Because the index of labour input is one-dimensional (the only unit are hours worked), no issue of transitivity arises and we can immediately define the ***multilateral index of labour productivity*** as:

$$\ln \pi^{ij} = \ln \lambda^{ij} - \ln h^{ij}. \tag{15}$$

Finally, to compute a multilateral Törnqvist index of multi-factor productivity $\tilde{\mu}^{ij}$ we construct the geometric mean of the bilateral MFP comparisons between i and each of the N countries:

$$\ln \bar{\mu}^{i} = \tfrac{1}{N} \sum_{k=1}^{N} \ln \mu^{ik} \tag{16}$$

The ***multilateral Törnqvist index of multi-factor productivity*** $\tilde{\mu}^{ij}$ is defined as

$$\ln \tilde{\mu}^{ij} = \ln \bar{\mu}^{i} - \ln \bar{\mu}^{j}. \tag{17}$$

The ***multilateral decomposition of the labour productivity index*** follows the same logic and is given by

$$\ln \tilde{\pi}^{ij} = \ln \tilde{c}^{ij}_{ICT} + \ln \tilde{c}^{ij}_{non-ICT} + \ln \tilde{\mu}^{ij} \tag{18}$$

where

$$\ln c^{ik}_{s} = (1 - \bar{v}^{ik}) \varsigma^{ik}_{s} \qquad s = ICT, non-ICT$$

$$\ln \bar{c}^{i}_{s} = \sum_{k=1}^{N} \ln c^{ik}_{s} \qquad i = 1,2,....N$$

$$\ln \bar{c}^{j}_{s} = \sum_{k=1}^{N} \ln c^{jk}_{s} \qquad j = 1,2,....N$$

$$\ln \tilde{c}^{ij}_{s} = \ln \bar{c}^{i}_{s} - \ln \bar{c}^{j}_{s}$$

Results

The empirical productivity measures developed in the present paper all relate to the total economy. This reflects data constraints more than a choice. Preferably, computations would

208 The OECD/Eurostat Purchasing Power Parities Programme uses the Eltetö and Köves (1964) and Szulc (1964) "EKS" method to derive their spatial deflators. The EKS method reaches transitivity by a transformation that is identical to the one in equation (12), the only difference being that the EKS method uses a Fisher Ideal index number formula whereas we have used a Törnqvist formula.

also single out the corporate or business sector as well as individual industries. However, measures of capital input and hours worked are not easily available in such a sectoral breakdown and calculations remain at the aggregate level, in line with the OECD Productivity Database.

We start by reproducing the set of data on output and hours worked for 2002 that forms the basis for the measurement of relative labour productivity levels. Of the seven countries under consideration, only France exceeds the labour productivity level of the United States. Labour composition may actually be one of the explanatory factors behind this. OECD (2005) shows that the employment rates for young and older workers are particularly low in France compared to other OECD countries. High minimum labour cost relative to average labour cost has tended to lower demand for labour, especially certain groups such as young and low-skilled workers. By implication, employment is concentrated in the most productive segment of the population (Bourlès and Cette 2005), an effect that is not controlled for in our undifferentiated measure of labour input and which has to be taken into account when interpreting productivity figures.

T 13 – 1 Levels of GDP, hours worked and labour productivity in 2002

USA = 100

Multilateral index of:	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
GDP at 2002 PPPs	5.5	8.9	16.6	21.5	0.8	16.5	100.0
Hours worked	6.8	10.9	15.3	22.4	1.4	18.7	100.0
Labour productivity	80.1	82.1	109.0	95.7	60.8	88.0	100.0

Source: OECD Productivity Database.

Table 13–2 below shows multilateral indices of capital services, capital intensity and capital productivity. As outlined in the methodological section, indices of capital services differ from indices based on net or gross capital stocks insofar as different assets are weighted with their share in total user costs. User costs are designed to capture the marginal productivity of assets so that high productivity assets receive larger weights. Typically, short-lived assets such as information and communication products fall under this category because short service lives and rapid price declines require high marginal productivity while such assets are in operation. Consequently, indices of capital services will tend to be higher for those countries whose investment and capital stock structure is biased towards high-productivity, short-lived capital goods relative to other countries. While the indices of capital services reflect also each country's size, indices of capital intensity and capital productivity are normalised by labour input and output. One notes considerable differences in capital intensity (i.e., capital services per hour worked) between countries.

T 13 – 2 Levels of GDP, hours worked and labour productivity in 2002
USA = 100

Multilateral index of:	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
Capital services	6.1	8.4	14.1	23.0	0.7	12.1	100.0
Capital intensity	89.5	77.8	92.6	102.3	50.8	64.5	100.0
Capital productivity	89.5	105.5	117.7	93.5	119.7	136.5	100.0

Source: OECD Productivity Database and author's calculation.

Checking the results against similar studies, we find that our results are in the same order of magnitude as O'Mahony and de Boer (2002) as far as the relative capital intensities between the United Kingdom and the United States are concerned[209] and considering that O'Mahony and de Boer use a measure of net capital stock. However, the gap with their results for France seems wide – they find a much higher relative capital intensity than we do.

The bilateral results for Canada and the United States seem to be roughly[210] in line with the relative capital intensity computed by Rao et al. (2003). We were, however, unable to match our bilateral measures of capital intensity with those available from the Database of ICT Investment and Capital Stock Trends of the *Centre for the Study of Living Standards*[211] although there are also a number of differences in concept and scope which may account for differences in outcome.

Table 13–3 exhibits multilateral indices of labour, capital and multifactor productivity for the year 2002. There are only limited possibilities to compare the result with other studies: Rao et al. (2003) find a similar MFP ratio for Canada vis-à-vis the United States but use a different concept of capital input. Jorgenson (2003) uses a constant quality measure of labour input whereas we use a simple measure of hours worked, which makes the comparison of the productivity residual difficult. O'Mahony and de Boer (2002) make a similar adjustment for labour composition as Jorgenson but do not adjust for capital composition. They find a larger productivity gap between the UK and the United States than we do and a smaller difference between the UK and France.

209 With the UK=100, our capital per hour ratios are 155 for the USA, and 158 for Germany in the year 2002. This compares with O'Mahony's and de Boer (2002) values of 146 for the USA and 147 for Germany in the year 1999.

210 Rao et al. (2003) compute relative a capital intensity of 95% for the year 2000 between Canada and the United States. However, their calculation relates to the business sector, and not to the total economy as in our study. Furthermore, the authors use a measure of the net stock in 1997 dollars, and so differ from the capital services concept used in the present study. If the USA has a relatively larger share in short-lived ICT capital, this would explain why our measure of capital intensity shows a relatively higher value for the USA than the measure obtained by Rao et al. (2003).

211 Available from http://www.csls.ca/. In Table S32 of the database, the non-residential capital stock per worker in the Canadian business sector shows up with a 131% value over the corresponding U.S. figure.

T 13 – 3 Capital, labour and multifactor productivity in 2002

USA = 100

Multilateral index of:	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
Multifactor productivity	81.5	86.6	110.5	94.4	70.7	97.0	100.0
Labour productivity	80.1	82.1	109.0	95.7	60.8	88.0	100.0
Capital productivity	89.5	105.5	117.7	93.5	119.7	136.5	100.0

Source: OECD Productivity Database and author's calculations.

Finally, we show the decomposition of labour productivity ratios into the effects of capital intensity and MFP, where capital measures are broken down into ICT and non-ICT capital goods. The outcome is presented in table 13–4 below. Several observations are in place.

First, the table starts with a measure of GDP per capita before moving to the labour productivity index. The index of GDP per capita can be broken down into labour-utilisation and labour productivity gaps of the countries relative to the United States. It is immediately apparent that lower working hours per capita account for the main part in the GDP per capita gap in the two European countries (this holds for many European countries as well, see OECD 2005, 2006). This is due to low participation of people of working age in the labour market and high unemployment. The effect is typically reinforced by fewer hours worked per employee, as part-time work is more prevalent and annual working hours for full-time workers are lower. Labour productivity differences account for the bulk of differences in GDP per capita vis-à-vis the United States for the other countries in the sample, as can be seen from an index of labour utilisation that is close to 100 for Australia, Canada, New Zealand but also relatively high for the United Kingdom. Note, however, that the simple accounting of the difference in the GDP per capita gap may give a distorted picture of countries' relative strengths and weaknesses because aggregate labour utilisation and productivity can be interdependent. Countries with low labour utilisation may not employ many low productivity workers, thereby artificially boosting measured labour productivity relative to that in countries with high employment rates.

Second, the decomposition of the labour productivity index shows that, of the countries in the sample, only New Zealand and the United Kingdom have markedly different indices of labour productivity and MFP. In Australia, France and Germany, the effect of capital intensity does not play an outstanding role. All countries show however an index of ICT capital intensity that is less than 100, indicating a lower ICT capital intensity than the United States. This is consistent with other studies and has been the source of much discussion about the growth effects of ICT investment.

Third, the present calculations make no allowance for differences in the composition of the labour force in the various countries. One working hour is counted as one hour, independent of the level of skills and human capital of the person providing labour input. Thus, the differentiation of different types of assets that turns out to be important for a conceptually correct measure of capital input, has not been applied for labour input, mainly because data limitations have not allowed to implement the relevant calculations. This has consequences for the interpretation of the MFP measure: if a country's labour force is relatively more qualified or skilled than another country's labour force, this will have a positive effect on measured labour productivity. This labour productivity enhancing effect should be explicitly identified (see, for example Jorgenson 2003) rather than buried in the MFP residual as is the case in the calculations at hand[212].

Robustness of results

Many uncertainties prevail in the measurement of capital input, in the measurement of output and in the measurement of PPPs and the results shown above should be interpreted with a good deal of caution. For example, Ahmad et al. (2003) have estimated that level comparisons of GDP may well be subject to an error margin of several percentage points. OECD/Eurostat PPPs for GDP, while based on several thousand price observations, are nonetheless subject to statistical noise and a rule of thumb sets a 5 percentage point margin within which it may be difficult to make reliable statements about significant differences between countries' volume GDP per capita. Capital service measures, in particular when constructed at the international level, are also subject to error margins, partly because some of the underlying investment series may have been estimated, in particular for early periods. A particular issue in this context is the choice of an initial productive stock for non-residential structures: an assumed service life of 40 years would require investment series for structures from the 1940s to obtain an estimate of the productive stock in the mid-1980s. Such data are not available at the international level, and some rather simplifying assumptions have been made to establish a starting value for the stock of non-residential structures. Overall, then, there are good reasons to believe that level comparisons of capital and labour input are subject to measurement error and this part of the paper aims at establishing some bounds for such errors.

We proceed with a very simple Monte-Carlo simulation. Starting point is the assumption that the following variables are subject to measurement error: GDP, PPPs, hours actually worked, and capital services. More specifically, we assume that the observations of each of these variables are randomly distributed around their true value. Based on our point estimates for each variable, we generate a set of observations that enter the productivity level computations. For example, we generate GDP_s^i, i.e., an observation s for country i's GDP by the relationship $GDP_s^i = GDP^i(1+\varepsilon)$ where GDP^i is the value for country i's GDP from

212 To get a sense for the relative importance of labour composition in our ***MFP estimates***, an approach proposed by Bourlès and Cette (2005) can be applied. The idea is that when employment rates are low, the average skill of employed workers is higher than when employment rates are high. The fact that high-skilled workers are hired before low-skilled workers or, alternatively, that unemployment is concentrated among low-skilled workers seems to be a well-established empirical observation. Consequently, ***by regressing productivity level*** differences ***against differences*** in employment rates, ***it is possible*** to get a handle on differences in the skill composition of employment. A simple version of the Bourlès ***and*** Cette (2005) method applied to the data at hand shows remarkable differences in results for France whose relative MFP level drops from over 110% as initially measured to just over 101% and 98% when relative employment rates and the position in the business cycle are controlled for. The figures for Germany also show a relatively important drop (about four percentage points) when based on total employment rates. For all other countries in the sample the effects are much smaller.

T 13 – 4 Decomposition of labour productivity ratios in 2002

Multiplicative decomposition

Multilateral index of:	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
GDP at 2002 PPPs	5.5	8.9	16.6	21.5	0.8	16.5	100.0
Population	6.9	10.9	21.3	28.6	1.4	20.6	100.0
GDP per capita	79.6	81.8	77.9	75.1	61.2	80.1	100.0
=Effects of labour utilisation (hour worked per capita)	99.4	99.7	71.4	78.4	100.6	91.0	100.0
*Labour productivity	80.1	82.1	109.0	95.7	60.8	88.0	100.0
Labour productivity	80.1	82.1	109.0	95.7	60.8	88.0	100.0
=Effects of capital intensity	98.2	94.8	98.6	101.4	86.0	90.7	100.0
of which:							
ICT capital	97.6	96.6	95.6	96.4	94.6	96.0	100.0
Non-ICT capital	100.7	98.1	103.2	105.2	90.9	94.5	100.0
*MFP	81.5	86.6	110.5	94.4	70.7	97.0	100.0

T 13 – 5 Decomposition of labour productivity ratios in 2002

Additive decomposition*

Multilateral index of:	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
GDP per capita	-20.4%	-18.2%	-22.1%	-24.9%	-38.8%	-19.9%	0.0%
Effects of labour utilisation (population per hour worked)	0.5%	0.2%	31.1%	20.6%	-0.4%	7.9%	0.0%
Labour productivity	-19.9%	-17.9%	9.0%	-4.3%	-39.2%	-12.0%	0.0%
Effects of capital intensity	-1.8%	-5.2%	-1.4%	1.4%	-14.0%	-9.3%	0.0%
of which:							
ICT capital	-2.4%	-3.4%	-4.4%	-3.6%	-5.4%	-4.0%	0.0%
Non-ICT capital	0.7%	-1.9%	3.2%	5.2%	-9.1%	-5.5%	0.0%
Interaction term	-0.0%	0.1%	-0.1%	-0.2%	0.5%	0.2%	0.0%
MFP	-18.5%	-13.4%	10.5%	-5.6%	-29.3%	-3.0%	0.0%
Interaction term*	0.3%	0.7%	-0.2%	-0.1%	4.1%	0.3%	0.0%

*The product of two index numbers cannot be easily de-composed into the sum of two simple discrete percentage differences – there remains an interaction term unless one chooses an additive de-composition based on continuous (i.e., logarithmic) percentage differences or based on a more complex discrete de-composition.

the national accounts and ε is an independently and normally distributed error variable with mean zero and a standard deviation of 0.02. In other words, we generate a set of data with the property that the GDP estimate from the national accounts is the most probable realisation and that there is a near 99% probability that the randomly generated observation for GDP lies within a range of 5% below and 5% above their mean, the observed value from the national accounts. A plus/minus 5% margin is generous and probably overstates the true likelihood of measurement errors. But we prefer to err on the high side than to evoke too optimistic a picture of precision in economic measurement.

Similar assumptions as for GDP levels are made for the other variables and a set of 100 artificial observations of GDP, PPPs, hours worked and productive stock for every asset and every country is generated for the year 2002.

For each of the 100 observations, we compute multilateral indices of capital services, labour and capital productivity, capital intensity and MFP. We compute the average and standard deviation of all observations to obtain statistical bounds[213] for the estimates at hand. Upper and lower bounds confine the area that contains 99% of all outcomes given the error structure that underlies the Monte Carlo experiment. They are shown in the following tables and graph.

Upper and lower bounds provide an order of magnitude for the uncertainties involved in the estimation of international indicators. The bracket for MFP estimates, for example, comprises up to 10 percentage points around the point estimate. In the case of the United Kingdom this means that on the basis of our data with their assumed observation error of +/-5%, there is a 99% probability that MFP relative to the United States may be situated somewhere between 89.4% and 103.9% (table 13–9). Or labour productivity for France can be located somewhere between 101% and 116% of the U.S. level – a particularly large range. These boundaries once more show that precise rankings of countries may be difficult to obtain and in general should not be undertaken when countries are clustered around similar values of indices of productivity or per capita income – a point that has also been made in the context of the OECD/Eurostat PPP programme (OECD 2004).

213 Given the various transformations that are necessary to obtain multilateral indices, it is not possible to demonstrate that, as a consequence of assuming normal distribution of the errors for the base data, the multilateral indices are also normally distributed. However, we apply a Jarque-Bera test to check for normality of the results generated by the Monte Carlo simulation and find that for virtually all variables the null hypothesis of a normal distribution cannot be rejected. This permits the construction of confidence intervals on the basis of normal distributions.

T 13 – 6 Upper and lower bounds for labour productivity in 2002

USA = 100

	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
Upper bound	85.5	87.9	117.1	102.5	65.1	93.5	100.0
Point estimate	80.1	82.1	109.0	95.7	60.8	88.0	100.0
Lower bound	74.6	75.9	100.5	89.8	56.7	82.4	100.0

Source: OECD Productivity Database and author's calculation.

T 13 – 7 Upper and lower bounds for capital intensity in 2002

USA = 100

	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
Upper bound	97.1	87.9	101.2	110.6	55.1	69.7	100.0
Point estimate	89.5	77.8	92.6	102.3	50.8	64.5	100.0
Lower bound	81.7	75.9	83.9	94.6	46.7	59.6	100.0

Source: OECD Productivity Database and author's calculation.

T 13 – 8 Upper and lower bounds for capital productivity in 2002

USA = 100

	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
Upper bound	99.4	117.6	132.6	103.5	132.8	150.9	100.0
Point estimate	89.5	105.5	117.7	93.5	119.7	136.5	100.0
Lower bound	79.8	93.6	102.9	84.1	106.7	121.6	100.0

Source: OECD Productivity Database and author's calculation.

T 13 – 9 Upper and lower bounds for multi-factor productivity in 2002

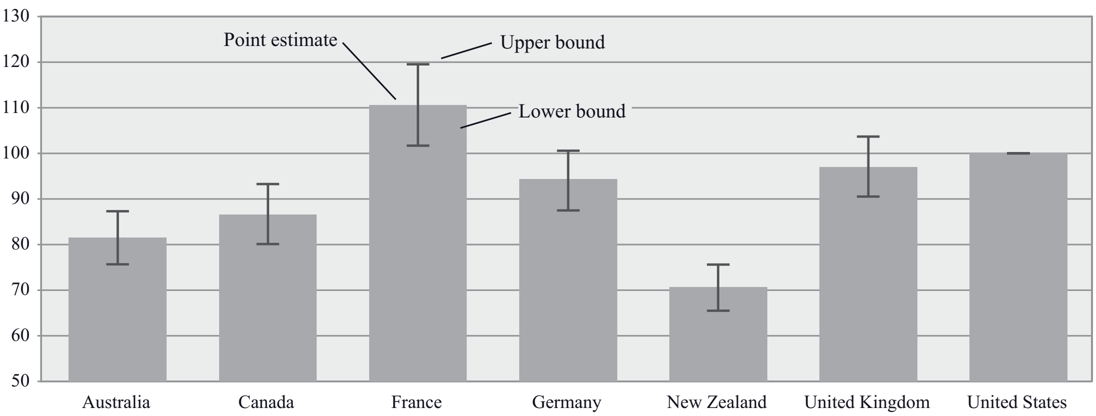
USA=100

	Australia	Canada	France	Germany	New Zealand	United Kingdom	United States
Upper bound	87.3	93.1	119.3	101.3	75.8	103.5	100.0
Point estimate	81.5	86.6	110.5	94.4	70.7	97.0	100.0
Lower bound	75.7	79.9	101.5	88.2	65.8	90.3	100.0

Source: OECD Productivity Database and author's calculation.

Upper and lower bounds for multi-factor productivity in 2002
USA = 100

G 13–1



Conclusions

The present study provides a set of partial and multi-factor productivity levels for seven OECD countries and shows how GDP per capita differences can be broken down into differences in labour utilisation, ICT and non-ICT capital intensity and MFP. The paper focuses on the statistical aspects of these indicators and refers to determinants and analysis of productivity only at the margin. Three main conclusions arise from this work:

- Level estimates of capital and multi-factor productivity are feasible and provide a useful complement to the labour productivity estimates that have been an integral part of the OECD productivity estimates for several years.
- Methodology matters – the choice of the conceptually correct measure of capital input shapes results as does the choice of index number formulae when comparisons along both the time and spatial dimension are undertaken.
- Statistical uncertainties remain and results have to be interpreted with a good deal of caution. We provide Monte Carlo estimates to examine the effects of measurement errors in the base data and these simulations showed that boundaries for the resulting indicators can be important.

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14. RESEARCH AND DEVELOPMENT AS A VALUE CREATING ASSET

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Introduction

In the current environment of rapid technological change, research and development (R&D) has proven to be an important element of economic growth. R&D is considered one of a number of measures of innovation performance and various studies have shown that investment in R&D is an important source of productivity growth (for example Griliches, 1981). R&D investment reduces production costs, as inputs are more effectively transformed in to outputs, and it alters output characteristics, thereby providing new products to the marketplace (Bernstein and Mamuneas, 2004). As a result, the promotion of investment in R&D has become a priority within the EU.

In Barcelona, 2002, EU heads of Government set a target for EU R&D to reach 3 per cent of GDP by 2010, with two-thirds of this coming from businesses. As a result of this, many EU countries set domestic targets, including the UK. The UK government set a target of 2.5 per cent of GDP by 2014 (total UK R&D currently stands at 1.78 per cent of GDP, ONS 2006). In the scenario attached to the governments R&D target it envisages that business R&D will reach 1.7 per cent of GDP with R&D in higher education and government making up the balance.

In 2004, expenditure on R&D in the UK totalled £21bn, an increase of 1 per cent in cash terms from 2003. However, as a percentage of GDP the rate of R&D in the UK has been falling over the past three years from 1.86 per cent in both 2002 and 2003 to 1.78 per cent of GDP in 2004 (ONS, 2006).

The official guidelines for collecting R&D data come from the OECD Frascati manual. The manual deals exclusively with the measurement of human and financial resources devoted to R&D, namely R&D ‘input’ data. It provides a platform for internationally comparable data on R&D. The manual describes R&D as ‘comprising creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications’.

214 This paper presents the current stage of an ongoing project jointly funded by the Office for National Statistics and Eurostat. As such its content is work in progress and we would welcome comments and suggestions. All the analysis presented here was carried before the latest ONS BERD data revisions. We are grateful to earlier comments from Tony Clayton and Mark Rogers. All remaining errors and omissions are the responsibility of the authors. The statistical data presented here is Crown Copyright and is reproduced with the permission of the Controller of HMSO and the Queen’s Printer for Scotland. Opinions expressed here are those of the authors and do not necessarily represent the views of HM Government.

The manual acknowledges three types of R&D activities: basic research, applied research and experimental development. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on the existing knowledge gains from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

Although it is widely accepted that expenditure on R&D by firms is a means to improving their productivity via new processes and product innovations, it is not recorded by National Accounts in a way that reflects this. R&D is currently treated as an intermediate input for businesses and current consumption for government and non-profit institutions.

At the Statistical Policy Committee (SPC) in November 2006 the European Member States came to a conclusion on how to handle the introduction of R&D activity as capital formation in the update of the SNA. This conclusion will be presented to the UN Statistics Commission meeting at the end of Feb 2007, when the SNA revisions will be agreed upon (the SPC expects the European view to be accepted).

The SPC concluded that ‘compulsory’ satellite accounts should be developed in the short to medium term in order to address the ‘substantial’ conceptual and measurement difficulties involved with treating R&D as an asset. It is recommended that the final decision on including R&D expenditure in core National Accounts should be taken once sufficient evidence is gained through experience in Satellite Accounts, showing that it can be measured with appropriate confidence.

As part of the consultation on the SNA 93 revisions, the Canberra II group of experts have made several recommendations to the Advisory Expert Group (AEG). Eight recommendations have been made:

1. The 1993 SNA should be changed to recognise the outputs of R&D assets, and the acquisition, disposal and depreciation of R&D fixed assets should be treated in the same way as other fixed assets.
2. In principle, freely available R&D should not be included as capital formation, but in practice it may not be possible to exclude it. The assumption is that including freely available R&D would not lead to significant error (this area is currently under review).
3. The definition of an asset should be reviewed to ensure that it covers the assets of non-market producers adequately.
4. The definition of R&D given in the Frascati Manual (FM) should be adopted in the SNA.
5. The Frascati system provides the best means of deriving estimates of R&D statistics, principally gross fixed capital formation (GFCF). However, there are shortcomings in the Frascati data and the Frascati Manual should be amended to better support the needs of the SNA.
6. Most R&D output is produced over several periods and the SNA recommendations for the production of other assets should apply. Most R&D production is on own account, which implies recording it as GFCF as it occurs under the current recommendations.

7. Detailed input price indexes, corresponding to the constituents of the estimates of R&D GFCF, should be used to derive constant price estimates of R&D output and GFCF.
8. Patented entities should no longer be recognised as assets in the system.

In preparation for revisions to the SNA relating to R&D, Eurostat have funded an ONS project to assess the practical and methodological issues involved in capitalising R&D in National Accounts. This paper presents the current state of this work and identifies areas where further work is needed. The second section provides a methodological overview, covering the estimation of R&D GFCF, estimation of R&D deflators and the estimation of depreciation rates for R&D capital. The third section describes the UK data sources on business expenditure on R&D and also other required sources that are available for implementing the methodology outlined in the previous section. Currently the focus is just on the business sector element of R&D. The fourth section presents estimates for the UK business sector based on applying the methodology outlined in the second section to the UK data described in the third section. The fifth section looks at the contribution of R&D to productivity growth. Conclusions and future work are covered in the last section.

Methodological overview

Methodological issues

Linking tables: Linking Frascati based expenditure to SNA

In order to capitalise R&D we need to translate Frascati expenditure data into an SNA compatible format. The value of R&D that we want to capitalise within the SNA framework is gross output minus intermediate inputs. The first step involves converting Frascati sectors into SNA sectors. Robbins (2005) provides the following link table.

T 14–1 Link table – Frascati sectors to SNA sectors

Frascati manual	SNA
Business enterprise sector	Non-financial corporations
	Financial corporations
Government sector	General government sector
Private non-profit sector	Non-profit institutions serving households (NPISH)
Higher education sector	General government
	NPISH
Abroad	Rest of the world

De Haan and van Horsten (2005) suggest three product groups to help translate GERD (gross expenditure in R&D) to SNA:

1. Market R&D – their value should be determined by estimated basic prices. Production costs should be used if reliable market prices are not available.

2. Non-market R&D – are by convention valued by the sum of production costs. They suggest that by convention all non-market output of goods and services is consumed by the government sector. They highlight that the sum of outlays as reflected by GERD is not consistent with the sum of production costs in accordance with National Account principles. They suggest replacing the figures on capital expenditure included in GERD with an estimation of COFC[215]. Robbins (2005) identifies R&D as a non-market good based on its producer, either government, universities or non-profit institutions.
3. Own Account – The SNA rule is to value own account production using market prices. When a suitable market price can not be used, the 'second best' option should be used i.e. the sum of the production costs.

In order to arrive at our gross output figure we need to sum intermediate consumption, capital services and net value added[216]. A bridge table between the Frascati manual and SNA data on R&D would include the following (Soli Peleg, Central Bureau of Statistics, Israel, 2006):

I. Output

A. Frascati manual GERD
(1) **Plus** Acquisition of R&D to be used as input in R&D production
(2) **Plus** Depreciation of Capital goods owned by R&D producers and used in R&D production
(3) **Plus** Net operating surplus contained in R&D output measured at basic prices
(4) **Plus** other taxes less other subsidies on production
(5) **Minus** Capital expenditures

B. R&D output by SNA93 definitions
Equal to GERD + (1) + (2) + (3) + (4) – (5)

II. Data for preparation of supply and use tables

Exports and imports of R&D

(1) R&D exports
(2) R&D imports

Not all the data implied by the above are available for R&D in the UK (Operating surplus, exports and imports of R&D output).Table 14–2 gives an indication of the UK data we do

215 COFC represents the reduction in the value of the fixed asset used in production during the accounting period resulting from physical deterioration, normal obsolescence or normal accidental damage. (OECD manual: Measuring capital, 2001).

216 Net value added is the sum of compensation of employees, other taxes on production and imports less subsidies plus net operating surplus.

have available and the adjustments we need to make to come up with a satisfactory gross output figure. This table is based on linking work done by the BEA (Robbins, 2005).

T 14 – 2 UK data availability

Non-financial corporations	Financial corporations	General government	NPISH
Business Enterprise Research and Development (BERD) survey	BERD	GOVERD (HERD for public universities)	Non-profit expenditure on R&D (HERD for private universities)
Minus capital expenditure for financial corporations	Minus capital expenditure for non-financial corporations	Minus capital expenditure including those for land and structures	Minus capital expenditure by NPISH serving business
Plus expenditure for NPISH serving business	Plus expenditure for NPISH serving business	Minus current expenditure for non-plant machinery and equipment, as well as purchased and own-account software (estimated with ratio of equipment and software to gross output)	Plus capital services
Plus R&D purchased as an intermediate input to production of R&D in the corporate sector (includes cost of any purchased R&D	Plus R&D purchased as an intermediate input to production of R&D in the corporate sector (includes cost of any purchased R&D	Plus capital services	n/a
Minus historical cost depreciation	Minus historical cost depreciation	Minus payments for trade in R&D services	n/a
Plus capital services on structures, equipment and software owned by R&D performers and used to perform R&D in the UK	Plus capital services on structures, equipment and software owned by R&D performers and used to perform R&D in the UK	n/a	n/a

Freely available R&D

In this paper we take the recommendations outlined in section 1 as given. However, recommendation two remains under discussion and no clear guidance or recommendation has yet been decided. The decision of whether or not to include freely available R&D as part of GFCF has proven to be controversial. The argument is focused largely on Higher education and Government sectors. At present the discussion is looking at excluding basic research for these two sectors, given that it would seem likely that there is no strategy in place to capture future economic benefits. Business enterprises, on the other hand, are assumed to have a profit motive and presumably think that their basic research will lead to future income, even if the results are published. Therefore, they can be expected to have a strategy in place to exploit the knowledge gained from their basic research (Aspden 2006).

Since this paper covers only business R&D, we are going to assume that we include freely disseminated R&D.

We also argue the case that unsuccessful R&D is a cost of producing R&D and is therefore indirectly incorporated in to the market value of R&D assets given they are valued at cost. Therefore, unsuccessful R&D would not have an asset life independent of successful R&D in the National Accounts. This would see R&D being treated the same as mineral exploration, where it is viewed that the returns from the successes are sufficient overall to pay for the failures.

Potential for double counting

There is a potential problem with an overlap with computer software. The Frascati Manual identifies three types of capital expenditure:

1. Land and buildings
2. Instruments and equipment
3. Computer software

The UK BERD survey asks for data under land and buildings and plant and machinery and does not separate out software. Mandler and Peleg (2003) highlight two types of potential R&D software overlaps:

1. R&D may be performed with the aim of developing a software original
2. The development of software may be part of an R&D project

Mantler and Peleg (2003) also distinguish between two products:

1. An asset – the software – that can be used repeatedly in production
2. R&D that is a product in itself, whether regarded as an asset or as intermediate consumption

Contrary to this view de Haan and Van Horsten (2005) assume that R&D fully devoted to the development of a new software original, will generally constitute an inseparable part of the production process, with a single identifiable output. Their view and current SNA93 says that all R&D with the specific goal of developing a software original should be identified as software and not as R&D. When it is not possible to separate R&D software development within an R&D project then that software should not be recorded as a separate asset.

De Haan and Van Horsten (2005) agree with Mandler and Peleg (2003) accounting recommendations when software is developed as a supplementary tool. If it can be identified as such then the software should be identified as a separate asset and the consumption of fixed capital of this software should be part of the production costs of R&D output.

The main issue for the ONS is not so much double counting within the software industry, but the amount of R&D software being double counted within other industries. In BERD software development outside of the software industry is recorded under the product sold by the company. This software development (if classified as R&D by the company) will be included in their capital expenditure figures on the BERD form. However, ONS is likely to have already picked these figures up in its own-account software numbers, which in the future will be based on the total wage costs of labour working on own-account software production (see Chamberlain, Chesson, Clayton and Farooqui, 2006).

Whereas it will be relatively straight forward to compare the computer software industry figures from R&D and ICT surveys, the water is a little cloudier with regards to working out how much double counting has occurred for own-account software within non-computer orientated industries.

Another potential issue of double counting arises. Estimates from surveys collecting data on GFCF will include some intellectual property as the present forms do not instruct respondents to exclude it. Therefore adding in the results of the R&D survey to National Accounts will potentially lead to double counting. Additionally, not all expenditure by companies in the R&D industry will result in intellectual property. For example they also have to invest in furniture and fittings, computers etc. These numbers will be picked up not only in the R&D survey, but also within standard investment surveys, so again double counting is an issue.

Table 14–14ss in the appendix however, lists the breakdown of expenditures per industry by salaries and wages, other, plant and machinery and land and buildings for 2002. They show that the issue of double counting is different across industries, but on the whole the expenditure split is largely biased towards salaries and wages rather than capital, hence the double counting issue may not in fact be that large. Charles Aspden (2006) suggests that all producers of capital products acquire capital to produce them and this type of double counting is part and parcel of the current SNA.

Current price GFCF

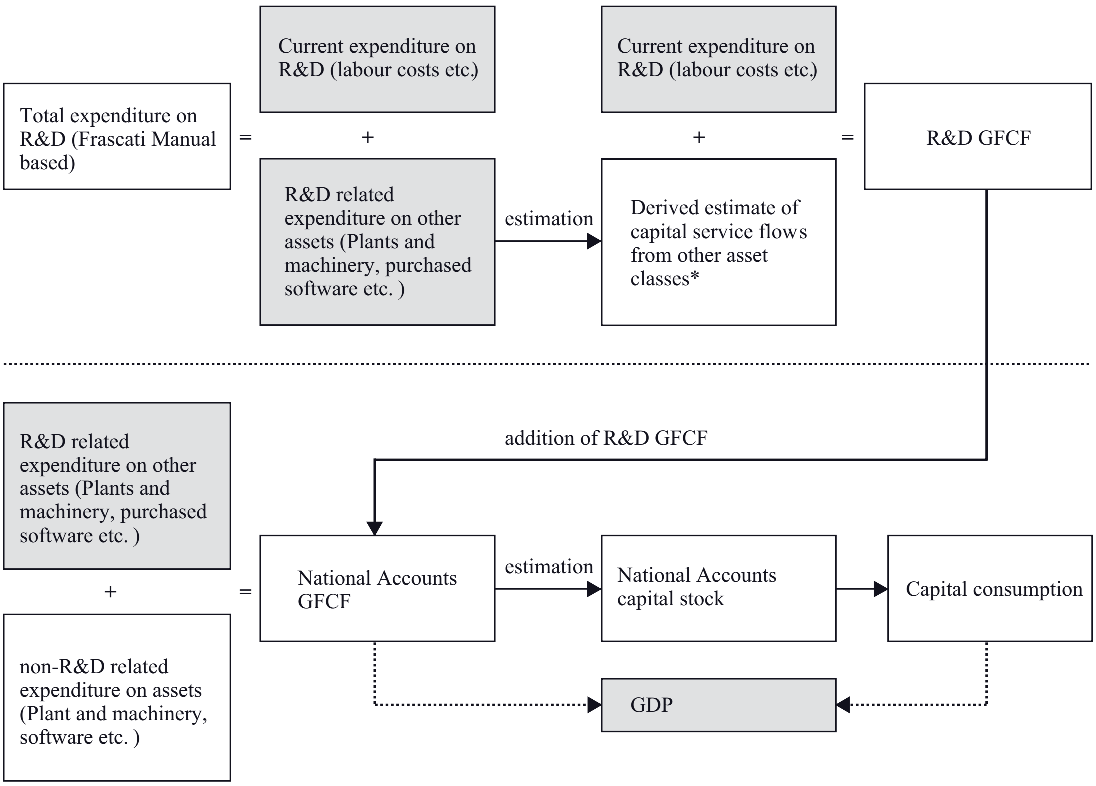
In order to estimate 'at cost' GFCF we need to make some adjustment to Frascati based expenditure data. Figure 1 below provides a diagrammatic representation of how we get from Frascati based total expenditure on R&D to a position where R&D is capitalised in the National Accounts. Figure 1 identifies that capitalising R&D will impact on total National Accounts GCFC and also on capital consumption, with both these effects having an impact on measured GDP.

We identify three different methods to derive the estimate of capital service flows from other asset classes. This capital service flow is essentially an estimate of the input of the other capital (mostly tangible capital), used in the R&D process, to the R&D capital stock. In the first model, this input is proxied by consumption of fixed capital (COFC) plus an assumed return on those assets. In the second and third models, the capital service flow from the assets used in the R&D process is measured directly. One method uses rental rates, the other capital services growth rates.

Graph 14–1 highlights that there is possibly some double counting of the other asset classes (plant & machinery etc.) used in R&D. In Figure 1 an estimated return on these assets is used to form part of R&D GFCF. Once we have R&D GFCF and added it to existing National Accounts GFCF we estimate a whole economy capital stock, from which we derive capital consumption to form part of GDP. The existing National Accounts GFCF will already include R&D related expenditure on other asset classes. This suggests that there is a case for excluding the R&D related expenditure on these other asset classes from the National Accounts GFCF (the grey box) or just taking R&D GFCF as current expenditure (just taking R&D GFCF as equal to the blue box).

Upper and lower bounds for multi-factor productivity in 2002
USA = 100

G 14–1



* Can either be derived as consumption of fixed capital COFC (capital consumption) plus a normal return on capital used or direct capital services estimates

The expenditure data we are interested in for our calculation of GFCF can be broken down in to two clear areas, intramural[217] (current and capital) and extramural[218]. Intramural expenditure can be split further between:

217 Intramural expenditures are all expenditures for R&D performed within a statistical unit or sector of the economy during a specified period, whatever the source of funds.

218 Extramural expenditures are the sums a unit, organisation or sector reports having paid or committed themselves to pay another unit, organisation or sector for the performance of R&D during a specified period. This includes acquisition of R&D performed by other units and grants given to others for performing R&D.

1. Current expenditure:

Salaries and wages: includes all overtime payments, bonuses, redundancies, commissions and holiday pay and should be gross.

Other: Purchases of goods and services from outside the unit, including overseas purchases, and scientific services should be included, provided no R&D is involved. Contractors employed on R&D projects are included here.

2. Capital expenditure:

Land and Buildings

Plant and Machinery

This should include annual gross expenditure on fixed assets used in R&D projects. Land and buildings comprises the acquisition of land and buildings, costs of major improvements and modifications or repairs.

We used the total extramural figure as an estimate for R&D purchased as an intermediate input. Hence we summed expenditure bought within and outside the UK. We, however, acknowledge the issue here with transfers versus purchases.

We have created three different estimates for R&D GFCF. They differ by the way in which we have estimated the services flow into R&D GFCF from the capital expenditure on land & buildings and plant & machinery used as part of the R&D process.

Method 1: Consumption of fixed capital (COFC) plus an assumed return

In method 1 our estimate of R&D GFCF is calculated as the following:

$$GFCF_t^{CP} = \left(C_t + \sum_a I_{at}^{CP} \right) - \sum_a I_{at}^{CP} + \sum_a COFC_{at} + \sum_a R_{at}$$

Where C_t is current expenditure on R&D, I_{at}^{CP} is current price investment in the asset type *a* being used in the R&D process[219], $COFC_{at}$ is the consumption of asset type *a* being used in the R&D production process and R_{at} is the assumed return on asset type *a* being used in the production process.

COFC in time *t* for an asset of type *a* is given by the following.

$$COFC_{at} = K_{at} \cdot \delta_a$$

Where K_{at} is the net stock of asset type *a* at time *t* and δ_a is the rate of depreciation of asset *a*. To calculate a net stock for each asset type we used the perpetual inventory method (PIM).

219 Using UK data we can only identify two asset types here - land & buildings and plant & machinery.

A geometric PIM was used to calculate net stock as follows.

$$K_{at} = \sum_{\tau=0}^{\infty} (1-\delta_{a,t-\tau})^{\tau} \cdot I_{a,t-\tau}$$

Where I is constant price investment in asset *a*. In constructing this PIM we made the following assumption about the net capital stock in the initial year, assuming a steady state.

$$K_{a0} = I_{a0} / \delta_a$$

Finally for this model, we needed to calculate R_{at}. We used the Australian Bureau of Statistics assumption that the rate of return on capital used in the R&D process is 5 per cent.

$$R_{at} = 0.05 \cdot K_{at}$$

Method 2: Capital services estimated using rentals

In method 2 our estimate of R&D GFCF is calculated as the following:

$$GFCF_t^{CP} = \left(C_t + \sum_a I_{at}^{CP} \right) - \sum_a I_{at}^{CP} + \sum_a CS_{at}$$

Where variables are as defined above and CS_{at} is the capital service flow at time *t* from the asset type *a* being used as part of the R&D process[220].

For method 2 CS_{at} is calculated as the real level of capital services.

$$CS_{at} = K_{at} \cdot r_{at}$$

Where r_{at} is the rental for asset *a* at time *t*. The rental is calculated using the Hall-Jorgenson (Hall and Jorgenson, 1967) formula for the cost of capital in discrete time *t*.

$$r_{at} = T_{at}[\delta_a \cdot p_{at} + R_t\, p_{a,t-1} - (p_{at} - p_{a,t-1})]$$

where p_{at} is the price of an asset of type *a* at time *t*, δ_a is the rate of depreciation, and R_t is the rate-of-return. T_{at} is the tax-adjustment factor which is given by the following:

$$T_{at} = \left[\frac{1-u_t D_{at}}{1-u_t} \right]$$

where u_t is the corporation tax rate and D_{at} is the present value of depreciation allowances as a proportion of the price of asset type *a*.

220 Capital services refer to the flow of productive services from the stock of capital. Capital services recognises that the same stock of capital may be used more or less intensively (capacity utilisation).

Method 3: Capital services estimated using capital services growth rates

In method 3 our estimate of R&D GFCF is calculated as the following:

$$GFCF_t^{CP} = \left(C_t + \sum_a I_{at}^{CP} \right) - \sum_a I_{at}^{CP} + \sum_a CS_{at}$$

This is as in method 2. Here however CS_{at} is calculated using a different method. In the initial year the capital service input to R&D is estimated using the real level of capital services as in method 2.

$$CS_{a0} = K_{a0} \cdot r_{a0}$$

Subsequent years are calculated as follows.

$$CS_{at+1} = CS_{at} \cdot g_{at} \text{ for } t = 1, 2, \ldots$$

Where g_{at} is the growth rate of capital services for asset *a* at time *t*.[221]

Constant price GFCF – Volume estimates: Industry specific deflators

A suitable deflator is needed in order to convert current price R&D GFCF into constant price GFCF. If we want to look at the contribution of R&D expenditure to economic growth and productivity then we need to correct for inflation. Jankowski (1991) highlights the absence of relevant deflators, needed for investigating the links between R&D and other components of the innovation process.

The major problem associated with constructing a deflator for R&D is that it is a very heterogeneous product. By definition every project is different and hence will not command the same price in the market place. Given that the majority of R&D is carried out on own account, this makes it hard, if not impossible, to calculate a market price (output price). As a result the next best solution would appear to be the use of input prices.

The ONS has used input based indexes to estimate output volumes. These may well seem inappropriate, but there are many other areas within National Accounts where they are used when a better alternative is not available. We have calculated industry specific deflators for business R&D and we began by identifying the expenditure areas on BERD that we were interested in:

Wages and salaries
Other current expenditure
Land and buildings
Plant and machinery.

221 Capital services growth rates are a much more common output of statistical offices than estimated rental rates. UK capital services growth rates are published annually (see Wallis (2005)) but currently rentals are not.

We calculate R&D cost components and their appropriate weights in order to calculate a simple weighted index and a divisia index. Cameron (1996) argues that a divisia index is theoretically and empirically better at capturing changes in the cost of R&D than fixed weighted indices such as the Laspeyres or Paasche indices.

The following table indicates the data sources we used:

T 14 – 3 Deflator data sources

R&D component	Proxied by	Source
Wages and salaries	Index of earnings of science and technology professionals	Annual Survey of Hours and Earnings (ASHE)
	Index of average earnings of technicians	ASHE
	Index of average earnings of Administrative occupations	
Other current expenditure (materials etc)	PPI (input) materials and fuels purchased by manufacturing excluding FBTP	Producer price indices
Capital	Separate index for plant and machinery and land and buildings	National Accounts capital stock deflators

The UK BERD form asks for firms to breakdown their average employment on R&D (number of full time equivalents) in to three areas:

Scientists and Engineers: Includes Professional scientists or engineers engaged in the conception, or creation of new knowledge, products, methods and systems.

Technicians: Are qualified personnel who participate in R&D projects by performing scientific and technical tasks, normally under the supervision of professional scientists and engineers. They will usually have scientific or engineering qualifications.

Other: Supporting staff include skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects.

In order to obtain wage information for these three occupational areas we used data from the Annual Survey hours and Earnings (ASHE). From this dataset we were able to obtain data on gross weekly wages (based on April figures) for 33 industries across several standard occupational classification (SOC) codes.

Because the SOC codes changed (from SOC90 to SOC2000) in 2002 we also had to match SOC90 and SOC2000 to make them as consistent as possible across our time horizon.

The following table highlights the codes we used for each:

T 14 – 4 SOC codes

SOC90	SOC2000
21: Engineers and technologists	21: Science and technology professionals
30: Scientific technicians	31: Science and technology associate professionals
40: Admin/clerical officers and assistants in the civil and local govt	41: Administrative professionals
41: Numerical clerks and cashiers	4214: Company secretaries
45: Secretaries, PAs, typists, word process operators	4215: PAs and other secretaries
46: Receptionists, telephonists and related occupations	4216: Receptionists
49: Clerical and secretarial occupations	4217: Typists

We merged together the admin codes for each SOC to produce one weekly wage figure as proxy wages for ‘other’ on the BERD form. For example, for SOC90 we merged 40, 41, 45, 46 and 49 to give us one average weekly wage for each of the 33 industries. The same was done for SOC2000 i.e. we merged 41, 4214, 4215, 4216 and 4217 to produce one broad admin weekly wage. We were able to obtain data from 1997–2004 across the thirty three industries covered by BERD for the following three areas:

1. Science and technology Professionals
2. Technicians
3. Administrative occupations

We used these as proxy wage estimates for the three employment sectors defined on the BERD form, namely 1. as a proxy for Scientists and engineers, 2. as a proxy for technicians and 3. as a proxy for other.

For all the industries bar two we were able to obtain information. However, for sectors A (agriculture, forestry and fishing) and X (recycling), the small sample sizes made the information disclosive. For these two industries we used wage data that represented the entire sector and not the three specific occupational areas we were after. Hence for A and X we used industry aggregate weekly gross wages.

We used a simple weighting technique to create our initial index and then calculated a divisia index to see if there was much difference. We choose 2000 as our base year (making it consistent with our other National Accounts indices).

Initially a price index was calculated for each of the three employment areas; scientists, technicians and other and then the weights were applied to these indices:

$$W_s = \frac{E_s}{E_T};\ W_t = \frac{E_t}{E_T};\ W_o = \frac{E_o}{E_T}$$

Where:

W_s : Weight for scientists and engineers

W_t : Weight for technicians

W_o : Weight for 'other'

E_T : Total Frascati based expenditure on salaries and wages

E_s : Frascati based expenditure on scientists and engineers

E_t : Frascati based expenditure on technicians

E_o : Frascati based expenditure on 'other'

An aggregate index for salaries and wages was then calculated as:

$$P_{WS} = P_s W_s + P_t W_t + P_o W_o$$

Where P_s, P_t, and P_o are the price indices for scientists and engineers, technicians and other workers. For current expenditure we were unable to create an industry specific index due to data restrictions. We used a PPI input index as a proxy, namely PPI materials and fuels purchased by manufacturers excluding FBTP. On the capital side, we were able to use deflators already provided by National Accounts.

We then calculated an aggregate R&D index for each of the thirty three industries represented in BERD, applying the same methodology as above. Each index for salaries and wages, current other, plant and machinery and land and buildings was multiplied by its relevant weight and summed.

Lag times

It takes time to complete an R&D project and while work continues there is an accumulation of work in progress in inventories. Aspden (2005) notes that in concept, that once the project is complete the inventory should be run down and transferred to fixed capital formation.

Pakes and Shankerman (1979) note that there are two types of lag.

- Gestation lag is the time taken to undertake the R&D project
- Application lag is the time taken from completion of the project to its initial commercial use.

They suggest that the sum of gestation and application lags may range from 1.5 to 2.5 years. De Haan and van Horsten (2005) suggest the implication of such lags is that R&D output is initially recorded as work in progress i.e. changes in inventories. The completed R&D project is then recorded as GFCF when it is finished in the subsequent year, counterbalanced by negative withdrawals from inventories.

The BEA (1994) notes that survey based research found that gestation lags range from one to two years and the application lags range from less than one year to more than two years. For the purpose of deriving capital formation of R&D only (half) the gestation lag needs to be considered and the BEA used a one year lag.

Aspden (2005) suggests that once a quantum of knowledge has been gained then it can be said there was fixed capital formation. This implies that you do not necessarily have to wait until the project has been completed before GFCF is recognised. This line of argument implies that R&D output need not be very long in inventory before it can be legitimately viewed as an asset that contributes to further R&D production or some other output.

There are a number of assets that require a number of accounting periods to be produced e.g. large construction projects. The bulk is undertaken on own account, which implies recording it as GFCF as it occurs. That which is intended to be sold should be recorded as work in progress of the producer (note that SNA 93 recommendations on this regard are subject to review by the Canberra II group as part of the issue “Classification and terminology of non-financial assets”).

Depreciation rates

In calculating an R&D stock, evidence supports the use of the perpetual inventory method (PIM). The gross stock of R&D would be a measure of the cumulative value of past investment still in existence. Whilst the net capital stock would be equal to the gross stock less the accumulated depreciation on assets in the gross stock. Depreciation rates can be based on asset lives or they can be deduced using econometric studies of new and second-hand asset prices.

Whereas some research treats R&D as a permanent part of the capital stock once added, the consensus thinking is that once R&D capital has entered the capital stock it is gradually removed by depreciation (consumption of fixed capital).

The empirical evidence on depreciation rates for R&D assets is limited. The research that has been carried out has either taken on estimating depreciation rates using econometric models (for example Bernstein and Mamuneas, 2004) or using a patent renewal method (for example Pakes and Schankerman, 1978, 1984). The little evidence that has emerged from both types of analysis has on the whole produced a common message that industrial knowledge depreciates faster than physical capital. Mansfield (1979), Pakes and Shankerman (1978,1984) suggest there is little knowledge capital left after ten years. Bernstein and Mamuneas (2004) estimate that R&D capital depreciates at 2 to 7 times that rate of physical capital.

Depreciation rates reflect technical efficiency and indicate the productiveness of ‘old’ capital required to generate the same level of services as ‘new’ capital (Jorgenson, 1989 and Hulten and Wykoff, 1996). The growth of R&D capital depends on its ‘economically useful life’. If the depreciation rate increases, then more resources need to be used in knowledge creation in order to maintain a constant knowledge outcome. This re-allocation of resources would raise the opportunity cost of R&D, and ceteris paribus, reduce the rate of knowledge creation. Hence it is important to estimate an R&D depreciation rate given it is a critical component for the measurement of R&D capital (Bernstein and Mamuneas 2004).

Bernstein and Mamuneas (2004) consider R&D depreciation within the context of intertemporal cost minimisation, where depreciation rates are estimated simultaneously with other parameters characterising the overall structure of production. They characterise R&D depreciation as a geometric or declining balance form[222]. The justification for this comes from a series of papers by Griliches (1979, 1990 and 1995). Griliches gives two justifications for this:

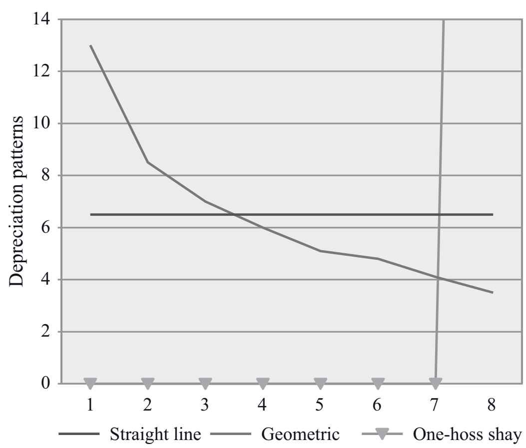
1. There is approximately a contemporaneous link between R&D and the services emanating from this investment through innovation and invention
2. Typically innovation and invention are short-lived, and replaced at a rapid rate

These imply that efficiency declines relatively faster in the early part of the service life of R&D investment, and therefore R&D depreciation approximates declining balance.

The BEA (1994) in the production of R&D satellite uses the PIM with uniform average service lives, straight-line depreciation and a bell-shaped distribution within each vintage of capital to determine discards (Winfrey). They acknowledged that geometric depreciation is typically used for R&D studies, with a rate of 11 per cent the midpoint of a range published by academic researchers. Hence, although the BEA uses straight-line PIM for fixed tangible capital, they chose an average service life for R&D capital that yielded a net stock most comparable to a net stock from a geometric depreciation rate of 11 per cent: an eighteen year service life yielded the closest match.

The easiest way to look at depreciation rates is graphically. The following graph highlights, straight-line, geometric and one-hoss shay (light-bulb) depreciation rate patterns.

Depreciation patterns **G 14–2**



The econometric results from Bernstein and Maumuneas (2004) estimate the following depreciation rates: 18 per cent for Sic 28 (Chemical products), 26 per cent for Sic 35 (nonelectrical machinery), 29 per cent for Sic 36 (electrical products) and 21 per cent for Sic 37 (transportation equipment). These imply that R&D capital depreciates in about three to five years.

Nadiri and Prucha (1996) estimate a depreciation rate of 12 per cent for the US manufacturing sector (geometric depreciation rates). They estimated a model of factor demand that allowed for estimating jointly the depreciation rates of both physical and R&D capital for the US total manufacturing sector. Their 12 per cent estimate of depreciation is

222 A Geometric pattern is a specific type of accelerated pattern. An accelerated pattern assumes higher £ depreciation in the early years of an assets service life than in the later years. This is in comparison to a straight-line depreciation pattern that sees equal £ depreciation over the life of the asset.

very close to the ad hoc assumption usually used as a starting point in most empirical analysis (15 per cent). They used only gross investment data to generate estimates of the depreciation rates as well as consistent series for the stocks of R&D capital. The 12 per cent estimate is not too dissimilar to studies that use R&D capital stocks as an input in the production function, Griliches (1980) and Bernstein and Nadiri (1988, 1991).

Other econometric estimates for depreciation rates have produced the following results:

T 14 – 5 Empirical depreciation estimates

US sectors	Baruch and Sougiannis (1999)	Ballester, Garcia-Ayuso and Livnat (2004)
Chemicals and Pharmaceuticals	5–16%	12%
Machinery and Computers	8–19%	17%
Electrical and Electronics	4–20%	18%
Transportation	7–17%	20%
Scientific Instruments	13–24%	15%
Overall aggregate industries	11–20%	n/a

On average the estimations for depreciation rates of R&D stock range from around 10 to 25 per cent. This corresponds to an average service life of about 5–10 years.

We are proposing to estimate a depreciation rwate for the whole economy using econometric methods. The method will be to look at the impact past R&D has on productivity (gross value added at market prices) to get some idea of the rate of depreciation. That is, if R&D done five years ago has, on average, zero impact on value added today then we can insinuate the life length mean of R&D as being 5. We estimated the following:

$$\Delta GVA_t = \sum_{s=1...T} \alpha_s C_{t-s} + N_t + K_t$$

Where ΔGVA_t is the change in gross value added from time *t* to time *t-1*, C_t is investment in R&D, K_t is other capital inputs and N_t is labour input. Clearly there are various econometric issues surrounding the estimation of the equation above but we will not go into detail here.

R&D capital stock

Once we have constant price R&D GFCF and an estimated depreciation rate it is easy to estimate the R&D capital stock. Once again a geometric PIM is assumed but here we used the methodology of Guellec and Van Pottelsberghe (2004) for calculating the net R&D capital stock in the initial year. Guellec and Van Pottelsberghe (2004) assume a constant annual rate of growth of the past investment:

$$RD_t = \frac{GFCF_t}{1-\lambda(1-\delta)}$$

Where RD_t is the R&D Capital stock at time *t*, $GFCF_t$ is constant price R&D GFCF at time *t*, δ is the depreciation rate of R&D (constant over time) and λ:

$$\lambda = \frac{1}{1+\eta}$$

Where η is the mean annual rate of growth of $GFCF_t$.

UK data sources

Business Enterprise Research and Development (BERD)

The BERD is an annual survey designed to measure R&D expenditure and employment in the UK. Since 1995, the BERD survey has used a stratified random sample, stratified by product group and employment sizebands, where sizeband 1 (400+) is sampled 1:1, sizeband 2 (100–399) is sampled roughly 1:5 and sizeband 3 (0–99) being sampled roughly 1:20. These sampling fractions were reduced in 1998 as 400 more forms were made available for sampling.

In the first stage of the sampling procedure the largest 400 firms are chosen and in 2003s survey that corresponded to those enterprises doing more than £2.6m of R&D. These companies have either been identified from previous returns or from one of the other data sources. These 400 firms are then sent a long form.

There are a number of sources that contribute towards the sampling frame for the BERD. The ABI business survey asks a filter question about whether or not a firm engages in R&D. The DTI and Scottish executive provide ONS with R&D information on companies. Finally, the press is used to add to the sampling frame.

For those firms not receiving a long form, they are broken down in to the remaining two employment sizebands mentioned above. Enterprises are then selected randomly from each size band using the sampling fractions applicable to that band. Those identified are then sent a short form.

For non-selected firms, data is imputed on the basis that these enterprises have the same R&D to employment ratio as selected reporting units in their class.

Imputational Procedure:

Data for non-selected reporting units is imputed in the following way. Let E_I denote company employment (held on the IDBR for all reporting units in both surveys) and X_I denote a certain variable such as intramural R&D, where i indexes reporting units. The imputation is as follows:

1. The ratio $\frac{X_{IJ}}{E_{IJ}}$ is calculated for all selected observations in a given cell j, outliers are discarded.
2. The mean of this ratio is calculated for each cell j as

$$\frac{\sum_{i=1}^{nJ} \frac{X_{ij}}{E_{ij}}}{N_j}$$

3. This ratio is multiplied by company employment of non-selected reporting units to derive an estimate

$$\hat{X}_{ij} = E_{ij} \cdot \frac{\sum_{i=1}^{nJ} \frac{X_{ij}}{E_{ij}}}{N_j}$$

of the variable X for non-selected reporting units in that cell.

Annual Respondent Database (ARD)

The ARD is constructed from a compulsory business survey. Until 1997 it was created out of the ACOP and ACOC (Annual Censuses of Production and Construction); these were combined into the ABI (Annual Business Inquiry) in 1998. To create the ARD, the other surveys are converted into a single consistent format linked by the IDBR references over time.

The data prior to 1998 cover the vast majority of production and construction activities (construction from 1993 only), but from 1997 the ABI also incorporates six other previous surveys covering distribution and other service activities. Hence from 1997 data on services are stored on the ARD. This increased coverage is reflected in the number of individual business contributors to the ARD rising from approximately 15,000 for 1980 to 1996 to approximately 50,000 for 1997/98 and to over 70,000 for 1999.

The businesses selected for the surveys have been drawn since 1994 from the ONS Inter-departmental Business Register (IDBR). The IDBR covers about 98 percent of business activity (by turnover) in Great Britain. Each year a stratified sample is drawn for the ABI and thus the data stored on the ARD is from business respondents returning the questionnaires that are sent out by the ONS.

The ABI is collected in two parts: ABI(1) is an employment record, collected as soon as possible after 12th December. ABI(2) is financial information, which may be submitted up to twelve months after the financial year end.

The proportion of businesses sampled varies with the size of the firm (in terms of employment). The ABI is a sample of smaller firms, but a census of larger ones. The ABI follows the 'Osmotherly' rules; if a small firm (fewer than ten employees) is sampled once, it is not sampled again for at least three years, for any survey. Since 1998 the sampling fractions have been as shown in Table 14–6.

T14–6 Sampling fractions

Size of firm (employees)	Percentage of firms sampled
<10	25
oct. 99	50
100–249	100 or <=50 (varies by industry)
250 or more	100

Smaller firms may receive a “short form”. These do not require detailed breakdowns of totals. Hence for certain variables the values may be imputed from third party sources or estimated rather than returned by respondents.

National Accounts data

We obtained data from National Accounts on life length means and deflators.

The nature of the BERD data means that that the data can be split in to thirty-three product groups. However, this is not entirely consistent with National Accounts. Hence we needed to carry out some matching. The easiest way was to match National Accounts codes (CDID) to SIC codes and then round up to the broader product group level. Within any product group we have a number of SIC codes covering various different areas within that industry (see table 14–13 in the appendix). For land and buildings it was evident that the SIC codes within each product group tended to have the same CDID codes, hence the same deflators and life length means.

However, this was not the case for plant and machinery. It was evident that the SIC codes within certain product group codes had different CDID codes and hence we had multiple deflators and life length means within the product group. Therefore, we had to make some adjustments. We calculated the ratio of plant and machinery expenditure for each relevant SIC within the product group compared to total expenditure for that product group. We then weighted the life length means or deflators with these ratios to give us one life length mean and deflator for each of the 33 product groups:

Once we had the life length means for each industry we could calculate the depreciation rates for land and buildings and plant and machinery. The depreciation rate δ is calculated using the following equation

$$\delta = R / \overline{T}$$

where R is called the ‘declining balance rate’ and $\overline{T}$ is the life-length mean. *R* will differ across asset types. When *R=2*, as it does for intangibles such as R&D, we have what is referred to as the ‘double declining balance’ method.

Capital services data

These estimates of capital services growth and rentals are based on Wallis (2005). Once again some aggregation was required to get from the 57 industries at which capital services estimates are published to the required 33 product groups.

UK estimates

Business investment in R&D and R&D capital stock

Table 14–7 shows our estimates for GFCF using our three different methodologies and compares them with the current R&D expenditure based measure as published in ONS (2006), ‘Research and Development in UK Businesses (MA14). Table 14–7 shows that all 3 methods give GFCF above the MA14 estimate of total R&D expenditure. This means that the flow from the other capital assets being used as part of the R&D process, plant & machinery and land & building, is greater than the expenditure on these assets. This reflects the fact that investment in the stock of these assets is greater than the depreciation of the stock i.e. there is an increasing stock of other assets that are being used in the R&D process.

The main thing to note from Table 14–7 is that the results from the three methods are quite similar. This means that despite methods 2 and 3 being preferable on theoretical grounds, as they directly measure capital services flows, using method 1 would give robust estimates. It is expected that some countries would not have the required capital services data to implement methods 2 or 3.

T 14–7 Business investment in R&D
£bn

Year	MA14: Total R&D expenditure	Method 1	Method 2	Method 3
1997	9.5	10.3	10.4	10.2
1998	10.1	10.9	11.1	10.8
1999	11.3	12.5	12.7	12.3
2000	11.5	12.4	12.5	12.1
2001	12.3	13.5	13.4	13.1
2002	13.1	15.0	15.1	14.5
2003	13.7	15.1	15.1	14.6

We ran the PIM to create our business sector R&D capital stock estimates using two different depreciation rates. Table 14–8 shows the results from using an average from empirical studies of 15 per cent.

Table 14–9 shows estimates of UK business sector R&D capital stock using our 50 per cent depreciation rate.

T 14–8 Business R&D capital stock, 15 per cent depreciation
£bn

Year	Method 1	Method 2	Method 3
1996	50.7	71.1	63.1
1997	53.4	70.8	63.9
1998	56.3	71.2	65.1
1999	60.4	73.2	67.7
2000	63.6	74.6	69.6
2001	67.6	76.8	72.2
2002	72.4	80.3	75.9
2003	76.5	83.4	79.0

T 14–9 Business R&D capital stock, 50 per cent depreciation
£bn

Year	Method 1	Method 2	Method 3
1996	19.6	19.7	19.8
1997	20.1	20.2	20.1
1998	20.9	21.2	20.8
1999	23.0	23.2	22.8
2000	23.9	24.1	23.4
2001	25.4	25.4	24.9
2002	27.6	27.7	26.9
2003	28.9	28.9	28.0

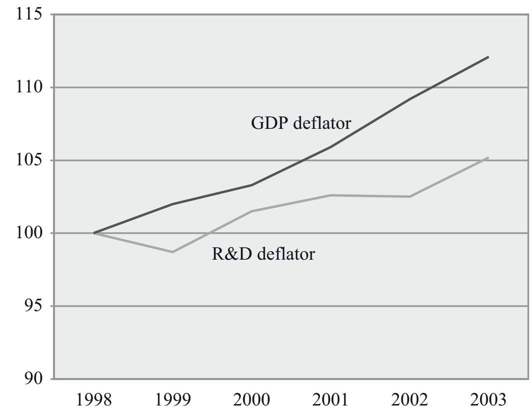
R&D deflator

Graph 14–3 shows our estimated deflator for business sector R&D against the UK GDP deflator. It is clear that the two differ quite a bit. This suggests that the GDP deflator is not a good proxy.

We also produced industry specific deflators which showed significant differences between industries (see tables 14–14 to 14–20 in the Appendix).

GDP deflator and estimated R&D deflator
1998 = 100

G 14–3



Depreciation rate

Our preliminary results are based on a panel of industry data for the period 1998–2003. From this panel we estimate a whole economy depreciation rate. In future we want to use a firm level panel to estimate industry specific deprecation rates. Table 14–10 show the results of our chosen regression.

As the forth lag of R&D investment is insignificant the results suggest a life length mean for UK R&D of 4 years. The insignificance of L4 and L5 suggests that assuming a geometric depreciation rate for the UK may not be appropriate. The insignificance of L4 suggests a 'one-hoss shay' approach may be more appropriate.

If we assume a declining balance rate of 2 and use our formula for depreciation discussed already ($\delta = R / \overline{T}$), this implies a depreciation rate for UK R&D of 50 per cent, a rate much higher than those rates presented in the empirical studies discussed above. Clearly we do not place much weight on this result but it does suggest that the approach we have taken could provide sensible estimates of depreciation for R&D capital following further development.

Contribution of R&D to productivity growth

After capitalising R&D it was important to look at the impact this would have on productivity. We wanted to assess how R&D worked as a capital investment at firm level, showing the 'return' to R&D investment in the production function.

We created a panel data set, merging BERD data and ARD data from 1998–2003. This gave us a panel dataset containing 16,095 observations. 1460 of which were long form, 4960 short form and 9311 unselected firms.

T 14–10 Regression results
£bn

Dependent variable:

Lag of R&D expenditure	Coefficient	Standard error	t-value
Lag 1	-9.16	5.01	-1.83
Lag 2	25.67	7.15	3.59
Lag 3	-24.59	6.91	-3.56
Lag 4	5.42	6.86	0.79
Lag 5	2.95	5.76	0.51

We started by using a model common to a lot of empirical studies of the R&D contributions to productivity growth, an extended Cobb-Douglas production function including time trends and firm specific effects:

$$Y_{it} = AN^{\alpha 1} K_T^{\alpha 2} K_R^{\alpha 3} E$$

Where Y is some measure of value added, K_T is capital, N is labour, K_R is R&D capital, A is a parameter representing spillovers (proxied by the sum of R&D within the industry) and E is the error term.
In log form:

$$y_{it} = a + \alpha_1 n_{it} + \alpha_2 k_{T,it} + \alpha_3 k_{R,it} + e_{it}$$

Where, e^{i} is the error term and *a* is the impact of external knowledge on the firm's productivity.
We have the choice of assuming constant returns to scale (CRS) in the Cobb-Douglas production function: $\alpha^1 + \alpha^2 + \alpha^3 = 1$ or not.

$$y_{it} - n_{it} = a + \lambda t + (\phi - 1) n_{it} + \alpha_2 (k_{T,it} - n_{it}) + \alpha_3 (r_{R,it} - n_{it}) + e_{it}$$

Where $\alpha^1 + \alpha^2 + \alpha^3 = \phi$. If there is CRS then $\phi = 1$ and $1 - \phi = 0$.
There were several estimation issues that we faced with our preliminary estimates. Firstly there is the double counting issue. R&D expenditures used to calculate the firm level capital stock will include expenditures on labour and capital. It is likely that these expenditures will already have been included in our other explanatory variables, N and K. Rogers (2005) highlights this as an issue. Schankerman suggests that the problem will bias R&D coefficients downwards.

Our preliminary results estimate an elasticity of 0.095 per cent. The estimate of 0.095 per cent implies a 10 per cent increase in BERD is associated with an increase in productivity of 0.95 per cent. We then extended our analysis, adding in various different dummies to account for Industry make-up (services or manufacturing) and foreign ownership (US, Japan and Europe). We found an average difference between the impact of services and manufacturing on productivity, with services on average being more productive. Interacting services and the R&D capital stock suggested that an increase in R&D capital stock leads to a bigger increase in productivity for services than for manufacturing. When we looked at the industry make-up more closely, we found that an increase in the capital stock in services and primary industries leads to a larger increase in productivity than manufacturing. Whereas construction and energy have a negative impact compared to manufacturing. Taking account of firm ownership suggested UK firms add more to productivity. Finally it appears that UK owned firms and US firms have an additional effect from an increase in the R&D capital stock on productivity over and above the rest of the world.

T 14–11 Productivity results

Equation	N	K T	T R	Services	UK	US	Japan	EU
1 Spillovers	0.64***	0.33***	0.095***	n/a				
	(26)	(21)	(8.76)					
2 Services dummy	0.69***	0.29***	0.061***	0.12***				
	(29)	(18)	(6.35)	(2.75)				
3 Interactive services dummy	0.69***	0.29***	0.061***	0.008				
	(29)	(18.4)	(6.15)	(1.85)				
4 Country dummies	0.67***	0.32***	0.066***	n/a				
	(28)	(20.7)	(7.12)					
5 Country dummies	0.67***	0.32***	0.066***	n/a	0.20***	0.32***	0.12	0.08
	(28)	(20.7)	(7.12)		(4.94)	(5.87)	(1.27)	(1.42)
6 Interactive country dummies	0.67***	0.32***	0.05***	n/a	0.25***	0.39***	0.019	0.011
	(28)	(20.7)	(4.2)		(4.75)	(5.70)	(1.72)	(1.52)

Conclusions and future work

We have addressed several issues involved in the capitalisation of R&D for the UK National Accounts. The first issue we addressed was calculating R&D GFCF. We presented three separate methods; the first involved calculating COFC and a normal rate of return, the second estimated capital services using rentals and the third estimated capital services using capital service growth rates. The results presented in table 14–7 show that there is little difference between the three methods and hence for those countries that may not be able to produce capital services estimates, GFCF estimated using COFC and a normal rate of return should be equally satisfactory.

Estimating an R&D specific deflator bought a number of issues to the fore. R&D is a very heterogeneous product by definition and hence each project will not command the same price in the market place. Hence this makes it virtually impossible to calculate an output based deflator. As a result we calculated an index using input prices. We also produced industry specific deflators which showed significant differences between industries (see tables 14–14 to 14–20 in the Appendix). Our estimate for a business sector R&D specific deflator showed that the use of a GDP deflator in R&D capitalisation calculations may not be an accurate proxy.

In calculating an R&D capital stock we used the PIM. This required an estimation of an R&D specific depreciation rate. We were slightly constrained by time horizon of UK microdata (starting in 1997), however, we still estimated a whole economy depreciation rate using econometric methods. Our preliminary results imply a depreciation rate for UK business R&D of 50 per cent. This is a somewhat higher rate of return to UK R&D than that estimated in empirical studies to date. However, these results are only preliminary and we need to carry out more econometric analysis on this issue.

Our productivity analysis is very much in its preliminary stages. Using firm level data we have estimated an elasticity of 0.095 per cent. This implies a 10 per cent increase in BERD is associated with an increase in productivity of 0.95 per cent. We intend to continue our analysis in this area, paying more attention to our measure of the spillover effect. Future analysis will also take on a more macro approach, looking at aggregate productivity growth in order to estimate GDP per worker.

The most notable thing that comes out of our work so far is that not only is calculating depreciation rates the most difficult element but also that estimated R&D capital stock is also most sensitive to the depreciation rate than it is to changes in the way we calculate R&D GFCF and our R&D deflators.

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Appendix

Appendix A

T 14–12 GDP and R&D deflators

£bn

Product group code	S&W	Materials	P&M	L&B
A	41.636	36.748	6.881	14.736
AA	43.409	52.402	2.652	1.537
AB	7.147	92.852	0.000	0.000
AC	44.906	53.436	1.512	0.145
AD	51.275	39.053	3.737	5.936
AE	56.990	37.415	4.468	1.127
AF	44.008	45.716	8.051	2.225
AG	37.054	48.358	10.781	3.808
B	49.618	44.058	5.917	0.407
C	42.961	44.936	10.905	1.197
D	54.425	25.291	20.100	0.184
E	35.105	56.537	1.223	7.135
F	32.418	37.179	2.010	28.392
G	50.884	40.044	6.923	2.150
H	44.652	47.829	6.424	1.095
I	28.752	41.256	24.065	5.927
J	46.592	41.391	11.740	0.278
K	60.732	38.038	1.231	n/a
L	51.620	45.034	3.344	0.001
M	41.013	50.085	5.332	3.571
N	52.313	43.358	2.203	2.126
O	45.214	49.896	4.809	0.082
P	49.651	44.459	5.646	0.244
Q	47.427	47.119	4.948	0.506
R	44.652	47.829	6.424	1.095
S	47.859	48.491	3.229	0.422
T	8.919	90.860	0.189	0.032
U	41.766	58.219	0.016	n/a
V	33.433	60.479	6.086	0.003
W	54.464	32.384	6.649	6.504
X	61.765	31.952	6.283	n/a
Y	53.477	42.143	2.491	1.890
Z	56.530	37.736	5.727	0.007

Note: For a description of the product group codes see Table 14–13.

T 14–13 BERD product groups and SIC codes

£bn

Product Group Code	Description	SIC 2003
A	Agriculture, Hunting and Forestry, Fishing	01, 02, 05
AA	Wholesale and retail trade; Repair of motor vehicles, motorcycles and personal household goods; Hotels and restaurants	50, 51, 52, 55
AB	Transport and Storage	60, 61, 62, 63
AC	Post and Telecommunications	64
AD	Financial Intermediation; Real estate; Legal; Market Research; Business and Management consultancy; Advertising; Architectural and engineering activities and related technical consultancy; Technical testing and analysis	65, 66, 67, 70, 71, 74
AE	Compute and related activities, including software consultancy and supply	72
AF	R&D services	73
AG	Public administration	75 to 99
B	Extractive Industries including solids, liquids and gases	10, 11, 12, 13, 14
C	Food products and beverages; Manufacture of tobacco products	15, 16
D	Textiles and clothes; Tanning and dressing of leather; Manufacture of luggage, handbags, saddlery, harness and footwear	17, 18, 19
E	Wood and products of wood and cork; manufacture of articles of straw and plaiting materials. Pulp, paper and paper products; Publishing, printing and reproduction of recorded media	20, 21, 22
F	Refined petroleum products and coke oven products; Processing of nuclear fuel	23
G	Chemicals, chemical products and man-made fibres (excluding manufacture of pharmaceutical, medical chemicals and botanical products)	24 (excluding 24.4)
H	Pharmaceuticals, medical chemicals and botanical products	24.4
I	Rubber and plastic products	25
J	Other non-metallic mineral products	26
K	Basic iron and steel and ferro-alloys; Manufacture of tubes; casting of iron and steel	27.1, 27.2, 27.3, 27.51, 27.52
L	Basic precious and non-ferrous metals; Casting of light metal; Casting of other non-ferrous metal	27.4, 27.53, 27.54
M	Fabricated metal products, except machinery and equipment	28
N	Machinery and equipment not elsewhere classified	29
O	Office machinery and computers	30
P	Electrical machinery and apparatus not elsewhere classified	31
Q	Radio, television and communications equipment apparatus	32
R	Medical precision and optical instruments, and appliances for measuring, checking, testing, navigating and other purposes	33
S	Motor vehicles, trailers and semi-trailers; Parts and accessories for motor vehicles and their engines	34
T	Railway and tramway locomotive and rolling stock; Motorcycles and bicycles	35.2, 35.4, 35.5

Product Group Code	Description	SIC 2003
U	Building and repairing of ships and boats	35.1
V	Aircraft and spacecraft	35.3
W	Furniture; Jewellery and related articles; Musical Instruments; Sports goods; Games and toys; Miscellaneous manufacturing not elsewhere classified	36
X	Recovered secondary raw materials, recycling	37
Y	Electricity, gas and water supply	40, 41
Z	Construction	45

Appendix B

T 14–14 GDP and R&D deflators

Price Indices		
Year	GDP	R&D
1998	100.0	100.0
1999	102.0	98.7
2000	103.3	101.5
2001	105.9	102.6
2002	109.2	102.5
2003	112.1	105.2

T 14–15 R&D industry level deflators

Industry						
year	A	AA	AB	AC	AD	AE
1997	95.7	100.7	98.4	101.3	100.8	103.2
1998	94.9	97.4	99.8	99.1	98.5	101.5
1999	96.4	98.6	97.0	96.6	96.9	100.9
2000	100.0	100.0	100.0	100.0	100.0	100.0
2001	99.1	102.7	99.0	99.0	101.2	107.1
2002	104.2	100	94.4	99.3	104.0	109.1
2003	105.2	101	95.5	98.8	103.2	112.9

T 14–16 R&D industry level deflators

Industry						
year	AF	AG	B	C	D	E
1997	99.2	104.2	99.2	97.5	102.3	98.2
1998	96.6	100.2	104.7	101.7	106.6	96.3
1999	95.2	97.9	102.2	101	96.2	93.7
2000	100	100	100	100	100	100
2001	99.4	99.4	104.4	101.7	111	96.9
2002	97.6	95.5	107.3	102.5	103.6	95.2
2003	100.2	97.5	101.4	102.8	99.3	96.5

T 14–17 R&D industry level deflators

Industry						
year	F	G	H	I	J	K
1997	97.7	99.8	100.3	96.7	95.3	94.2
1998	94.5	97.5	100	95.8	95.4	97.6
1999	98.1	97.9	99.2	96.6	96.9	95
2000	100	100	100	100	100	100
2001	101.8	101.5	99.7	100.5	100.8	103.3
2002	102.4	100.8	100.3	101.5	103.2	110
2003	102.4	98.6	105.6	101.9	104.5	107

T 14–18 R&D industry level deflators

	Industry					
year	L	M	N	O	P	Q
1997	93.8	105.2	99.2	103	98.1	99.5
1998	95.4	103.2	99.4	99.9	99.2	98.4
1999	96.1	97.4	99.2	100	98.7	97
2000	100	100	100	100	100	100
2001	101.8	103.5	101	104.2	101.4	105.5
2002	95.2	101.1	102.6	102.2	101.4	104.4
2003	96.3	101.6	100.9	103.3	105	108.3

T 14 – 19 R&D industry level deflators

Industry						
year	R	S	T	U	V	W
1997	97	99.2	105.9	94.3	97.5	98.6
1998	95.7	97.8	104.9	95.4	97.1	90.9
1999	94.3	96.7	99.1	97.8	95.7	91.3
2000	100	100	100	100	100	100
2001	102.5	105.3	101.4	104.1	99	100.9
2002	102.9	104.5	97.1	101.5	95.5	103.7
2003	105.1	109.2	97.9	100.8	96.2	107.1

T 14 – 20 R&D industry level deflators

Industry			
year	X	Y	Z
1997	96	102.3	100.5
1998	99.3	97.6	95.3
1999	100	96.5	95.7
2000	100	100	100
2001	97.4	97.5	104.1
2002	96.2	101.8	101.8
2003	98.2	103.5	104.5

15. EMPIRICAL ANALYSIS OF THE EFFECTS OF R&D ON PRODUCTIVITY
Implications for productivity measurement?

By Dean Parham[223]
Productivity Commission, Australia

Introduction

There is little, if any, dispute that R&D is a major source of long-term productivity growth. But there is empirical uncertainty about the *magnitude* of the productivity gains from R&D.

This quantitative uncertainty was again highlighted in a study by two colleagues at the Productivity Commission (Shanks and Zheng 2006).[224] They set out to update and extend previous time-series analysis of the effects of R&D on Australia's productivity performance.[225] Previous studies had generated estimates of returns to Australian R&D that seemed implausibly high – a result that is not uncommon in this type of analysis, irrespective of country of investigation (Diewert 2005). With the possibility that limitations on degrees of freedom had been an issue in the previous studies, it was judged that new analysis based on a further 10 years or so of data, plus developments in quantitative tests and techniques, could provide a clearer fix on the effects of domestic and foreign R&D on Australian productivity performance. As it turned out, the modelling results were fragile – and more so than expected. Estimates of performance effects fell within wide confidence intervals and were sensitive to seemingly reasonable modifications to variable and model specifications. Diagnostic tests revealed standard estimating equations to be mis-specified.

This paper outlines the Shanks and Zheng analysis and discusses the reasons for the empirical difficulty in pinning down a magnitude on the effect that R&D has had on productivity. One reason is the use of a constructed variable – capitalised R&D expenditure – as a proxy measure of the stocks of knowledge. The paper highlights the conceptual and

223 PO Box 80 Belconnen ACT 2616 Australia. Email: dparham@pc.gov.au. The author is grateful for assistance and comments from Sid Shanks. Helpful feedback and comments were also received from Ian Bobbin, Ralph Lattimore and Jonathan Pincus. Remaining errors and omissions are his. The views expressed are those of the author and should not be attributed to the Productivity Commission.

224 The work was undertaken as part of an ongoing stream of investigations into productivity trends, their causes and their consequences. Papers and reports produced in this stream of work can be accessed at http://www.pc.gov.au/commission/work/productivity/index.html

225 A number of available cross-country studies, for example, Englebrecht (1997) had generated the somewhat troublesome result that foreign R&D had a negative effect on Australian performance.

empirical difficulties in using the constructed R&D capital in quantitative analysis. The paper goes on to discuss proposals to capitalise R&D expenditure in countries' national accounts and the implications for measurement of productivity in the national accounts. Many of the measurement concerns about R&D capital that arise in empirical analysis would also apply to capitalisation of R&D in the national accounts, especially in relation to productivity measurement.

The paper proceeds as follows. The next section outlines the key concepts for discussion and overviews broad trends in R&D in Australia and the OECD. The third outlines the methods and results of the Shanks and Zheng study and discusses possible reasons for the vague findings. The fourth section highlights estimation problems that likely stem from the capitalisation of R&D. The fifth section describes the proposals for changes to national accounts conventions, which includes capitalisation of R&D, and the sixth section assesses their implications for productivity measurement. Concluding remarks are made in the last section.

Key concepts and trends

R&D, knowledge, innovation and productivity

R&D is conventionally defined as:

…creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. (OECD 2003)

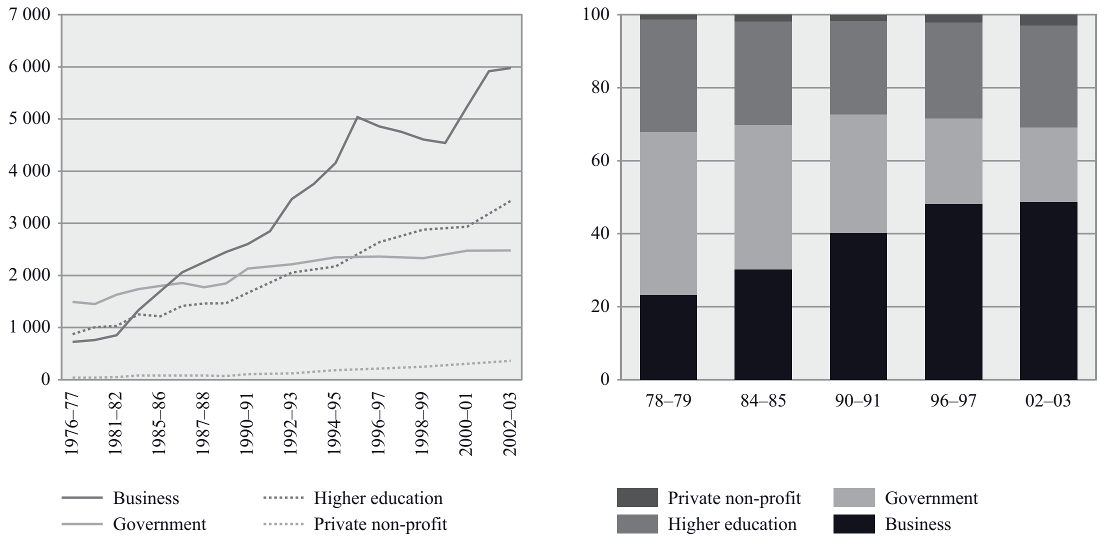
The R&D process can be characterised (albeit rather crudely) as a process of transforming R&D inputs into R&D outputs. R&D inputs are the existing stock of knowledge, the expertise and creativity of researchers, supporting labour, capital services (from assets such as buildings, structures and equipment), materials and purchased services. R&D outputs are increments to the stock of knowledge and new technologies (applications of existing knowledge). These outputs might also be termed 'discoveries' and 'inventions'. R&D can also serve the purpose of enhancing 'absorptive capacity' – that is, the ability to identify, assimilate and apply relevant knowledge.

Conceptually, R&D finishes where commercialisation starts.[226] Further investment in pre-production or commercialisation activities is normally required to take inventions to the stage where they can be introduced into commercially-viable production and use.

The introduction of new commercialised technologies may also involve other complementary investments, which might rightfully share in the responsibility for performance gains. Adoption of some technologies also involves other costs, such as staff training and complementary investments in capital (other equipment or modifications to buildings).

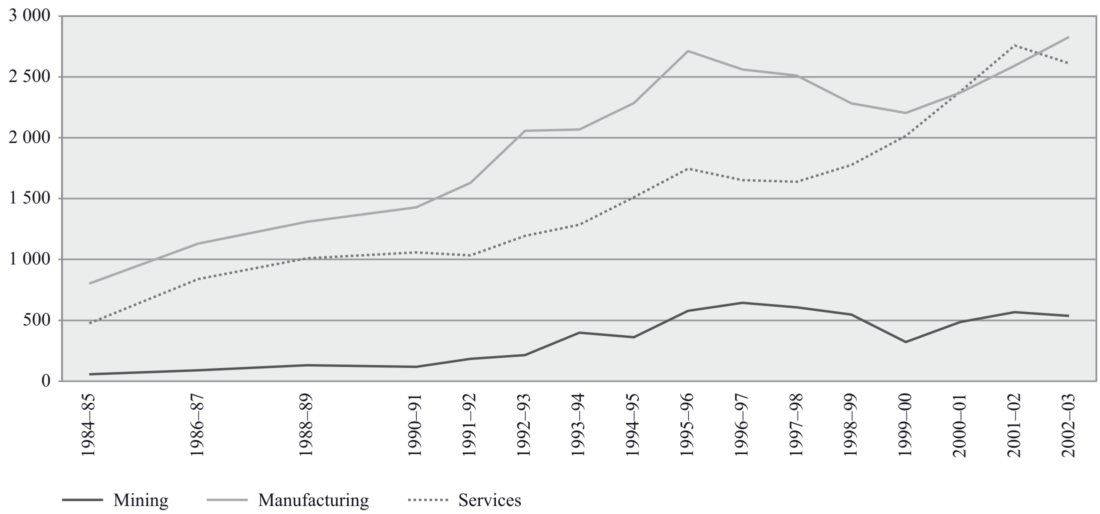
226 In practice, the distinction between R&D and commercialisation may not be precise. Furthermore, R&D does not necessarily lead in linear fashion to commercialisation. The commercialisation process can identify the need for further R&D work to make an application viable.

Real R&D expenditure and shares in total expenditure, by institutional sector, 1976–77 to 2002–03 **G 15–1**



Source: Shanks and Zheng (2006)

Real business R&D expenditure, by industry sector, 1984–85 to 2002–03 **G 15–2**



Source: Shanks and Zheng (2006)

R&D activity is not the only form of knowledge accumulation. Various economic theories have also highlighted the roles of education, acquisition through technology license or capital equipment (with embodied knowledge), and learning by doing.

There are various theories about how knowledge affects productivity. One view is that knowledge is just like a physical asset that exhibits diminishing returns. Other views emphasise the public-good nature of knowledge (spillovers from non-rival and non-excludable discoveries), and the positive influence of the size of the current stock of knowledge on the productivity of knowledge investment (which offsets diminishing returns). There are also theories about 'disruptive' technologies, which impose adjustment costs and have a negative effect on productivity for a time, before leading ultimately to stronger productivity performance.

Magnitude and composition of R&D effort

Australia is a small player on the world R&D stage. Three quarters of OECD R&D effort is concentrated in three regions – the US (which alone accounts for about 44 per cent of OECD expenditure on R&D), Japan and Europe (especially Germany and France). Australia accounts for about 1.3 per cent of R&D expenditure in the OECD area.[227]

Most empirical analysis focuses on business sector R&D. Although public sector R&D is obviously also important to productivity, it is generally of a different ilk – having long-term effect on commercially-implementable knowledge and applications. Business R&D tends to be focussed more on near-term applications.[228]

Australian expenditure on R&D has expanded about fourfold in real terms since the mid-1970s. Most of the increase has been in business sector R&D and came between the mid-1980s and mid-1990s (graph 15–1). There was also a shift in business sector R&D toward services in the 1990s (graph 15–2), a development that is related to the increased use of information and communication technology (ICT) in Australia (Shanks and Zheng 2006).

The broad features of the Australian trends were similar to world patterns, although there were differences in timing. Business R&D has become more important generally in the OECD area and there has also been an increase in services R&D, at least in the major R&D-performing countries. Growth in R&D activity in the OECD area was slower through the second half of the 1980s and the first half of the 1990s – the period of major R&D growth in Australia – but accelerated from the mid-1990s.

Local tax incentives are thought to have contributed substantially to the growth and timing of change in Australian R&D activity. Recorded R&D expenditure started to accelerate (through an announcement effect) in the lead up to the introduction of an R&D tax concession in the fiscal year 1985–86. At least some of the initial increase was due to reclassification of pre-existing expenditure as R&D, rather than to a genuine increase in activity. Growth in

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227 Australia ranked 11 in size of R&D spend in 2001 and was grouped with Sweden, the Netherlands, and Spain as countries spending between 1 and 2 per cent of the OECD total on R&D.

228 There is also an issue with a characteristic of much public sector R&D that it becomes 'freely' available. The associated knowledge assets may have high spillover value, but have low value in terms of appropriable revenues.

'creative' use of the scheme led to introduction in 1996–97 of restrictions on the coverage and rate of tax concession. Business R&D expenditure declined in the second half of the 1990s (graph 15–1 and 15–2).

R&D capital stocks

As outlined above, (genuine) R&D activity is an investment in knowledge accumulation and in the development of technologies. The corresponding assets – the stocks of knowledge and technologies – are intangible assets whose values are largely unobservable. There are some R&D output measures, specifically patents, but they have rather severe coverage and other limitations, especially for measurement of knowledge stocks on a national scale.[229]

This measurement difficulty looms as a fundamental problem in establishing a link empirically between R&D and productivity. As Fraumeni and Okubo (2002, p.1) aptly put it, 'Although the existence of a link between R&D, technical change, and economic growth is widely acknowledged, this link is difficult to quantify because the benefits from, or output of, R&D, a critical component of the link, are not easily measured.'

The main practical measurement option put forward (both in empirical analysis and national accounts proposals) has been to approximate the volume of knowledge assets by capitalised R&D expenditures, in which the series of expenditures is formed into a stock via the perpetual inventory method (PIM). The essence of the PIM is to form a yearly stock estimate by adding new R&D expenditure in the year to the existing stock and subtracting 'depreciation' or obsolescence of the existing stock. In equation form:

$$K_R^{t+1} = (1-\delta)K^t + R^t$$

where K_R^{t+1} is the R&D capital stock in year t+l, δ is a constant (or time-independent) rate of depreciation, K^t is the R&D capital stock in year t; and R^t is the R&D expenditure in year t.

Graph 15–3 gives a sense of the trends in domestic and foreign R&D capital stocks.[230] Foreign R&D stocks are weighted sums of R&D stocks in other countries of technology relevance to Australia. There are differences in the movements of domestic and foreign R&D stocks. Growth in the Australian R&D stock took off in the mid-1980s and slowed from the mid-1990s. Growth in the foreign stock was generally steadier, but showed a *decline* in growth rate from the mid-1980s to the early 1990s. The difference in timing suggests that there were

229 Patent protection tends to be used more for technological advances in products than in processes. Many contributions to the stock of knowledge simply cannot be patented. Some R&D-performing industries (such as software development) do not make significant use of patents, because the net benefits from costly and slow processes to secure intellectual property rights are outweighed by the gains to be had from speed of new products to market. Furthermore, simple patent count measures do not take account of the wide variation in the value of patents – which is very low in many cases. Markets for knowledge are also too thin to provide sufficient and reliable valuations on heterogeneous R&D outputs. Some knowledge can be marketed, for example, through license fees. But a lot of privately-generated knowledge is retained within individual firms in order to preserve technological and market advantage.

230 As discussed later in the paper, there is uncertainty about the appropriate depreciation rate to use in the PIM. Alternative assumptions obviously produce different results.

some country-specific factors (such as tax incentives) driving Australian investment in R&D, rather than general changes in technological opportunities as represented by foreign R&D investment.

The Shanks and Zheng empirical analysis

Shanks and Zheng (2006) – hereafter referred to as 'SZ' – examined the relationship between R&D and productivity within a conventional quantitative framework. Its comprehensiveness, if not exhaustiveness, undoubtedly sets their study apart from others. As mentioned in the introduction, the fragility of results that became evident in the early stages of the project was something of a surprise, at least in terms of its extent, and led to a thorough-going search for alternative model and variable specifications that might yield more robust results. Of particular relevance in the context of this paper, the study hardly left a stone unturned in exploring the relationship between capitalised R&D and Australia's productivity.

The starting point for the SZ analysis was a Cobb-Douglas production function of the form:

$$\ln Y = \ln A + \alpha_1 \ln K_o + \alpha_2 \ln K_R + \beta \ln L + \lambda t + \sum_{i=1}^{n_i} W_i \ln Z_i$$

where Y is output, K_o is other (physical) capital, K_R is R&D capital, L is labour input, A is a constant, t is time and Z_i are control variables. The vast majority of R&D-productivity studies are set within this framework.

Two transformations of this equation were estimated. Most reliance was placed on a 'two-step' method. Taking the physical capital and labour terms to the left-hand side, the dependent variable becomes MFP. Independent observations of MFP come from the national accounts.[231] The other transformation was to subtract the log of the labour input, L, from each side. The estimation equation in this case seeks to explain labour productivity.

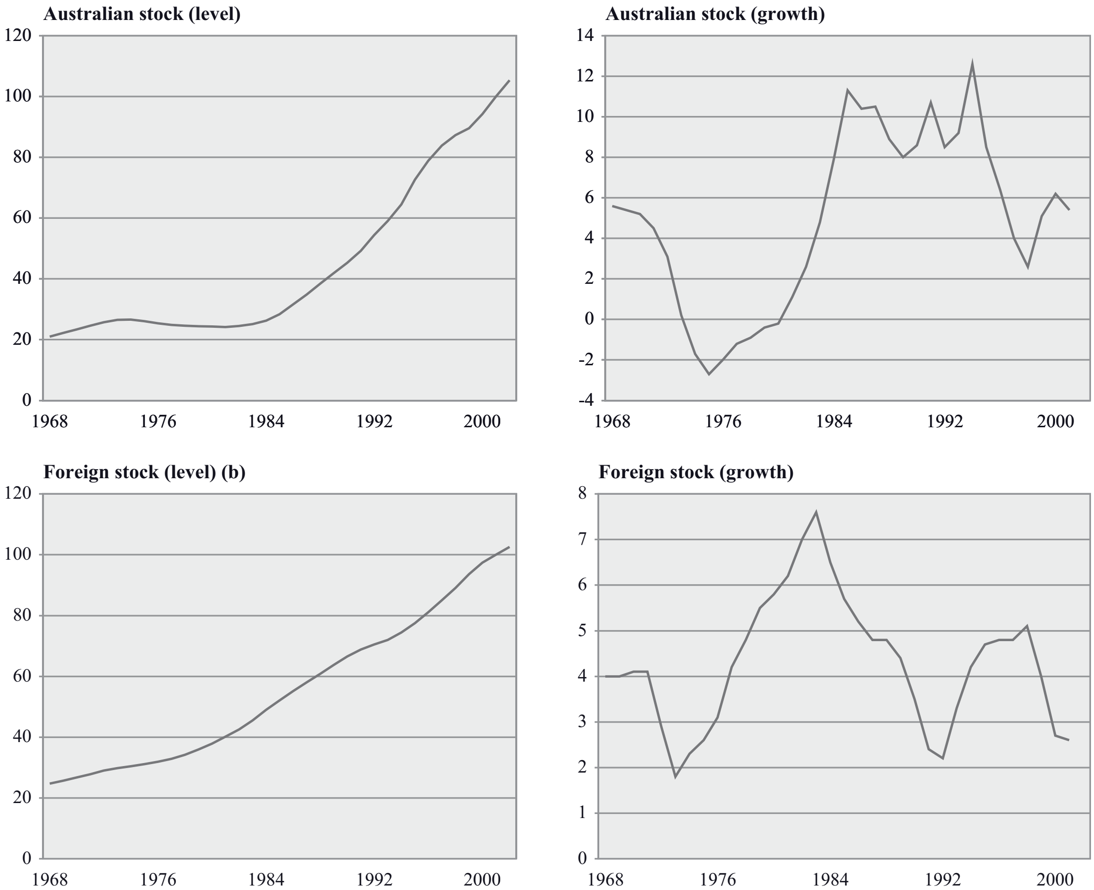
Most of the analysis was conducted at the aggregate level – the market sector of the economy – for which MFP estimates are available from the ABS national accounts. Some analysis was also undertaken for certain industry groupings within the market sector – agriculture, mining, manufacturing, and (combined) wholesale and retail trade.

Alternative calculations of R&D capital stocks

SZ used the PIM to form R&D capital stocks as an approximation to stocks of knowledge. They were well aware that this is open to a number of criticisms (see SZ, pp. 65–73), but had little practical alternative. Nevertheless, they did attempt to explore the criticality of assumptions needed to implement the PIM by undertaking extensive sensitivity analysis. This included:

231 The transformation conserves degrees of freedom because it becomes unnecessary to estimate the parameters α and β. The assumption underlying the transformation and use of national accounts estimates is that there are constant returns to scale and that competitive markets ensure that factors are paid according to their marginal products.

Domestic and foreign business R&D capital stocksa, level and growth, 1968-69 to 2002-03(a) **G 15–3**



(a) Stocks of business sector R&D constructed via the PIM, with an assumed depreciation rate of 15 per cent.
(b) Foreign stocks for individual countries weighted and summed using country shares in Australian imports of elaborately transformed manufactures as weights.

Source: Shanks and Zheng (2006)

- alternative deflation of current R&D expenditures (use of a general producer price deflator or separate deflators for the labour, capital and materials cost components of R&D expenditures);
- alternative constant depreciation rates (between 5 and 30 per cent a year);
- use of variable depreciation rates (increasing from 7.5 to 15 per cent a year) to reflect the possibility of greater knowledge obsolescence over time as the economy became more open and subject to greater competitive pressure[232];

232 Higher depreciation rates over time could also be consistent with a structural shift in R&D activity towards shorter-lived, ICT-based, services-oriented technologies.

- formation of stocks from data on all performed R&D and from data on own-financed R&D; and
- formation of foreign R&D stocks based on a variety of weighting schemes to aggregate the R&D expenditures of different countries.

The effects of different depreciation rate assumptions on the levels of capital stocks are shown in Figure 4 and on growth rates in capital stocks in Figure 5. The selection of a constant rate of depreciation in the range of 5 to 15 per cent does not affect the general trends. The rise in R&D capital is smoother, though, with a lower depreciation rate. There is a *decline* in R&D capital in the mid-1970s with the 10 and 15 per cent depreciation rates.

Estimation of standard levels models

SZ also explored many variations of general model specification. The standard model in levels was estimated both with limited control variables and with extended specifications of control variables. The limited specification was intended to capture long-term relationships and controls were only included to allow for spillovers from foreign R&D capital stocks, business cycle effects and time-dependent effects on productivity. The extended specifications also included variables to allow for such influences as human capital, infrastructure and changes in the policy and institutional environment.[233]

The standard static model with limited controls had highly serially correlated errors, implying a model mis-specification. Adding controls improved the behaviour of residuals, but the estimated coefficient on domestic R&D was imprecise. Whilst the point estimate of the return on R&D was evaluated at 60 per cent, a finding of a zero rate of return on R&D could not be rejected (Table 1).

There was also exploration of dynamics and lags within the confines of limited degrees of freedom. This was designed to allow for the fact that there can be lags between R&D investment and discovery, between discovery and application and between application and commercialisation.[234] Extensive testing of dynamic specifications produced one better-behaved model but, again, the estimate of the domestic R&D coefficient was imprecise.

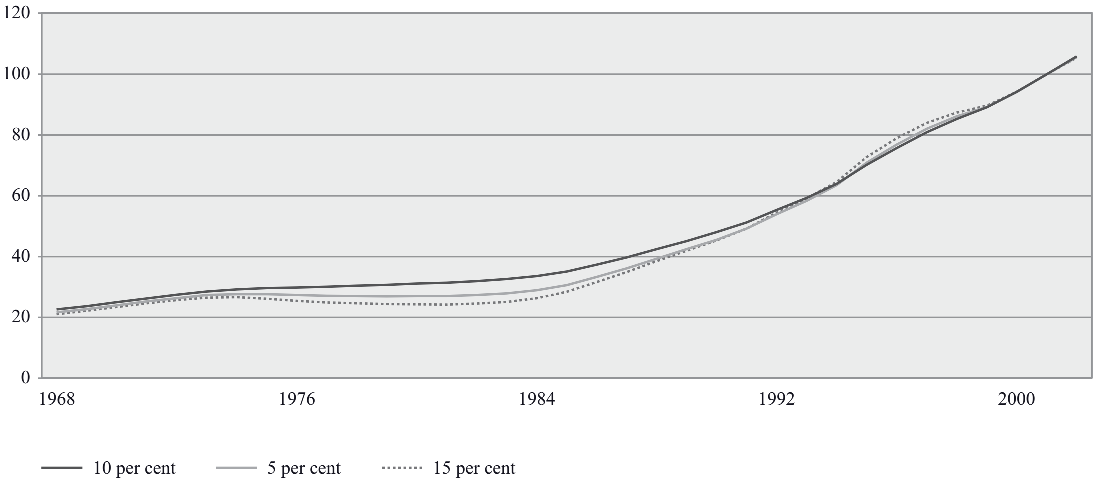
It was common to find a negative coefficient on either domestic R&D stocks or on foreign R&D stocks, depending on which control variables were included in extended model specifications.

Estimation problems were encountered irrespective of choice of specific depreciation rate. Sensitivity testing of alternative depreciation rates showed some variation in implied returns. But there was no strong tendency for models to favour higher or lower decay rates in terms of producing more precise estimates with better overall model fit.

233 A ‘test-down’ procedure was employed, in view of limitations on degrees of freedom, in order to identify stronger explanators and leave aside weaker ones.

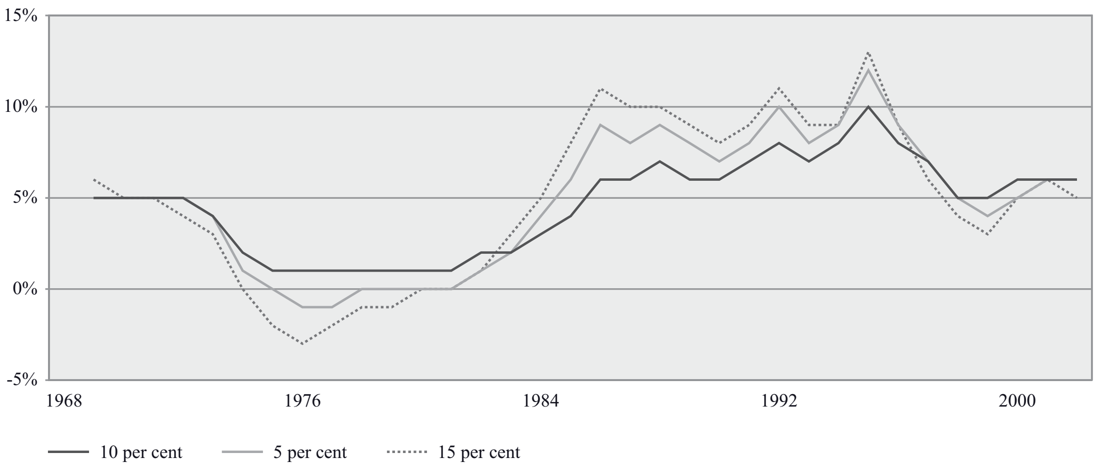
234 There can also be diffusion lags in an aggregate context. To a certain extent, the PIM captures the accumulation of a number of years of expenditure needed to generate discoveries and applications. But there is no weighting scheme attached to expenditures in different years.

R&D capital stocks based on alternative depreciation rates **G 15–4**



Source: Shanks and Zheng (2006)

Growth rates in R&D capital based on alternative depreciation rates **G 15–5**



Source: Shanks and Zheng (2006)

Overall, it was possible to find models that explained MFP in reasonable fashion, but the contribution of domestic business R&D could not be pinned down. Human capital and reductions in industry protection were found to have quite robust effects. Effects of communications infrastructure, ICT capital, and moves to decentralised wage determination were generally well estimated, albeit with some sensitivity to specification.

Further exploration

SZ went even further in their quest to find a clear relationship. They specified other models in which R&D was related to productivity in *growth* form. These models were motivated by endogenous growth theories, but were simplified specifications. They overlooked mechanisms of knowledge accumulation other than R&D, and interactions between the mechanisms. One growth formulation related the change in growth of R&D stocks to the change in the rate of productivity growth. Another form related R&D intensity (R&D stocks or changes in R&D stocks in proportion to GDP) to changes in the rate of productivity growth.

T 15 – 1 Estimates of the effect of R&D on Australia's productivity from standard levels models(a)

Coefficient estimates with standard errors in brackets

	Domestic Business	Foreign	Implied return (%)	Reject return of zero?	Comment
1. Basic model (limited controls) –					
(a) Static	Mis-specified	Mis-specified			Highly serially correlated errors
(b) Dynamic	0.021	0.220***	60	No	One model statistically OK. Domestic coefficient imprecise.
	-0.034	-0.042			
2. Extended model (extended controls) –					
(a) Static	0.019	0.042*^	60	No	Adding controls did not 'uncover' a more precise coefficient estimate
	-0.044	-0.023			
3. Two equation MFP –					
(a) Basic static	0.020 **b**	0.281***	60	-	Slope shifts indicated a significant reduction in the domestic business elasticity post 1985–86
	Post 85–86	-0.023			

(a) *** Indicates statistically significant at greater than one per cent, ** five per cent, and * ten per cent. '^' indicates foreign measure based on USPTO patents granted rather than R&D-based knowledge stock.
(b) Early to mid-1980s slope shifts were negative indicating a decreasing elasticity.
Source: Shanks and Zheng (2006)

A two-equation specification was also explored. Equations were separately specified for factors that affect business investment in R&D and for R&D and other factors that affect productivity. The two equations were estimated within a related system. This approach showed some promise, as well as a continuation of some estimation problems. There were indications that foreign R&D had a positive effect on the Australian economy both via domestic R&D and directly.

Why the fragility

SZ put forward a number of possible explanations for the fragility of estimates, some of which appear specific to analysis of Australian R&D over the observation period used in their study. The observation period appeared important because the addition of another 10 years or so of data had increased fragility and reduced precision, rather than the other way around. This was attributed to: a number of shocks to both investment (including R&D) and to productivity that had disrupted and obscured a long-term relationship between R&D and productivity; and the inability to adequately control for these shocks in the regressions. In very broad terms, a series of policy and institutional changes that gathered momentum from the mid-1980s had helped to transform the Australian economy from being domestically-oriented and resistant to change to one that is more outward-oriented, flexible and innovative.

But there are perennial issues that undermine the stability and precision of results from this kind of analysis – irrespective of country of analysis (Diewert 2005). Limited degrees of freedom often contribute to a lack of precision in time series analysis. The tendency of variables to be collinear can lead to spurious results. Of particular note for this paper, there are also issues to do with the formation of R&D stocks.

A closer look at assumptions underlying the construction of R&D capital

Constructed variables sometimes present problems in econometric analysis because they are relatively ‘smooth’, exhibiting too little variation to be associated with the variation exhibited by other factors of interest. In this case, the variation in the constructed R&D stock variable is relatively smooth. Moreover, it is likely to be dampened in comparison to the variation in the true stock of knowledge. Several key assumptions in implementation of the PIM work to dampen variation in knowledge stocks, as represented by R&D capital.

The productivity of R&D activity

One key assumption underlying the PIM is that the rate at which R&D inputs produce R&D outputs – that is, the productivity of R&D activity – is fixed over projects and time. With this assumption, the volume of outputs of knowledge and technologies can be represented by the use of inputs for the purposes of accumulation into a stock.[235]

[235] The issue of successful/unsuccessful R&D is subsumed within the assumption of constant productivity of R&D. A constant productivity of R&D can capture a uniform rate of success in generating R&D outputs.

Fixed productivity of R&D across projects is implied by the method of deflation of current price expenditures on R&D inputs. In implementation of the PIM, uniform price deflation is applied to all current-price input expenditures at a point in time. This is tantamount to assuming that each dollar of expenditure at a point in time generates the same amount and quality of output.[236] In reality, R&D activity generates heterogeneous outputs with a wide range of qualities, and in different appropriability conditions.[237] A given usage of R&D input can therefore generate a wide range of asset values.

The assumption of intertemporal fixity in R&D productivity is implied by the accumulation of real R&D expenditure as an approximation to the accumulation of R&D outputs. There is plenty of evidence, however, that the productivity of R&D has not remained constant over time.

Technological opportunities and the organisation of R&D activity are two major influences on the productivity of R&D. Technological opportunities – crudely, the 'ease' of discovery and invention – flow and ebb as areas of research enter increasing returns in the early stages after a breakthrough and subsequently reach diminishing returns as a technology class becomes 'fished out'. How effectively and efficiently R&D is organised at the firm, industry, national and (increasingly) international levels also affects the amount of knowledge generated per unit of input used. For example, the focus on national innovation systems highlights the gains from development of research infrastructure and competencies, and from specialisation, collaboration and knowledge transfer and so on.[238]

The relationship between measured inputs and R&D outputs can also change as a result of input cost increases – unless they are fully stripped out by input cost deflators. The general evidence is that R&D costs have risen faster than general producer prices, although the degree seems to vary across countries and time (SZ, pp. 60–62). Use of a general GDP deflator would tend to overstate the increase in real R&D expenditure and, under the constant productivity assumption, the increase in R&D outputs. A particular case is where the salaries of researchers increased more rapidly than general costs; and more than general salaries in the instance where a general labour cost deflator is used.

236 It would not be necessary to assume that each dollar generates the same output if there was a constant pattern of outputs in terms of their type (eg basic discoveries and specific applications) and quality or significance. It could be then argued that a 'representative' relationship between R&D expenditure and outputs holds at each point of time and general price deflation can be applied. These are strong assumptions, however.

237 Firms have a range of innovation strategies that can generate different outcomes with respect to the asset value of R&D activity. While some position themselves on the 'technology edge' and invest in R&D in order to generate knowledge assets, others undertake R&D in order to make relatively minor incremental adaptation of technologies, without expectation of long-lived payoff from their investment. In the extreme, some R&D could be for defensive reasons to ensure that there is less risk of a competitive penalty if the firm does not undertake some R&D in order to be aware of technological trends and where and how to access them. A lot of R&D is undertaken under conditions of 'winner takes all' rivalry. If one firm achieves the breakthrough, was all R&D undertaken by all competitors equally valuable?

238 Research collaborations in certain areas between industry competitors, coordinated multinational R&D activity through subsidiaries and contracting of R&D to new performing countries such as China and India play a much greater part these days in international business R&D.

Changes in policy settings have undoubtedly undermined the assumption of constant R&D productivity in a further way in Australia. As noted in section 2, the introduction of R&D tax concessions in the mid-1980s induced some 'phantom' increases in R&D expenditure, which would have meant that the volume of R&D output per measured dollar of input had declined, all other things equal. Much of the aggregate increase came through the entry of small firms which, if scale of activity is important, would not have promoted improved productivity of R&D. Moreover, the increasingly 'creative' use of the concession over time would have meant that the phantom increases were not confined to the period of introduction of the concession, when there was an incentive to reassign pre-existing expenditure as R&D activity. After the scheme was tightened in the second half of the 1990s, the phantom element would have declined and thereby raised the output/expenditure ratio in Australian R&D.

The depreciation of knowledge

The use of a constant rate of depreciation in implementations of the PIM is another practice that attracts concern. It is common to assume a single average depreciation rate or average asset life, selected with reference to the life of patents or similar information. Against this, it is contended that the rate of decay in the usefulness of knowledge varies across R&D outputs and, at times, in discontinuous ways. New discoveries can render some existing knowledge unexpectedly obsolete – or more valuable.

Changes in the composition of R&D activity can affect the average depreciation rates of knowledge. For example, it is widely considered that the asset values of outputs of ICT-based R&D are relatively short-lived. The shift toward ICT-based R&D in the 1990s would therefore have increased the average rate of depreciation.

Implications

The assumptions of constant productivity of R&D and of constant knowledge decay help to smooth the movements in R&D capital stocks, in comparison to likely movements in the true knowledge stocks. Variation in input use is likely to be less than the variation in outputs (and values) generated across projects and time. The assumption of constant knowledge depreciation is likely to have a strong dampening effect, as it removes the effect of random shocks to the value of existing knowledge.

The dampened variation in R&D capital stocks then becomes a problem for econometric analysis in establishing a link between variations in knowledge stocks and variations in economic performance. SZ did not attempt to test the assumption of constant productivity of R&D. They did test alternative depreciation rates and introduced a variable rate of depreciation, but found little improvement in results. It may well be that 'over-smoothing' still occurred within the range of depreciation alternatives tested.

Moves to capitalise R&D in the national accounts

There have been moves for some time to introduce capitalised R&D expenditures into countries' national accounts. Capitalisation of R&D was canvassed in lead-up discussions on the conventions to be introduced in SNA93, but was not included in the final agreement.

The ‘Canberra II Group’ of national accounting experts has given the issue further consideration in discussions on a new round of proposals for changes to national accounts conventions.

The motivation for capitalising R&D in the national accounts comes, in a sense, from a different direction. In the analytical context, capitalisation of R&D is motivated by the desire to investigate the relationship between knowledge accumulation and growth. In the national accounts context, however, capitalisation stems from the question, ‘Is R&D better treated as an expense or as an investment?’ Approximation of knowledge stocks by R&D capital is a common component, but the relationship between R&D capital and growth is not an immediate focus of the national accounts proposals.

The case for treating R&D as investment is conceptually strong. Normally, R&D more closely resembles a commitment of resources in order to generate assets that can be drawn on in the future to generate a range of production gains. Treating it as such and capitalising R&D expenditures would provide a consistent accounting link between investment expenditure and the corresponding asset. Whilst it is argued below that the distinction between the ‘expense’ and ‘investment’ character of R&D is actually blurred, its portrayal as investment is theoretically sound.

It is proposed that the PIM method be used to construct R&D capital in the national accounts. Whilst there are likely to be some differences in the details of implementation, the fundamentals are likely to be along the lines outlined above in relation to the SZ study, namely:

- measurement of current price business R&D investment;[239]
- deflation of the series to provide volume measures;[240]
- accumulation of the investments into a stock; and
- application of a rate of depreciation to the stock.

There have been a number of experimental investigations of capitalisation of R&D and ways of incorporating R&D capital into the national accounts (Fraumeni and Okubo 2002, ABS 2004, Robbins 2006, Edworthy and Wallis 2006). These studies, in effect, take the accumulation of input expenditure, deflated by general price deflators, as a given. They tend to focus attention on the selection of an average rate of depreciation and the sensitivity of results to different depreciation rates.

239 Estimates of R&D expenditure derived on the basis of the Frascati Manual (OECD 2003) include expenditure on assets such buildings, land and software. These estimates can be adjusted to form estimates of R&D investment by deducting expenditures on related assets and adding components to allow for consumption of capital and a ‘normal’ rate of return on capital used (ABS 2004).

240 The price deflator chosen is usually based on input costs, rather than output prices. R&D expenditures on labour, capital and materials are deflated by respective cost deflators. Shanks and Zheng (2006) used a GDP implicit price deflator. They found not a lot of difference in accumulated stocks when they used separate factor cost deflators. With growth in contract research services, the possibility of better observing prices of research outputs is emerging. However, application is restricted by lack of time series of representative data.

Flow-on to other estimates

Capitalisation of R&D would have implications for a number of variables in the national accounts. With R&D treated as an investment, estimates of output and saving would be higher. With R&D capital treated as an asset, estimates of the aggregate capital stock and wealth would be higher.[241]

Various investigations suggest that capitalisation of R&D would make a sizeable difference to the *levels* of variables. For example, the ABS (2004) found that capitalising R&D would lift Australia's GDP by around 1.5 per cent. Fraumeni and Okubo (2002) estimated that US wealth would increase by 2 per cent. The effects of capitalisation are likely to vary across countries according to the relative importance of R&D.

As constructed, capitalisation of R&D would have a smaller effect on the *growth* rates in variables. For example, the ABS (2004) found differences in annual rates of GDP growth of no more than 0.07 of a percentage point, and mostly near zero. The small effect on growth rates is due to the relative size of, and relatively smooth change in, R&D expenditure.

Despite the inherent difficulties in selecting values for key parameters of the PIM, there is a defensible argument that capitalising R&D as part of measurement of output and wealth is an improvement over the current practice of expensing R&D. Moreover, any uncertainty about accuracy in measurement is unlikely to intrude heavily on variables of most interest – especially, GDP growth.

Implications of capitalisation of R&D for national accounts estimates of productivity

However, the implications of capitalisation of R&D for the derivation of national-accounts estimates of productivity nevertheless warrants some attention. In this context, the probability that a change in conventions would have little effect on estimates does not necessarily provide comfort. The issue is whether capitalisation of R&D would deliver more accurate and meaningful estimates of productivity.

First, how would capitalisation of R&D affect productivity measures? On the measurement of labour productivity, capitalisation of R&D would affect the measurement of output, but not labour input. Applying the same arguments as discussed above in relation to output, capitalisation of R&D would raise the measured level of labour productivity, but would generally have only minor effect on measured growth in labour productivity.[242] On measurement of multifactor productivity, there is an input effect, as well as an output effect. The logical extension of capitalising R&D in the national accounts is that R&D capital would enter the measured capital stock and the measured flow of capital services. Thus the level of both numerator and denominator of MFP would be higher than otherwise. It is likely that

241 Fraumeni and Okubo (2002) have stated and illustrated that failure to treat R&D as investment understates a nation's savings, wealth and potential for growth, including productivity growth.

242 With productivity measured in index number form, the change in levels would not be discernible. The effect on productivity growth would be more noticeable if R&D intensity is relatively high and increasing.

the level of MFP would be higher, but not to the extent of the increase in the level of labour productivity.[243] The effect on MFP growth would depend on how rapidly R&D activity is growing and how prominent R&D capital is in relation to total capital.

Second, how accurately would the R&D-based effects on productivity be measured? There are two components to this question; the accuracy with which R&D outputs would be captured in the measurement of output; and the accuracy with which services from intangible knowledge assets are captured in the measurement of inputs.

Discussion above in the context of the SZ analysis highlighted strong concerns about the extent to which R&D outputs can be represented by R&D inputs (expenditure). The implicit assumption of constant productivity of R&D across projects and time does not sit comfortably with the comparatively idiosyncratic nature of the R&D process. Fundamentally, R&D activity is not like typical production activities in which each unit of input committed contributes equally (or at least in stable or predictable fashion) to the generation of output. There can be (variations in rates of) research failures; success can be subject to serendipity, threshold effects, and interactions with pre-existing knowledge; and the quality of successful outputs can vary widely.

On the accuracy of measurement of R&D-based knowledge assets, there is also the issue of how well depreciation of knowledge is captured in the PIM (in addition to the issue of representing knowledge outputs by R&D inputs). At least on the face of it, the use of smooth rates of depreciation does not sit comfortably with: the diversity in rates of depreciation in different types of knowledge; and discontinuous change in the value of knowledge as discoveries render some existing knowledge suddenly obsolete or latent knowledge suddenly more valuable. Furthermore, the way in which R&D capital would be incorporated in the aggregate productive capital stock could be challenged. Aggregation of R&D capital with other assets would require a rental price weight, which would be constructed from estimates of the rate of depreciation of, and rate of return on, R&D capital. From an empirical if not theoretical point of view, there are doubts (see SZ analysis) that capitalised R&D can be treated in the standard framework that rewards assets according to their marginal products and equates returns on assets in the current period.[244]

Third, despite the likely measurement deficiencies, would capitalisation of R&D nevertheless be better in relation to measurement of productivity than the current approach of expensing R&D? The answer is not clear-cut. Whilst R&D is conceptually investment-like, that characterisation likely has a general and longer-term validity. R&D is generally considered to be a high-risk investment. Businesses are prepared to write off a lot of expenditure across a number of unsuccessful projects, with the hope and intention of making a small number of

243 The effect on labour productivity is likely to be greater than the effect on MFP, at least in level terms, because of the inclusion of additional capital in the MFP calculation. The difference between higher labour productivity and MFP would be explained by higher measured capital intensity of production.

244 There is also the issue that measurement of knowledge stocks is limited to accumulation via R&D activity. Baldwin et al (2005) noted that capitalisation of R&D would omit knowledge accumulation through the importation of technologies, which is a major source of knowledge for Canada.

highly-successful and financially-rewarding discoveries over the longer term. In effect, some of R&D expenditure is investment-like and some is expense-like. And the degree to which it is one or the other probably varies across time and countries.

In sum, it is not clear that capitalisation of R&D in the national accounts would deliver more meaningful estimates of productivity. It may do so. But it may not. It is an issue that warrants further investigation.

Concluding remarks

Proposals to capitalise R&D in the national accounts can be supported by defensible arguments, at least in relation to estimates of output and wealth. Conceptually, R&D activity is more akin to investment than it is to an expense. It can be argued that capitalising R&D is more consistent with this conceptual ideal and would provide accounting consistency between investment expenditure and its corresponding asset formation. There is, however, uncertainty about the accuracy with which R&D expenditure represents delivery of R&D outputs. Nevertheless, from a practical point of view, treating R&D expenditure as an investment rather than as an expense is probably the 'lesser of two evils'. Moreover, treating R&D as an investment is not 'intrusive', at least with respect to estimates of growth in output.

However, the judgment that capitalisation of R&D may be the lesser of two evils does not make capitalisation of R&D 'right', especially in regard to the measurement of productivity. The arguments and evidence presented in this paper raise questions about the extent to which incorporation of an input-based measure of R&D output and a PIM-based measure of R&D capital in productivity estimates would be useful and meaningful. The issue warrants further investigation.

What should be done, from the point of view of productivity estimation? The short answer is to proceed with capitalisation of R&D in the national accounts with some caution. Further investigation of the investment/expense nature of R&D and the implications for conventional productivity measurement would be helpful. Assessments for different countries would also be useful, as a change in measurement practice may be more relevant to some countries than others. For the time being, three options could be considered: do nothing – make no change to productivity measurement methods; full implementation – introduce R&D into the output measure and R&D capital into the capital input measure; and partial implementation – introduce R&D into the output measure, but leave the capital measure unchanged.

Whatever is done, transparency about any changes in methods will be important. It will help policy debates if users are well informed about the limitations of the R&D measures and about the interpretation of the revealed effects on productivity.

With time and further analysis, it would be important to come up with improved R&D output and stock measures. This most probably requires a direct measure that is independent of R&D inputs. Conceptually, a measure based on the value of the intangible assets produced would give a more accurate measure of output (and depreciation over time). But, of course, the substantial practical difficulties explain why this is not currently done. However, as markets for knowledge develop, the information base is likely to improve.

More fundamentally, more work is needed to better understand and represent the process of knowledge accumulation. This goes beyond R&D and national accounts conventions. For example, accumulation of knowledge can involve complex interactions between R&D investment, existing knowledge and human capital. Better understanding of knowledge accumulation would not only help policymaking directly, but may also help to identify meaningful ways to improve national accounts conventions.

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16. INFRASTRUCTURES AND NEW TECHNOLOGIES
as Sources of Spanish Economic Growth

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Introduction

The paper revises the impact of infrastructures and Information and Communications Technologies (ICT) on Spanish economic growth. It makes use of the Fbbva/Ivie capital services database recently released (Mas, Pérez and Uriel (2005)) which follows closely OECD (2001a, b) recommendations. The paper also addresses the problem posed by the presence of publicly owned assets, especially when implementing the endogenous approach to the internal rate of return determination. After offering an alternative to the standard approach, it carries out a growth accounting exercise considering explicitly three types of ICT capital assets (software, hardware and communications) and six different types of infrastructures (roads, ports, railways, airports, and water and urban infrastructures).

The point of departure is twofold. On the one hand, there is the role played by infrastructures on the US productivity slowdown of the seventies and eighties -highlighted in his seminal article by Aschauer (1989a). This paper deserved a great deal of attention not only in the US but in other countries as well[246]. Most papers make use of econometric estimations of either production or cost functions where public capital enters explicitly as an argument. The lack of agreement on the value of the output infrastructure elasticity was the dominant result, ranging from 0.73 in Aschauer (1989b) to even negative values obtained by some authors (see Sturm, Kuper and Haan (1996) for a review). The lack of adequate information on capital services provided by the different types of assets did not allow contrasting the econometric results with those obtained from a growth accounting framework. Their present availability for Spain led us to fill this gap.

The second reference is the intensive, as well as extensive, work done since the beginning of the nineties on the contribution of ICT to economic growth. While infrastructures displayed a leading role on the US productivity slowdown of the seventies and eighties, ICT accumulation

245 The results here presented are part of the FBBVA Research Programme. Support from the Spanish Science and Education Ministry ECO2008-03813 is gratefully acknowledged. Thanks are due to Francisco Pérez, Javier Quesada, Paul Schreyer, Ezequiel Uriel and Francisco J. Goerlich, as well as the participants in the Workshop organized by FBBVA-Ivie in Valencia, February 2006. Juan Carlos Robledo provided excellent research assistance»

246 Spain was not an exception and an important amount of papers dealing with the subject can be traced (see Mas & Maudos (2004) for details).

was identified as the major responsible factor of the US productivity upsurge since the mid nineties[247]. However, similar impacts were not observed – at least not with generality – in most of the European Union (EU) countries. Seemingly, significant impact was confined to countries with an important presence of the ICT producing sector[248].

In the case of Spain the debate on the role played by infrastructures on economic growth deserved a great deal of attention during the nineties. The issue at hand was not only how to promote growth but, most importantly, the consequences of the different public capital endowments among the Spanish regions in the (lack of) convergence of per capita regional incomes. Over the late nineties the slowdown of Spanish labor productivity, contrasting with the upsurge in the USA, put ICT capital in the center of the debate, substituting somehow the previous prominence of infrastructures in the growth debate.

Within this general framework, the paper follows the next structure. The next section sketches the growth accounting framework taken as reference. The third section reviews the treatment given to publicly owned assets by National Accounts as well as its implications. The fourth section summarizes the data used, and the fifth section illustrates the consequences of using the standard approach to the internal rate of return determination. The sixth section presents the results and the last section concludes.

The Growth Accounting Framework

Suppose that the production function recognizes three different kinds of capital

$$Q_t = Q_t(KP_t^{ICT}, KP_t^{INF}, KP_t^{O}, HL_t, B) \tag{1}$$

where Q_t is real Gross Value Added; KP_t stands for a volume index of capital services with the superscripts ICT, INF and O referring respectively to ICT, Infrastructures and Other forms of (non residential) capital; HL_t represents employment (hours worked); and B indicates the level of efficiency in the use of productive factors.

Standard growth accounting assumptions allow us to obtain:

$$\Delta \ln Q_t = \bar{w}^{HL}\Delta \ln HL + \bar{w}^{ICT}\Delta \ln KP^{ICT} + \bar{w}^{INF}\Delta \ln KP^{INF} + \bar{w}^{O}\Delta \ln KP^{O} + \Delta TFP$$

$$\bar{w}_t^{\chi} = 0.5\left[w_t^{\chi} + w_{t-1}^{\chi}\right] \text{ for } \chi = HL;\ ICT;\ INF;\ O \tag{2}$$

Without imposing any additional conditions, the labor share in equation (2) is defined as

$$w_t^{HL} = \frac{\sum_i CE_{i,t}}{TC_t} \tag{3}$$

247 Bailey (2003), Bailey & Gordon (1998), Gordon (1999), Jorgenson & Stiroh (2000), Oliner & Sichel (2000) and Stiroh (2002) among others.

248 Colechia & Schreyer (2001), O´Mahony & van Ark (2003), Pilat (2003), van Ark & Timmer (2006) and Timmer & van Ark (2005).

where CEi is labor compensation in the ith sector and TCt is total cost defined as

$$TC_t = \sum_j \sum_i VCS_{j,i,t} + \sum_i CE_{i,t} \quad (4)$$

Where VCSj,i,t is the value of the capital services provided by asset j in industry i. defined as:

$$VCS_{j,i,t} = cu_{j,t} KP_{j,i,t-1} \quad (5)$$

with cuj,t representing the user cost of asset j[249]. The share on total cost of each of the three types of capital assets is defined as

$$w_t^{\chi'} = \sum_{j \in \chi'} \sum_i \frac{VCS_{j,i,t}}{TC_t} \quad (6)$$

With χ' = ICT, INF, O. The growth rate of each variable in (2) is computed as a Törnqvist index. Thus, for ICT capital, the growth rate is defined as

$$\Delta \ln KP^{ICT} = \ln KP_t^{ICT} - \ln KP_{t-T}^{ICT} = \frac{1}{T}\left[\sum_{j=s,h,c} \sum_i \overline{v}_{j,t}^{ICT} (\ln KP_{j,i,t} - \ln KP_{j,i,t-T}) \right] \quad (7)$$

$$\overline{v}_{j,t}^{ICT} = 0.5 \left[\frac{VCS_{j,i,t}}{\sum_{j=s,h,c} \sum_i VCS_{j,i,t}} + \frac{VCS_{j,i,t-T}}{\sum_{j=s,h,c} \sum_i VCS_{j,i,t-T}} \right]$$

With s = software; h = hardware; and c = communications. The growth rate of infrastructures and of the remaining (other) forms of capital is computed in a similar manner.

If additional assumptions are imposed, namely: 1. Constant returns to scale (CRS) in the production function (1); 2. optimizing behavior by agents; 3. competitive markets; and 4. perfect foresight (in the sense that the ex-post rate of return implicitly computed by national accountants exactly matches the ex-ante rate) then, total cost equals total revenue (TCt =PQt) so that either term can be safely used interchangeably in equations (3) to (6). Additionally, in this case, wtHL + w_t^{ICT} + w_t^{INF} + wtO = 1 and equation (6) measures the output elasticity of each type of capital.

On the User Cost

The user cost expression in equation [5] can adopt different specifications. Let ´s assume that it is given by

$$cu_{j,t} = p_{j,t-1} [r_t - \pi_{j,t} + (1 + \pi_{j,t}) \delta_{j,t}] \quad (8)$$

249 Equation (5) assumes that the user cost for each particular type of asset is the same across industries. This assumption could be inadequate if the level of risk is different between industries –as most probably it is the case. It should be anticipated that the expected return on an asset that is owned and used in a risky industry should be higher than the expected return if the same asset is used in a low-risk industry. I thank P. Schreyer for driving my attention to this important point.

with $p_{j,t-1}$ representing the price of asset *j,* and $\pi_{j,t}$ its rate of variation*;* r_t is the nominal rate of return (common to all assets); and $\delta_{j,t}$ is asset *j* depreciation rate.

The next step is the determination of r_t in (8). For this one can follow either an exogenous or an endogenous procedure. According to the former one the rate of return must be related, in one way or another, to the market nominal rates of interest. By contrast, the endogenous procedure obtains the internal rate of return from equating Gross Operating Surplus (GOS) to capital revenues.

As it is well known, both procedures have their pros and cons. For the exogenous approach the main difficulty lies on the selection of the most suitable interest rate, while its main advantages can be summarized as follows: 1. no restrictive assumptions are needed, especially with regard to returns to scale and perfect competition; 2. it can easily deal with the presence of public goods; and 3. it allows to model r_t as an *expected* rate of return (no perfect foresight assumption needed).

On its side, the endogenous approach has the main advantage of conforming to main stream assumptions, namely that the production function presents constant returns to scale (CRS) in a perfectly competitive environment. The need to fulfill these assumptions becomes also its main inconvenient. To this, Schreyer, Diewert and Harrison (2005) add an additional problem. According to these authors, an endogenous rate of return for the total economy cannot be calculated because there is no independent estimate of *GOS* for government assets.

Before turning to this point, let's follow Jorgenson and Landfeld (2004) and further assume that r_t is a weighted average of the nominal interest rate and the internal rate of return, ρ_t:

$$r_t = \beta_t i_t + (1 - \beta_t) \rho_t \qquad (9)$$

That is, it is assumed that r_t *combines an exogenous component* (i_t) *together with an endogenous one,* ρ_t*. Equation [9] shows a standard financial structure for private firms, where the market interest rate reflects debt financing and the endogenous rate reflects equity financing. With this assumption, equation [8] becomes:*

$$cu_{j,t} = p_{j,t-1} [r_t - \pi_{j,t} + (1 + \pi_{j,t}) \delta_{j,t} \qquad (10)$$

We now turn to the problem posed by the presence of public assets.

The treatment of public assets

The presence of assets owned by the public sector becomes a problem –at least potentially- for the endogenous approach. The reason lies on the National Accounts (NA) practices. National Accounts do not assign a net return to the flow of services provided by public capital. The only recognized flow is fixed capital consumption. Jorgenson and Landfeld (2004) address the main problem in the following terms: "While the existing accounts do treat government expenditures on capital goods as investment, they include only a partial value for the services of government capital by counting the value of depreciation on government capital (no value is included for the services of nonprofit capital)…The present treatment of government capital implicitly assumes that the net return to government capital is zero, despite a positive opportunity cost". And they continue, "the net return to the capital stock must (be) estimated and added to depreciation to develop a service value. This estimation raises conceptual issues relating to the appropriate opportunity cost and empirical issues in estimating this cost" (pg. 12).

The above paragraph summarizes the main issues, with the following important implications:

1. The Gross Operating Surplus (GOS) figures provided by National Accounts are underestimated because the value of capital services provided by public capital is not fully considered.
2. Consequently, the value of output is also underestimated in NA figures, affecting both its level and rate of growth.
3. If the endogenous approach is used when computing the rate of return, points 1 and 2 above will have, at least potentially, consequences on:
   – The implicit rate of return
   – The input shares
   – The growth accounting results
4. If the exogenous approach is adopted, only point 2 above will have consequences on the growth accounting exercise.

Let's assume that the property of a given asset *j*, is divided between the public and private sectors. Thus, $KP_{j,t} = KP^p_{j,t} + KP^g_{j,t}$ -where the superscripts *p* and *g* denote respectively private and government property of asset *j*. According to National Accounts (NA), the Gross Operating Surplus (GOS) is computed as:

$$GOS^{NA} = GOS^{NA,p} + \sum_j \sum_i \delta_{j,t} p_{j,t-1} KP^g_{j,i,t-1}$$

That is, *GOS* in the *National Accounts* is *GOS* of the private sector plus depreciation of government assets. From an analytical perspective, and under the assumptions of the endogenous approach, the private sector *GOS* will equal private sector capital services. So, $GOS^{NA,p} =$ So, $GOS^{NA,p} = \sum_j \sum_i cu_{j,t} KP^p_{j,i,t-1}$ and it follows that:

$$GOS^{NA}_t = \sum_j \sum_i cu_{j,t} KP^p_{j,i,t-1} + \sum_j \sum_i \delta_{j,t} p_{j,t-1} KP^g_{j,i,t-1} \quad [11]$$

Thus, according to NA, the services provided by a given amount of capital are dependent on public or private asset ownership. Even so, most researchers are not aware of the specific methodology followed by *NA*. This is especially true when the internal rate of return is computed –as it usually is -from an equation such as (12):

$$GOS^{NA}_t = \sum_j \sum_i cu_{j,t} \left[KP^p_{j,i,t-1} + KP^g_{j,i,t-1} \right] \quad (12)$$

The fact that the usual way of computing the internal rate of return according to the endogenous approach is incorrect does not impair this procedure from being applied once the public ownership of some assets is fully recognized. As an alternative, the internal rate could be computed reordering equation [11] to get

$$GOS_t^{NA} - \sum_j \sum_i \delta_{j,t} p_{j,t-1} KP_{j,i,t-1}^g = \sum_j \sum_i cu_{j,t} KP_{j,i,t-1}^p = \tag{13}$$

$$= \sum_j \sum_i p_{j,t-1} \left[\beta_t i_t + \left(1-\beta_t\right) \rho_t - \pi_{j,t} + \left(1+\pi_{j,t}\right) \delta_{j,t} \right] KP_{j,i,t-1}^p$$

Once ρ_t has been computed according to [13] one can apply Nordhaus (2004) basic principle for measuring non-market activities: "Non-market goods and services should be treated as if they were produced and consumed as market activities. Under this convention, the prices of non-market goods and services should be imputed on the basis of the comparable market goods and services" (pg. 5). Thus, if one assumes the same rental price for capital $cu_{j,t}$ independently of who owns the asset[250], we can revise the National Accounts figures, in order to obtain a revised Gross Operating Surplus estimate, GOS^R, in the following way:

$$GOS_t^R = GOS_t^{NA} + \sum_j \sum_i cu_{j,t} KP_{j,i,t-1}^g - \sum_j \sum_i \delta_{j,t} p_{j,t-1} KP_{j,i,t-1}^g \tag{14}$$

Growth Accounting Implications

As already indicated, the explicit recognition of the provision of capital services by public assets –beyond capital consumption- affects the value, as well as the growth rates, of two of the variables involved in any growth accounting exercise: value added and capital input.

Let's PQ_t^{NA} be the aggregated nominal value added in year t according to National Accounts, while PQ_t^R denotes the revised nominal value added corresponding to the alternative approach proposed here. Equation (15) defines nominal value added in branch i, $PQ_{i,t}^R$, as:

$$PQ_{i,t}^R = PQ_{i,t}^{NA} + \sum_j cu_{j,t} KP_{j,i,t-1}^g - \sum_j \delta_{j,t} p_{j,t-1} KP_{j,i,t-1}^g \tag{15}$$

Real value added in sector i, $Q^R_{i,t}$, is obtained using National Accounts deflators (P^{NA}):

$$Q_{i,t}^R = PQ_{i,t}^R / P_{i,t}^{NA}; \qquad P_{i,t}^{NA} = PQ_{i,t}^{NA} / Q_{i,t}^{NA}$$

The rate of growth of aggregate real output (Q^R) is computed using a Törnqvist index as given by (16)

$$\frac{1}{T}\left[\ln Q_t^R - \ln Q_{t-T}^R\right] = \frac{1}{T}\left\{\sum_i 0.5\left[\frac{PQ_{i,t}^R}{\Sigma_i PQ_{i,t}^R} + \frac{PQ_{i,t-T}^R}{\Sigma_i PQ_{i,t-T}^R}\right]\left[\ln Q_{i,t}^R - \ln Q_{i,t-T}^R\right]\right\} \tag{16}$$

The growth rate of capital is given by an equation similar to (7) where VCS is computed in (5) using the alternative user cost given by (13). Before comparing –in the fifth section below- the results provided by both approaches the next section provides a brief description of the data characteristics and sources.

250 This assumption is also very useful since it prevents that changes in the organization of the public sector affect the performance of the economy. For instance, when the provision of capital services previously provided by the public sector (according to NA) it is now supplied by a public entity (now considered by NA similar to a private enterprise).

The Data

Fundación Banco Bilbao Vizcaya Argentaria (FBBVA) and the *Instituto Valenciano de Investigaciones Económicas* (Ivie) elaborate the Spanish capital database. The methodology follows the one proposed by the OECD in two Manuals: *Measuring Capital and Measuring Productivity*[251]. The Volume Index of Capital Services, KP_t, is constructed using a Winfrey S-3 Retirement Function and a Hyperbolic Age-Efficiency Function. The FBBVA-Ivie estimates consider 43 industries and 18 asset types. Table 16–1 presents the classification of industries and table 16–2 the 18 asset categories.

The information is available on a yearly basis for the period 1964–2002[252]. The FBBVA-Ivie database makes a clear distinction between assets owned by the private sector and those owned by the public sector[253]. The latter appear under the heading *Public Administration* in table 16–1 consisting of ten different industries (31–40). It is interesting to note that infrastructures enter twofold in the Spanish estimates: as assets in table 2, and also as industries in table 16–1. Infrastructures owned privately (such as highways or some water infrastructures) are included in the *Transport, Storage and Communication* industry (branches 23–26) or *Electricity, Gas and Water Supply* (branch 19). Publicly owned infrastructures are assigned to the branch *Public Administration* in table 16–1 (branches 31–36), together with non-market health, education, social work and the rest of public administration.

Table 16–3 will contribute to clarify the way investment in each type of infrastructure is treated in the Spanish capital estimates. For each year *t* we have a matrix with 18 different types of assets -detailed in table 16–2 in columns-, and the 43 industries in rows. For urban infrastructures it is only the public administration that carries out any investment in Spain. With respect to the remaining assets, either the private or the public sector can accumulate them. Take for example the asset "roads" in column 10. If the public administration is the active agent, we will record the amount invested in the row 31, *Road infrastructures*, under the *Public Administration* heading. However, if it is a private toll road we will record it in row 23 *Road infrastructures* under the heading *Transport, Storage & Communication*[254].

The information for the variables GOS^{NA}, PQ^{NA} and Q^{NA} comes from the Spanish National Accounts released by the Spanish *Instituto Nacional de Estadística* (INE). The total values have been obtained by the aggregation of the forty three industries detailed in table 16–1. Since residential capital is not considered part of the definition of productive capital, we exclude two items from gross value added: namely, rents from dwellings and incomes from

251 The details can be found in Mas, Pérez and Uriel (2005, 2006).

252 For the purpose of this exercise the information has been updated to 2004 on a provisional basis.

253 The public sector corresponds exactly with NA definition. That is to say, total public Gross Fixed Capital Formation figures in the Spanish capital services estimates are taken directly from NA.

254 The above procedure has a limitation, originated by the lack of sufficiently detailed information. This constraint deals with the one-to-one correspondence between assets and industries. A more realistic view would take into account that a given industry, lets say Airport, uses different types of assets coming from 16. other constructions n.e.c, 17. software, 8. other transport equipment, and so on. We are presently working on this important issue, but no definitive results are available yet.

T16–1 Classification of industries

Industry	Descriptionww	Code CNAE-93 = Code NACE Rev. 1
1	Agriculture, hunting and forestry	1–févr
2	Fishing, fish farming and related service activities	5
3	Mining and quarrying of energy producing materials	10–déc
4	Mining and quarrying except energy producing materials	13–14
5	Manufactures of food products, beverages and tobacco	15–16
6	Manufacture of textiles and wearing apparel; dressing and dyeing of fur	17–18
7	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	19
8	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20
9	Manufacture of pulp, paper and paper products; publishing, printing and reproduction of recorded media	21–22
10	Manufacture of coke, refined petroleum products and nuclear fuel	23
11	Manufacture of chemicals and chemical products	24
12	Manufacture of rubber and plastic products	25
13	Manufacture of other non-metallic mineral products	26
14	Manufacture of basic metals and fabricated metal products, except machinery and equipment	27–28
15	Manufacture of machinery and equipment n.e.c.	29
16	Manufacture of electrical and optical equipment	30–33
17	Manufacture of transport equipment	34–35
18	Manufacture of furniture; manufacturing n.e.c.; Recycling	36–37
19	Electricity, gas and water supply	40–41
20	Construction	45
21	Wholesale and retail trade; repairs	50–52
22	Hotels and restaurants	55
	Transport and storage and communication	60–64
23	Road infrastructures	
24	Railways infrastructures	
25	Airport infrastructures	
26	Port infrastructures	
27	Rest of Transport and storage and communication	
28	Financial intermediation	65–67
29	Real estate activities	70
30	Renting of machinery and equipment and other business activities	71–74
	Public administration	75, 80P, 85P
31	Road infrastructures	
32	Water infrastructures	
33	Railways infrastructures	
34	Airports infrastructures	
35	Ports infrastructures	
36	Urban infrastructures	
37	Non-market education	

Industry	Descriptionww	Code CNAE-93 = Code NACE Rev. 1
38	Non-market health	
39	Non-market social work	
40	Rest of public administration	
41	Market education	80P
42	Market health and social work	85P
43	Other community, social and personal services	90–93

T 16 – 2 Classification of Assets

Product	Description	Code CNPA96 = Code CPA96
1	Agricultural, livestock and fish products	1-mai
2	Metal products	28
3	Machinery and mechanical equipment	29
4	Office machinery and computer equipment	30
5	Communications	313, 32, 332–333
6	Other machinery and equipment n.e.c	31 (ex. 313), 331, 334–335, 36
7	Motor vehicles	34
8	Other transport material	35
9	Dwellings (Residential Construction)	45P
	Other constructions	45P
10	Road infrastructures	
11	Water infrastructures	
12	Railway infrastructures	
13	Airport infrastructures	
14	Port infrastructures	
15	Urban infrastructures	
16	Other constructions n.e.c.	
17	Software	72
18	Other products n.e.c.	Rest of codes

private household with employed persons[255]. The Bank of Spain publishes data for the nominal interest rates, i_t, and the ratio β_t. For the former one medium and long-term corporate loan rates are used, and for the latter one the ratio external funds/(external funds+equity) comes from a survey published yearly by the Bank of Spain's *Central Balance Sheet Office*.

Implications of the two approaches

From our perspective, the choice between the standard *vs* the alternative approach here proposed has consequences for the levels of Gross Operating Surplus and Value Added; and also for the growth rates of Value Added and Capital. Graph 16–1 plots the ratios between the two forms of computation for the two variables, GVA and GOS. GVA data for the alternative approach are given by equation (15) and those for GOS from (14). As can be seen, National Accounts underestimate the GVA figures by approximately 5%–6% and the GOS figures by 15%. In both cases the gap has increased since the mid nineties. However, these differences in levels are lower in terms of growth rates. Graphs 16–2 and 16–3 show that the differences in growth rates between the two approaches are practically non existing.

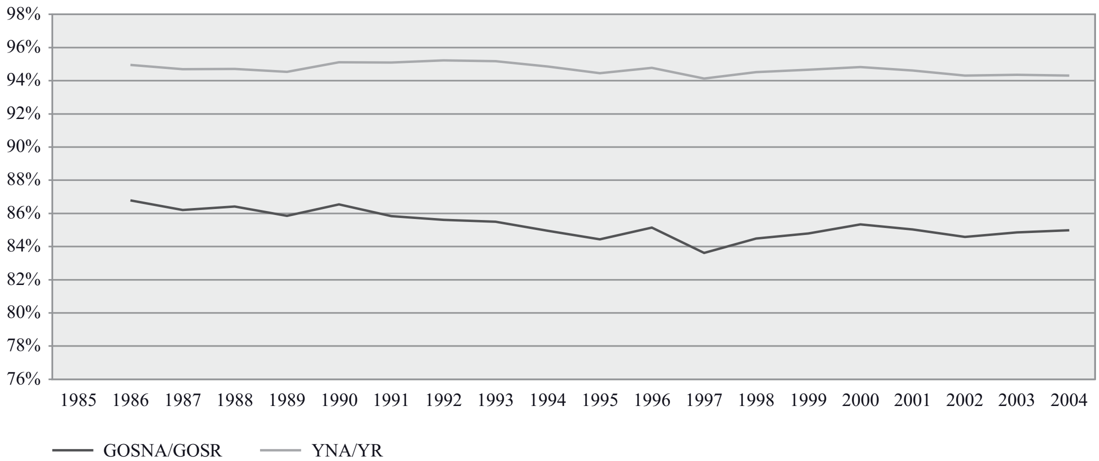
[255] Mas (2005) addresses similar issues but including residential capital, and thus rents, in the calculations.

T 16–3 Treatment of Infrastructures in the Spanish capital estimates. An illustration Recording of year t investment in infrastructures

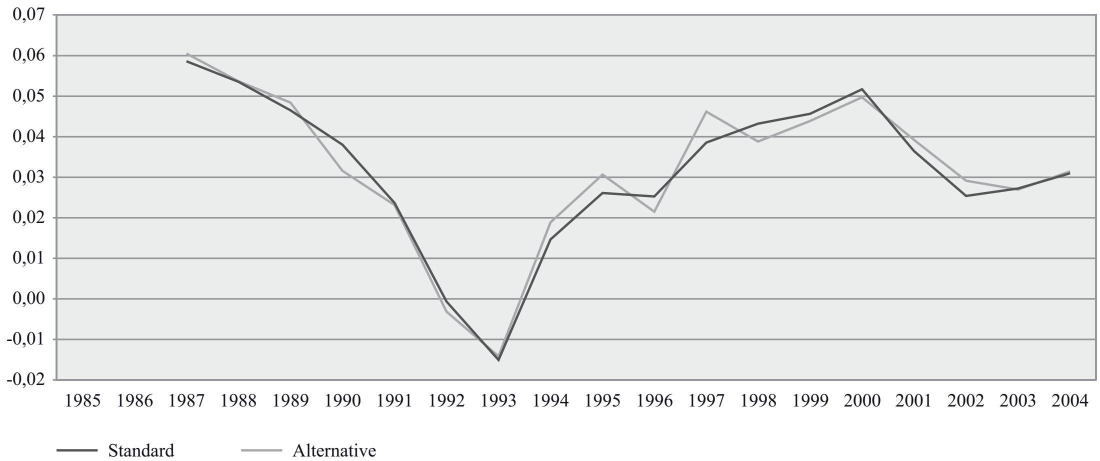
Year t (e.g. 2000)

INDUSTRIES	TYPES OF ASSETS									
	Infrastructures									
	1. Agric.	...	10 Road	11 Water	12 Rail-way	13.Airport	14.Port	15 Urban	...	18.Other
1. Agriculture, hunting & forestry										
2. Fishing										
...										
19. Electricity, gas & water supply				Private I						
…										
Transport, storage & communication										
23. Road infrastructures			Private I							
24. Railways infrastructures					Private I					
25. Airport infrastructures						Private I				
26. Port infrastructures							Private I			
27. Rest of transport, storage & communication										
...										
Public Administration										
31. Road infrastructures			Public I							
32.Water infrastructures				Public I						
33. Railways infrastructures					Public I					
34. Airport infrastructures						Public I				
35. Ports infrastructures							Public I			
36. Urban infrastructures								Public I		
...										
43. Other community, social & personal services										

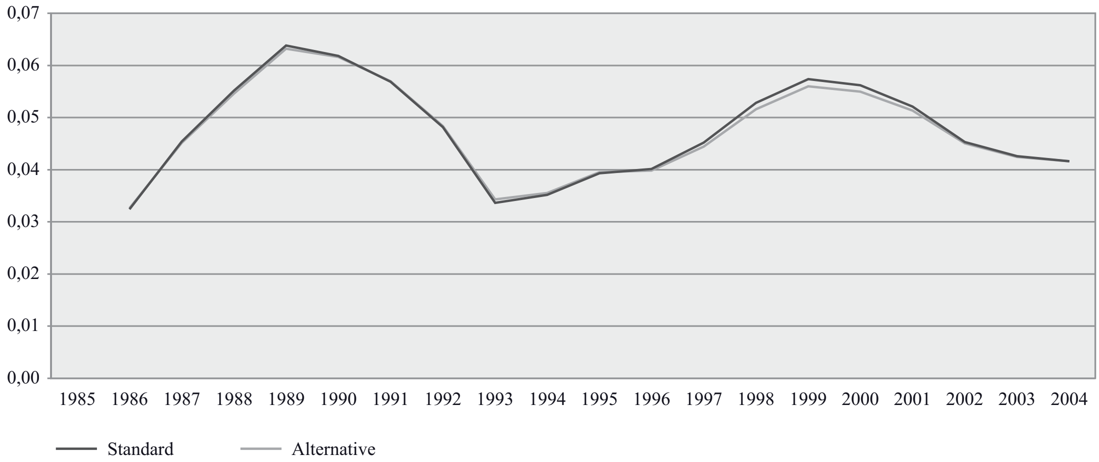
**Gross Value Added and Gross Operating Surplus.
Ratio National Accounts/Alternative Approach** **G 16–1**



Growth Rates of Value Added. Standard vs. Alternative Approach **G 16–2**



Growth Rates of Capital. Standard vs. Alternative **G 16–3**



ICT and Infrastructures. Results

From now on, the results shown were obtained under the *alternative* approach assumptions. But before turning to the growth accounting results it is interesting to take a closer look to some of its determinants. The first one is the user cost. According to equation [10] the user cost expression has two elements: the price of the asset, $p_{j,t}$, and the user cost per euro invested: $[\beta_t i_t + (1 - \beta_t) \rho_t - \pi_{j,t} + (1+\pi_{j,t}) \delta_{j,t}]$. Table 16–4 presents the estimated total user cost -as well as each of its two components- for six infrastructures and three ICT assets.

The first thing to notice is that the user cost has increased for all the assets included in the infrastructures and ICT groups, with the only exception of *Office machinery and computer equipment* (hardware for short). At the beginning of the period, the user cost was lower for infrastructures than for ICT capital as a consequence of both, lower prices indexes and lower unit user costs. In contrast, in 2004 the user cost for hardware was lower than for infrastructures due to the strong price reduction of the former. In fact, while hardware experienced more than a six fold (6.3) accumulated price reduction, infrastructures prices more than doubled (2.4) between 1985 and 2004. Notice too that, as expected, the unit user cost of ICT assets has always been higher than for infrastructures due to the conjunction of two combined effects: higher depreciation rates -as a result of shorter services lives- and capital losses originated by falling prices, especially in hardware.

As already mentioned, most of the papers devoted to the analysis of the role of infrastructures on economic growth start by estimating an equation such as (1) –usually highlighting only infrastructure capital. They frequently impose constant returns to scale (CRS) and perfectly competitive markets. So the estimated coefficient is identified as the infrastructure's output elasticity. Under these assumptions, total cost (*TC*) equals total revenue (*PQ*) and equation (6) provides the expression for infrastructures' value added elasticity. Its computation is provided in table 16–5.

T16–4 User cost and its components. Infrastructures and ICT

			1985	1990	1995	2000	2004
1. Asset Prices $[p_{j,t-1}]$ and GDP Deflator (Pt)							
	Infrastructures		0.551	0.746	0.959	1.098	1.328
	ICT						
		4.2.3. Office machinery and computer equipment	1.656	1.473	1.095	0.428	0.268
		4.2.4.1. Communications	0.697	0.895	1.003	0.918	0.866
		4.3.1. Software	0.908	0.998	0.978	1.128	1.223
	GDP Deflator		0.541	0.764	1.000	1.131	1.326
2. Unit user cost $[\beta i_t+(1-\beta)\rho_t-\pi_{j,t}+(1+\pi_{j,t})\delta_{j,t}]$							
	Infrastructures						
		2.1. Road infrastructures	0.089	0.126	0.120	0.110	0.115
		2.2. Water infrastructures	0.098	0.137	0.133	0.124	0.130
		2.3. Railway infrastructures	0.101	0.139	0.133	0.124	0.125
		2.4. Airport infrastructures	0.103	0.139	0.132	0.119	0.121
		2.5. Port infrastructures	0.093	0.130	0.124	0.114	0.119
		2.6. Urban infrastructures	0.096	0.131	0.125	0.115	0.120
	ICT						
		4.2.3. Office machinery and computer equipment	0.410	0.403	0.432	0.437	0.382
		4.2.4.1. Communications	0.223	0.253	0.248	0.295	0.260
		4.3.1. Software	0.602	0.622	0.592	0.601	0.617
3. User cost (=2*3)							
	Infrastructures						
		2.1. Road infrastructures	0.049	0.094	0.115	0.120	0.153
		2.2. Water infrastructures	0.054	0.102	0.127	0.136	0.172
		2.3. Railway infrastructures	0.056	0.104	0.128	0.136	0.166
		2.4. Airport infrastructures	0.057	0.104	0.126	0.131	0.161
		2.5. Port infrastructures	0.051	0.097	0.119	0.126	0.158
		2.6. Urban infrastructures	0.053	0.098	0.120	0.126	0.160
	ICT						
		4.2.3. Office machinery and computer equipment	0.679	0.593	0.473	0.187	0.102
		4.2.4.1. Communications	0.156	0.226	0.249	0.271	0.226
		4.3.1. Software	0.547	0.621	0.580	0.678	0.755

Source: Own elaboration

For total capital, the estimated gross value added elasticity is around 0.37, while for non-infrastructures non-ICT is approximately 0.1 of a percentage point lower. Infrastructures elasticity increased over the period, presenting values around 0.05–0.06 since 1995. This figure is very close to the one obtained by Mas *et al* (1996) for Spain (0.086) and higher than in Goerlich and Mas (2001) for the fifty Spanish provinces (0.02). The aforementioned elasticities were computed from an econometric estimation of a production function equation similar to (1). The lower value of the elasticity when provincial data are used can be interpreted by the presence of spillover effects among contiguous territories. These figures reconcile the results obtained from the two alternative strategies, econometric estimation and growth accounting. However, it also contradicts a previous results obtained by Mas *et al* (1996) where, after the recursive estimation of a production function, the elasticity diminishes and does not increase as it is now the case.

T 16 – 5 User cost and its components. Infrastructures and ICT

		1985	1990	1995	2000	2004
Total Infrastructures		**0.038**	**0.047**	**0.057**	**0.053**	**0.060**
	Private	0.012	0.013	0.013	0.012	0.015
	Public	0.026	0.035	0.043	0.041	0.046
2.1. Road infrastructures		**0.013**	**0.018**	**0.023**	**0.023**	**0.026**
	Private	0.004	0.004	0.004	0.003	0.003
	Public	0.010	0.014	0.020	0.020	0.022
2.2. Water infrastructures		**0.012**	**0.014**	**0.015**	**0.013**	**0.014**
	Private	0.001	0.001	0.001	0.001	0.001
	Public	0.011	0.013	0.014	0.013	0.013
2.3. Railway infrastructures		**0.007**	**0.008**	**0.009**	**0.008**	**0.010**
	Private	0.005	0.005	0.006	0.005	0.007
	Public	0.002	0.003	0.003	0.003	0.003
2.4. Airport infrastructures		**0.001**	**0.001**	**0.002**	**0.002**	**0.002**
	Private	0.000	0.000	0.001	0.001	0.002
	Public	0.001	0.001	0.001	0.001	0.001
2.5. Port infrastructures		**0.002**	**0.003**	**0.003**	**0.003**	**0.003**
	Private	0.002	0.002	0.002	0.002	0.002
	Public	0.000	0.000	0.001	0.001	0.001
2.6. Urban infrastructures		**0.002**	**0.004**	**0.005**	**0.005**	**0.006**
	Public	0.002	0.004	0.005	0.005	0.006
ICT		**0.033**	**0.042**	**0.043**	**0.044**	**0.040**
4.2.3. Office machinery and computer equipment		0.009	0.013	0.012	0.009	0.008
4.2.4.1. Communications		0.020	0.022	0.022	0.023	0.019
4.3.1. Software		0.005	0.008	0.009	0.012	0.013
Non-Infrastructures, non-ICT		**0.297**	**0.277**	**0.260**	**0.257**	**0.280**
TOTAL		**0.368**	**0.367**	**0.359**	**0.355**	**0.380**

Source: Own elaboration

The database allows the distinction of infrastructures according to their ownership, private or public. However, from an economic standpoint this distinction has no consequences, since we are assuming that who owns the capital is not relevant for the impact of a given asset on the economy. Taken all together, the output elasticity of ICT assets is lower than that of infrastructures and it has remained fairly stable since 1990. The highest value corresponds to communications and the lowest to hardware, while software is the ICT asset showing the strongest elasticity increase.

The user cost values in table 16–4, allows us to compute the marginal product of each asset. If we keep assuming *CRS* and perfect competitive markets, profit maximization implies that the value of the marginal product of each factor of production must equal its price. Thus, the value of the marginal product of labor must equal the nominal wage. Similarly, the optimality condition implies that the value of the marginal product of capital must equalize the user cost. If we are interested in the physical marginal productivity, then the condition is that marginal productivity equals the user cost divided by the price of output.

However, we do not have a price for the assets -nor for output- but a price *index* equal for both to 100 in the base year (2000). Therefore, we do not have information on relative price *levels*, only about comparable inflation rates. This means that -if we want to compare the marginal productivities of different assets in a given year- we should make use of the information provided by section 2 in table 16–4, refered to unit user cost[256]. If, alternatively, we are interested in the time profile of marginal productivities, we should divide the user cost by the price index of output. This last calculation is provided in table 16–6 where the user cost in section 3 of table 16–4 has been divided by the GDP deflator in section 1 of the same table[257].

The information in section 2 of table 16–4 tell us that marginal productivities of ICT assets have always been higher than for infrastructures, specially for software due its short service life and consequently high depreciation. The time profiles provided by table 6 inform us that marginal productivities have been steadily decreasing along the period for ICT assets. This is not the case for infrastructures where it depends on the period under consideration. If we take 1985 as the initial year, marginal productivities have increased. But if we consider the period 1990–2004 we find a fairly constant path, or even a slight reduction.

The contribution of the different assets to output growth depends on two factors: their elasticity as well as their rate of growth. The latter ones appear in table 16–7. The rate of growth of total (non residential) capital has been rather strong in Spain, averaging 4.78% over the period 1985–2004, not showing a cyclical profile. ICT accumulation was even stronger, experiencing a marked slowdown during the period 1990–1995, when the Spanish economy went through a severe recession. The opposite profile was shown by public infrastructures, with their highest rate of growth precisely during those years. Since 1995

256 In the base year, the user cost and the unit user cost are the same. In the remaining years the differences are due, exclusively, to the time evolution of asset prices.

257 This procedure assumes that the marginal product of an asset is independent of the branch to which it is assigned. Alternatively, we could divide the user cost of an asset in industry i by the deflator of this same branch obtaining different marginal productivities depending on the branch using the asset.

T16–6 Marginal Productivities (User Cost/GDP Deflator)

		1985	1990	1995	2000	2004
Infrastructures						
	2.1. Road infrastructures	0.091	0.123	0.115	0.106	0.115
	2.2. Water infrastructures	0.100	0.134	0.127	0.120	0.130
	2.3. Railway infrastructures	0.103	0.135	0.128	0.120	0.125
	2.4. Airport infrastructures	0.105	0.136	0.126	0.116	0.121
	2.5. Port infrastructures	0.095	0.127	0.119	0.111	0.119
	2.6. Urban infrastructures	0.097	0.128	0.120	0.111	0.120
ICT						
	4.2.3. Office machinery and computer equipment	1.254	0.776	0.473	0.166	0.077
	4.2.4.1. Communications	0.287	0.296	0.249	0.240	0.170
	4.3.1. Software	1.010	0.812	0.580	0.599	0.569

Source: Own elaboration

public infrastructures have shown a noticeable deceleration that has been matched by a parallel upsurge of private infrastructures. While in 1985–1990 the rate of growth of private infrastructures was a modest 1.87% per year, in the last sub-period 2000–2004 it was four times higher, reaching 8.70%, mainly due to the extraordinary increase experienced by railways and airport infrastructures[258].

We have now all the ingredients needed to move to growth accounting. As already mentioned, infrastructures enter twice in the Spanish estimates: as assets in table 16–2, and also as industries in table 16–1. Therefore, from the perspective of the growth accounting framework, infrastructure capital affects the aggregate figures through its impact on two specific industries. Public infrastructures contribute to the growth rate of the value added generated by the *Public Administration* industry –and thus to aggregate value added- while privately owned infrastructures affect the growth rate of the *Transport, Storage and Communication* industry. Table 8 presents the result of the growth accounting exercise, taking as reference equation (2) but referred to labor productivity instead of total output.

Labor productivity grew at a rate of 1.08% per year during the period 1985–2004 but it went through very different phases. During the expansion years 1985–1990, as well as along the recession period 1990–1995, productivity growth averaged, respectively, 1.92% and 1.67%, well over 1.5% per year. Things changed in the following nine years of important

258 Over the last twenty years, Spain has carried out an intensive process of privatization of the main public companies closely related to the provision of public services: telephone and telecommunication, airports, air and maritime transport, energy, water resources and distribution, among others. Also, in railways and airport infrastructures, investments are now carried out by public entities not included as publicly owned infrastructures. In the Spanish estimates, if an asset is supplied until a given year by the public sector, and it either becomes privatized or it is managed by a public enterprise -not considered part of the definition of Public Administration-, then the investment on that year and thereafter is recorded in the row Transport, storage & communication in table 3.

T 16 – 7 Productive capital. Annual growth rates

Percentages

		1985–2004	1985–1990	1990–1995	1995–2000	2000–2004
Total Infrastructures		**4.82**	**4.95**	**5.40**	**3.92**	**4.76**
	Private	4.12	1.87	2.79	3.42	8.70
	Public	5.10	6.20	6.27	4.07	3.56
	2.1. Road infrastructures	**5.65**	**6.27**	**7.36**	**4.43**	**4.28**
	Private	1.62	0.82	1.19	1.30	3.58
	Public	6.65	8.05	8.77	4.95	4.38
	2.2. Water infrastructures	**2.95**	**3.41**	**3.57**	**2.60**	**2.03**
	Private	0.77	-0.15	-0.04	0.41	3.36
	Public	3.10	3.68	3.80	2.71	1.96
	2.3. Railway infrastructures	**4.63**	**3.16**	**3.37**	**3.74**	**9.04**
	Private	5.03	2.50	3.06	4.03	11.92
	Public	3.64	4.63	3.99	3.18	2.54
	2.4. Airport infrastructures	**6.03**	**3.86**	**3.99**	**4.98**	**10.67**
	Private	14.53	8.31	19.52	13.36	17.53
	Public	-0.95	2.95	-1.83	-2.41	-2.90
	2.5. Port infrastructures	**3.60**	**3.31**	**4.01**	**2.86**	**4.09**
	Private	2.64	2.31	2.70	2.52	3.15
	Public	8.11	10.61	10.36	4.10	7.17
	2.6. Urban infrastructures	**7.43**	**11.04**	**7.49**	**5.77**	**4.95**
	Public	7.43	11.04	7.49	5.77	4.95
ICT		**9.92**	**13.42**	**5.87**	**11.18**	**7.53**
	4.2.3. Office machinery and computer equipment	17.40	20.11	8.94	21.94	17.63
	4.2.4.1. Communications	6.04	8.00	3.77	7.10	4.95
	4.3.1. Software	10.81	20.20	6.82	9.14	4.71
Non-Infrastructures, non-ICT		**4.84**	**5.13**	**5.30**	**4.32**	**4.29**
TOTAL		**4.78**	**5.24**	**4.24**	**4.98**	**4.54**

Source: Own elaboration

output –and especially labor- growth. During the years 1995–2000 labor productivity growth was slightly negative (-0.08%) but it recovered its pulse – though modestly – over the years 2000–2004 (0.62%)

Over the whole period, 1985–2004, capital deepening contribution was responsible for most (89%) of total productivity growth. Infrastructures contributed with 12.96%, half the magnitude of ICT capital. It is interesting to concentrate on the last two sub-periods. The negative increase in labor productivity during the second half of the nineties originated in the combination of two factors: a strong deceleration of the capital endowments per worker, together with a negative contribution of Total Factor Productivity (TFP) growth. Capital deepening slowdown affected all forms of capital, with the sole exception of ICT capital. For the remaining forms of capital their contribution was almost nil, being private infrastructures contribution slightly negative.

T16–8 Growth Accounting. Labor productivity

Percentages

	1985–2004	1985–1990	1990–1995	1995–2000	2000–2004
1. Labor productivity growth (=2+6)	**1.083**	**1.924**	**1.670**	**-0.081**	**0.621**
2. Contribution of capital endowments per hour worked (=3+4+5)	**0.957**	**0.789**	**1.747**	**0.329**	**0.731**
3. Infrastructures. Total	**0.132**	**0.079**	**0.311**	**-0.007**	**0.126**
Private	0.026	-0.015	0.043	-0.008	0.082
Public	0.106	0.095	0.268	0.001	0.044
2.1. Road infrastructures	**0.069**	**0.049**	**0.163**	**0.009**	**0.042**
Private	-0.002	-0.009	0.007	-0.009	0.003
Public	0.071	0.058	0.157	0.018	0.039
2.2. Water infrastructures	**0.009**	**0.004**	**0.059**	**-0.020**	**-0.007**
Private	-0.001	-0.003	0.000	-0.003	0.001
Public	0.010	0.007	0.059	-0.018	-0.008
2.3. Railway infrastructures	**0.020**	**0.000**	**0.033**	**-0.003**	**0.057**
Private	0.017	-0.003	0.020	-0.000	0.057
Public	0.003	0.004	0.012	-0.002	-0.000
2.4. Airport infrastructures	**0.009**	**0.001**	**0.007**	**0.002**	**0.016**
Private	0.012	0.001	0.009	0.007	0.020
Public	-0.003	-0.000	-0.001	-0.006	-0.003
2.5. Port infrastructures	**0.004**	**0.001**	**0.013**	**-0.003**	**0.004**
Private	0.001	-0.002	0.008	-0.003	0.001
Public	0.003	0.002	0.005	0.000	0.003
2.6. Urban infrastructures	**0.022**	**0.024**	**0.036**	**0.009**	**0.014**
Public	0.022	0.024	0.036	0.009	0.014
4. ICT	**0.278**	**0.391**	**0.274**	**0.312**	**0.211**
4.2.3. Office machinery and computer equipment	0.130	0.181	0.117	0.190	0.133
4.2.4.1. Communications	0.073	0.101	0.095	0.069	0.051
4.3.1. Software	0.076	0.109	0.063	0.053	0.027
5. Non-Infrastructures, non-ICT	**0.547**	**0.319**	**1.161**	**0.025**	**0.394**
6. TFP (=1-2)	**0.126**	**1.134**	**-0.077**	**-0.410**	**-0.110**

Source: Own elaboration

Things changed in period 2000–2004. ICT capital deepening decelerated (from 0.312 to 0.211) while other forms of capital recovered their impulse. Especially noticeable was the increase experienced by infrastructures, which moved from a negative value (-0.007) in the years 1995–2000 to a positive one (0.126) in the last sub period. Even most important were the recovery of the non-infrastructures non-ICT capital (from 0.025 to 0.394) and the reduction of the negative contribution of TFP (from -0.410 to -0.110)[259].

[259] Further details can be found in Mas & Quesada (2005a,b & 2006)

Concluding remarks

New capital services data released by Fbbva/Ivie have made possible to carry out – improving and updating previous studies- an analysis of the impact of infrastructures and new technologies on Spanish growth. Used data include 43 industries and 18 different types of assets (including 6 types of infrastructures and 3 types of ICT capital). The chosen approach was growth accounting while most previous studies were forced to use –due basically to the lack of suitable data- an econometric perspective. National Accounts data are modified in order to take explicitly into account the capital services provided by public capital, especially when the endogenous approach to the internal rate of return determination is adopted. Accordingly, *GVA* figures provided by *NA* are underestimated by 5%–6% while Gross Operating Surplus is also underestimated by around 15%. However, the growth rates of both, *GVA* and that of the Volume Index of Capital Services, are not significantly affected.

Under some restrictive assumptions (constant returns to scale, perfectly competitive markets and optimizing behaviour) we compute the elasticities of the different types of assets as well as their marginal products. Computed infrastructures elasticities are similar to those obtained from previous econometric estimates in a range of around 0.06. By contrast, according to our estimates, we find slightly increasing infrastructures elasticities while previous results indicated the opposite trend.

Concerning marginal productivities we find, firstly, that the marginal productivities for the three ICT assets are higher than for infrastructures. And secondly, that ICT assets marginal productivities have decreased steadily and very rapidly, both in the case of hardware and software. By contrast, the marginal products of the six types of infrastructures have been fairly stable since 1990.

Finally, the growth accounting exercise carried out indicates that ICT contribution to Spanish productivity growth has been higher than infrastructures for the entire period 1985–2004. It was also higher in three of the four sub periods considered, being the recession years 1990–1995 the only exception. However, ICT capital deepening contribution slowed down in 2000–2004 compared to 1995–2000 in a general context of recovery of i) labor productivity; *ii*) capital deepening of the remaining forms of capital (including infrastructures) and *iii*) less negative TFP contribution.

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17. NEW TECHNOLOGIES AND THE GROWTH OF CAPITAL SERVICES
A Sensitivity Analysis for the Italian Economy over 1980–2003

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Introduction

The outstanding progress in Information and Communication Technology (ICT) witnessed in the past decade seems to have had a remarkable role in fostering economic growth both in developed and developing countries (Vu, 2004). However measuring and assessing the impact of ICT on economic growth is still a challenging task for most economies. The developments of the new economy have raised many essential questions about the measurement of intangible assets and high-technology capital. Indeed the answer to these questions can lead to better assessment of the economy's long run pace of economic growth and rate of technological advance.

The standard neoclassical approach provides a comprehensive and consistent framework to capital measurement (OECD, 2001a and b) and allows several possibilities about the choice of different depreciation patterns, efficiency decay profiles and rate of returns. But the identification of the most appropriate measure of capital services (to be used in productivity analysis) requires a sensitivity analysis to test the responsiveness of capital input to the above different assumptions.

In this paper, we illustrate the methodology adopted by the Italian Institute of Statistics (ISTAT) in calculating capital input for productivity measure and we address the following issues: How much sensitive is the measure of capital services to different age-efficiency and age-price profiles? What is the influence of different rates of return (exogenous versus endogenous)? Do ICT and Non-ICT capital services react in a different way to the assumptions on age-efficiency and age-price profiles? And on different rates of returns? And finally, what is the contribution of technological assets to the growth of capital services?

Here we provide some evidence for the Italian economy over 1980–2003 at the aggregate and industry level for a detailed asset type classification system. Our main findings are: i) the various measures of capital services do not differ substantially with respect to the choice of

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age-efficiency and age-price profiles but are more sensitive to different net rates of return; ii)in almost all years the volume index of capital services grows faster than aggregate capital stock and it shows a higher sensitivity to the business cycle; iii) in terms of the relative contribution of ICT to the growth of total capital services, the 80's were as much "ICT oriented" as the 90's, while in terms of absolute contributions the 80's were even more "ICT oriented"; iiii) both the growth of total capital services and ICT contribution were higher in the service sectors than in Manufacturing, Mining and Energy and Constructions.

The structure of the paper is as follows. The next section summarizes some issues on the measurement of capital service; the third section shows the empirical results for the Italian economy in 1980–2003 and some conclusions are drawn in the last section.

Measurement Issues

The measurement of the contribution of capital goods to the production process requires a two-stage method (OECD, 2001b): first, it is necessary to estimate quantity and price of the services provided by each type of asset (i.e. its productive capital stock and its user cost); then to construct an aggregate measure of the productive contribution of the different type of assets (i.e. of the aggregate flow of capital services).

In this paper we adopt the standard neoclassical approach that provides a consistent and comprehensive framework to the measurement of capital services. The standard model relies on some simplifying assumptions (constant returns to scale, perfect competition and long-run equilibrium and some stringent properties of the production technology necessary to guarantee a consistent aggregation) that are hardly met in real world economies. This implies that the results derived using this framework must be regarded as approximate at best (Hulten, 1990). The following paragraph provides a brief non technical overview of the neoclassical approach to the measurement of capital service (see Hulten, 1990, Jorgenson, 1989 and Diewert 2003 for comprehensive descriptions of both the theory and empirical issues on capital measurement).

The Productive Capital Stock and the user cost

In order to quantify the contribution of a specific type of asset to the production process it is essential to evaluate the flow of capital services generated by the asset during the accounting period. The flows of capital services are not (usually) observable; therefore they have to be measured by a proxy. The standard practice assumes that the service flows are in proportion to the productive capital stock.

For an asset whose service life is T years (i.e. an asset that remains in use in the productive process for T years), the productive capital stock is defined as a weighted sum of past investment of the last T years, where the weights reflect the efficiency decay of the asset as it ages (i.e. the fact that older assets are less productive than newer because of wear and tear).

The pattern of the quantity of capital services produced by an asset over its service life relative to the quantity produced by a new asset (i.e. the sequence of the weights used to define the productive capital stock) is referred to as the age-efficiency profile.

The estimate of productive capital stock must deal with the fact that the actual service life for assets put in place in a given year will not be the same for all assets.

So that to account for the heterogeneity in the service lives the usual approach is to assume that retirements follow a given distribution around the mean service life.

The age-efficiency and the retirement functions can be combined together to obtain a set of coefficients h^i_t to be used to weight past investments at constant prices I^i_t to calculate the productive capital stock S^i_t (see Schreyer et al. 2005):

$$S^i{}_t = \sum_{t=1}^{T} h^i_t I^i_t$$

Since there is scarce empirical evidence both on the efficiency decay of an asset and on its retirement profile, the age-efficiency and the retirement functions are often assumed to follow a specific pattern over the service life (instead of being estimated).

The user cost[261] (or rental price) of capital is a measure of how much does it cost using one unit of the services provided by that asset. More precisely, it includes the cost of financing the purchase of the capital good, its economic depreciation (i.e. the loss in value of a capital good as it ages, that it is described by the sequence of relative prices for different vintages of the asset, referred to as its age-price profile), the capital gains-losses due to asset price changes and the net burden due to the tax structure for business income.

For the purposes of this paper, we refer to a simplified formula of the user cost of capital that does not take into account fiscal factors:

$$u^i_t = q^i_t (r_t + d^i_t - g^i_t)$$

where q^i_t is the acquisition price for a new capital good, r_t is the net return on investment, d^i_t is economic depreciation rate and g^i_t measures capital gains-losses.

Since direct observations of the user costs exist only for rented capital goods, the usual way to estimate u^i is by imputing directly its components from observable data (as it is usually the case for r_t and g^i_t and as it might be the case for d^i_t, provided there is empirical evidence on new and second-hand asset prices) or by assuming that they follow a specific pattern (as it is usually the case for d^i_t when there are no observations of second-hand asset prices).

A crucial result that emerges from the neoclassical approach is that the price of an asset depends on the quantity of services it is able to provide, and thus the assumptions on age-efficiency and depreciation profiles cannot be made independently of each other.

More precisely, the basic idea is that the price of an asset depends on the discounted flow of income it will generate during its remaining lifetime and the flow of income depends on both quantity and price of services. In other words, economic depreciation and efficiency decay follow two (in general) different but not independent patterns over time.[262]

261 Jorgenson and Griliches (1967) linked the measurement of both the user cost and capital services.

262 Since the price of an asset at a given year depends on the flow of services it will generate during its remaining lifetime, both present and future declines in productive capacity of the asset affect the change in its price from one year to the following one (and not only the change in actual efficiency due to the fact that the asset is one year older).

Full consistency between the estimates of productive capital stock and user cost can be obtained assuming a specific profile for the age-efficiency function and then deriving the age-price profile by means of the relationship that expresses the price of an asset as a function of the discounted flow of its future income. Alternatively one can start from a measure of net capital stock and depreciation and then derive the age-efficiency profile (see Schreyer et al. 2005 for a detailed description of computational aspects of both avenues).

When productive and net capital are estimated independently, one should check that the pattern of economic depreciation implied by the age-efficiency profile be at least broadly consistent with that implied by the depreciation method used to estimate net capital stock and consumption of fixed capital.

Aggregation Across Assets

Once the productive stock for different types of assets have been estimated, they have to be aggregated to get a measure of the overall flow of capital services provided by the stocks (i.e. a volume index of capital services).

The aggregation procedure requires the choice of both a specific aggregation formula and of a system of weights.

In the standard approach, the aggregation is implemented by means of changing weight index (usually the Tornqvist index) and cost-share weights for each asset type, where the cost refers to the cost of using the asset during the accounting period.

Let S^i_t be the productive stock of type i asset, u^i_t is its user-cost and S is the flow of total capital services. By means of the Tornqvist aggregation, the (logarithmic) rate of change of S is:

$$\ln\left(S_t / S_{t-1}\right) = \sum_{i=1}^{n} 0.5\left(v^i_t + v^i_{t-1}\right)\ln\left(S^i{}_t / S^i{}_{t-1}\right) \qquad (1)$$

where $v^i_{t=} (u^i_t S^i_t / \Sigma_{i \in n} u^i_t S^i_t)$ is the cost-share of asset i in period t and *n* is the number of asset types.

The contribution of each type of capital good to the growth of overall capital services is equal to the rate of change of its real productive capital stock (that it is assumed to be equal to the rate of change of the flows of services it provides) times its share in the value of total cost for capital in that period.

Changing weight indexes are preferred to fixed weights indexes because they are not affected by the substitution bias. Moreover, the Tornqvist index has the theoretically desirable property that it is an exact index for a translog structure of production (Diewert, 1976).

Cost-share weights allow accounting for the heterogeneity of marginal products of each type of capital good (and so for changes in the composition of aggregate capital

For instance, if the efficiency decay follows the so-called one-hoss-shay pattern (no loss in efficiency until the asset is retired), there is no decline in actual efficiency for the T years during which the asset is productive. Nevertheless the age-price profile is declining over time because as time goes by the remaining asset life is shorter and the willingness to pay for it will be lower.

stock). In fact, under the standard neoclassical assumptions, differences in user-cost across assets reflect differences in their marginal products. So weighting the rates of change of the n asset-specific productive capital stocks with the relative cost shares is equivalent to assign a relatively larger weight to the rates of change of the assets that have an higher marginal product and it allows to account for the substitution among different types of capital goods.

Note that measures of capital input based on asset price weights, as the aggregate productive capital stock fail to account for changes in the composition of capital stock. One dollar worth of investment in computers increases aggregate capital stock as much as one dollar worth of investment in structures: the growth of aggregate capital stock is not affected by changes in its composition.[263]

The difference between the growth rates of the cost-shares weighted index and the directly aggregated capital stock is usually referred to as composition effect.

The composition effect is positive (i.e. the rate of growth of the flow of capital services is higher than that of the capital stock) when the asset whose productive stock grows relatively faster are those that have the relatively higher user cost. In other words, the composition effect is positive when there is a shift in the composition of investment towards assets that provide a relatively higher flow of services per unit of capital.

ICT and Non-ICT Capital Services

The standard growth accounting model outlined in the previous paragraph is modified by a breakdown of the flow of capital services into ICT and non-ICT services to evaluate the impact of technological assets on the growth of aggregate capital services.

A volume index of the flow of capital services from ICT (Non-ICT) capital goods is obtained by aggregating across productive stocks of ICT (Non-ICT) capital goods using the Tornqvist index with weights equal to the share of each asset in the value of total cost for ICT (Non-ICT) capital services.

If there are *ni* ICT-type assets and *nn* Non-ICT (with *ni*+*nn*=*n*), then the indexes of ICT and Non-ICT capital services (respectively $\ln(SI_t/SI_{t-1})$ and $\ln(SN_t/SN_{t-1})$) are:

$$\ln\left(SI_t / SI_{t-1}\right) = \sum_{i=1}^{ni} 0.5\left(vi_t^i + vi_{t-1}^i\right)\ln\left(S^i{}_t / S^i{}_{t-1}\right) \tag{2}$$

Where

$vi_t^i = u_t^i S_t^i / \sum_{i=1}^{ni} u_t^i S_t^i$ and

$$\ln\left(SN_t / SN_{t-1}\right) = \sum_{i=1}^{nn} 0.5\left(vn_t^i + vn_{t-1}^i\right)\ln\left(S^i{}_t / S^i{}_{t-1}\right) \tag{3}$$

263 Thus a volume index of the aggregate productive stock is not a proper measure of the change in the flows of services provided by the existing stocks; rather, it is a measure (in base-year prices) of the change in the hypothetical quantity of new assets that would produce the same flow of services as the actual capital stock (Hill, 1999).

Where

$$vn_t^i = u_t^i S_t^i / \sum_{i=1}^{nn} u_t^i S_t^i$$

These two indexes can be used to evaluate the contribution of ICT and Non-ICT capital goods to output growth in an extended growth accounting framework (for an application to the Italian economy see Bassanetti et al, 2004).

Another point of interest is evaluating the contributions of these two components to the growth of the overall flow of capital services.

The contribution of ICT (Non-ICT) capital services to aggregate growth is equal to the Tornqvist index of ICT (Non-ICT) capital services times the share of ICT (Non-ICT) cost in the value of total cost for capital services:

$$\ln(S_t / S_{t-1}) = 0.5(ci_t + ci_{t-1})\ln(SI_t / SI_{t-1}) + 0.5(cn_t + cn_{t-1})\ln(SN_t / SN_{t-1}) \quad (4)$$

where $ci_t = \sum_{i=1}^{ni} u_t^i S_t^i / \sum_{i=1}^{n} u_t^i S_t^i$ and $cn_t = \sum_{i=1}^{nn} u_t^i S_t^i / \sum_{i=1}^{n} u_t^i S_t^i$

i.e. ci_t is the share of ICT capital goods in the value of total cost for capital services in period t and cn_t is the share of non-ICT capital goods.

Implementation issues

There are alternative user cost formulas that are consistent with economic theory and there is no enough empirical evidence to discriminate among them. As a consequence, empirical practice has varied concerning the choice of the age-efficiency and age-price profiles and of the net rate of return and the specification of the retirement pattern and capital gains term.

The estimates of capital input used in the productivity measure published by ISTAT rely on the following assumptions. The productive capital stock of each type of asset is estimated assuming an age-efficiency profile concave towards the origin (i.e. efficiency falls at a rate that increases as the asset ages). The profile is derived from an hyperbolic function. The retirement pattern is a truncated normal distribution around a constant service life. The corresponding user cost is imputed as follows. The net rate of return is calculated as a weighted average of two market interest rates taken as a measure, respectively, of the cost of debt and of the opportunity cost implicit in internal sources of financing[264] (i.e. using productivity analysis jargon, we use an exogenous rate of return). The acquisition prices for new capital goods are calculated as the ratio of investment at current prices to investment at constant prices. The depreciation rate is obtained as the ratio of consumption of fixed capital at constant prices to net capital stock at constant prices. Net capital stock and consumption

264 Where the weight is a measure of the share of debt in total liabilities, the cost of debt is the market lending rate and the opportunity cost is the net average rate of return on Italian Treasury bonds (BTP). The sources for these data are Bank of Italy and ISTAT.

of fixed capital are estimated using the straight line model of depreciation (i.e. it is assumed that the age-price profile follows a pattern of linear decline). Note that different assumptions about the age-price profile lead to different depreciation rates. The capital gains-losses term at time t is defined as a moving average of the rates of changes in the asset price in the three years priors to t.

In this paper we evaluate the impact on the growth of capital input of different assumptions on depreciation rates, rates of return, and age-efficiency profiles.

The hyperbolic profile of efficiency decay is motivated by two main reasons: this pattern is considered a plausible description of the efficiency decay of many types of capital goods, and the depreciation pattern implied by this age-efficiency function is broadly consistent with the depreciation method used to estimate net capital stock and depreciation, i.e. the straight-line method (Blades, 1998, OECD 2001b).

A first alternative measure is obtained deriving directly the age-price profile from the assumed age-efficiency profile, instead of assuming a linear one. A comparison of these two measures allows us to assess if our capital input measure is consistent.

Another common choice for age-efficiency decay is the so-called geometric pattern (i.e. efficiency falls at a constant rate as the asset ages). An important result that characterizes the geometric model is that, when the maximum service life converges towards infinity, age-efficiency and age-price profile coincide. Usually it is assumed that this profile accounts both for efficiency decay and for retirements, so that no explicit retirement function is required for its implementation.

With respect to the nominal net rate of return, an alternative approach is to estimate it as an internal rate. This option is based on the assumption that the remuneration of capital services exhausts total non labour income measured from National Accounts (gross operating surplus plus an imputation for the component of gross mixed income attributed to capital). If this equality holds, given the estimates of total income and of productive capital stock and of the other components of user-cost for each asset, then net rate of return can be computed residually. This rate of return is referred to as endogenous rate.

Empirical Issues

This section presents a first set of results for the Italian economy in the period 1980–2003.

Both the productive capital stock and the user cost of capital have been estimated for nine types of capital goods that comprises non-residential gross fixed capital formation: machinery and equipment; furniture; hardware; communications equipment; software; road transport equipment; air, see and rail transport equipment; non-residential buildings and other intangibles and services.

Sensitivity Analysis

In this section we present a comparison between alternative measures of capital input obtained testing the following hypothesis: hyperbolic age-efficiency decay and linear age-price profile (hl); hyperbolic age-efficiency decay and integrated age-price profile (hi); geometric age-efficiency and age-price profiles [265] (gg). Moreover we consider also a non consistent measure based on the same linear decline both for the age-efficiency and age-price profiles (ll). Each of the previous assumption has been adopted in both exogenous (bi) and endogenous (en) net rate of returns measures of capital.

Table 17-1 reports the average annual rates of growth of the above mentioned eight measures of capital services and the corresponding measures of aggregate productive capital stock.

T 17 – 1 Growth of Capital Services (net of residential capital)

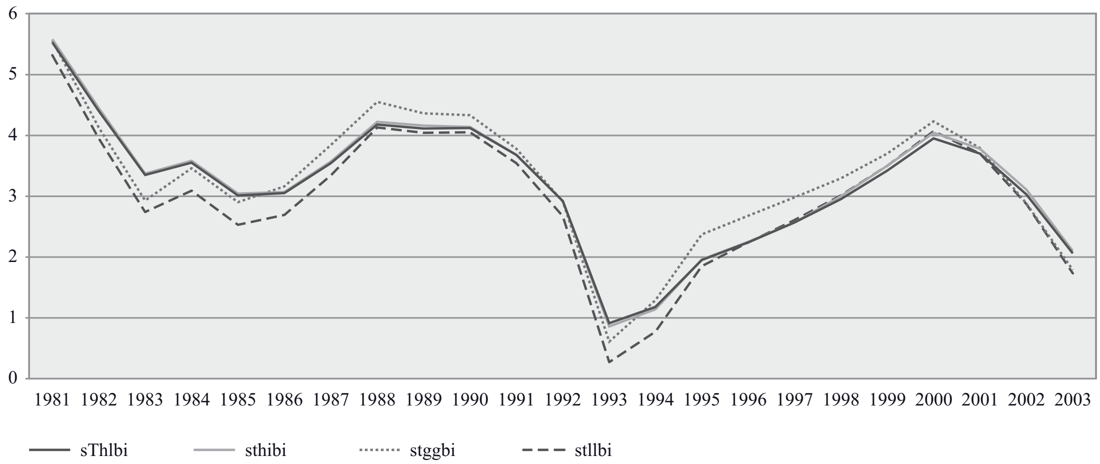
	1980–2003	1980–1985	1985–1990	1990–1995	1995–2000	2000–2003
hlbi	3.2	4.1	3.9	2.2	3.1	3.0
hlen	3.1	3.8	3.8	2.1	2.9	2.8
hibi	3.3	4.1	3.9	2.1	3.1	3.0
hien	3.2	3.9	3.9	2.1	3.0	2.9
ggbi	3.3	3.9	4.1	2.2	3.4	2.9
ggen	3.1	3.4	3.9	2.2	3.1	2.7
llbi	3.0	3.6	3.7	1.8	3.1	2.8
llen	2.8	3.2	3.5	1.8	2.8	2.6
capproh	2.7	3.2	3.3	2.1	2.4	2.4
capprog	2.7	2.8	3.3	2.2	2.6	2.4
capprol	2.5	2.7	3.1	1.8	2.4	2.3

[a] Average annual rate of growth in the period shown multiplied by 100
[b] Percentage points

Over the whole period we find that only minor differences (if any) exist between the consistent or broadly consistent measures of capital services (from **hlbi** to **ggen**). The growth of capital input is comprised in a range between 3.1% and 3.3%. The three measures (**hlen, hien, ggen**) based on endogenous rate of return record a bit lower average growth than the corresponding one based on the exogenous rate of return (**hlbi, hibi, ggbi**). On the other hand, the non consistent measure (**llbi, llen**) (based on the same linear pattern both for efficiency decay and depreciation) grows at fairly slower rates in both cases (2.8% using endogenous rate and 3.0% adopting exogenous rate).

265 The rate of depreciation for the geometric patterns, δ, as been calculated as δ = R/T, where R is the so-called declining-balance rate and T is the average service life. For each asset, T is the same one used in the other models. The value of R is based on Hulten and Wycoff (1981) and is set equal to 0.95 for non-residential buildings and to 1.65 for all other assets.

Capital service measures based on exogenous net rate of return: 1980–2003 **G 17–1**



The tested assumptions entail more significant differences if analyzed over shorter time periods. The average growth of alternative measures of capital input differ up to 0.5 percentage point in the 1980-1985 and only 0.1 percentage points in 1990-2005. But the exogenous rate of return always leads to higher growth of the volume of capital services. Graph 17–1 reports annual logarithmic rates of change of capital services based on exogenous net rate of return. Capital services based on hyperbolic efficiency decay are very similar all over the period, while the measure based on the geometric profile is a bit more sensitive to the business cycle. The same results hold adopting the endogenous rate of return.

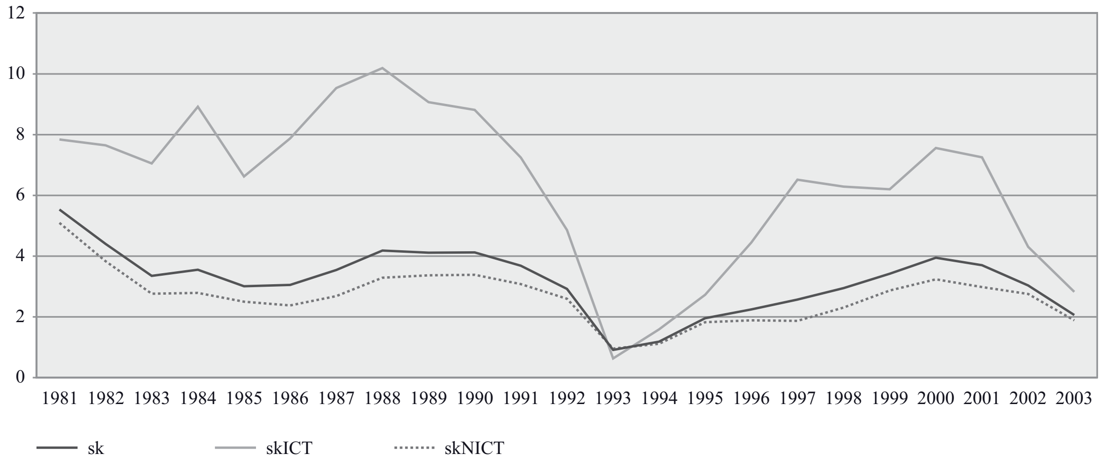
ICT and Non-ICT capital services

Graph 17-2 illustrates the annual rates of change in the volume index of total, ICT and Non-ICT capital services. Two results stand out immediately: ICT capital services show the fastest growth and the highest sensitivity to the business cycle compared to Non-ICT.

The average service life of ICT capital goods is shorter than that of non-ICTs. Hence ICT productive stock is more influenced by fluctuations of real investment than non-ICT. Further ICT real investment itself is relatively more sensitive to the business cycle (De Arcangelis et al., 2004). The rate of growth of ICT capital services followed two different patterns in the eighties and in the nineties. Since 1981 to 1991, the increase of technological capital ranged from 6% to 10%. In 1992, the currency crisis produced striking negative effects on total capital formation, inducing a considerable decline of the rate of growth of ICT capital services in 1993–1995 (respectively 0.72%, 1.57% and 2.61%) that recovered "pre-92" rates of growth only in 1997. In 2001–2003, ICT capital services declined sharply decreasing by 4%.

Table 17–2 and graph 17–3 show the contribution of ICT and non-ICT capital services to the growth of total capital services.

Total, ICT and non-ICT Capital Services: 1980–2003 **G 17–2**



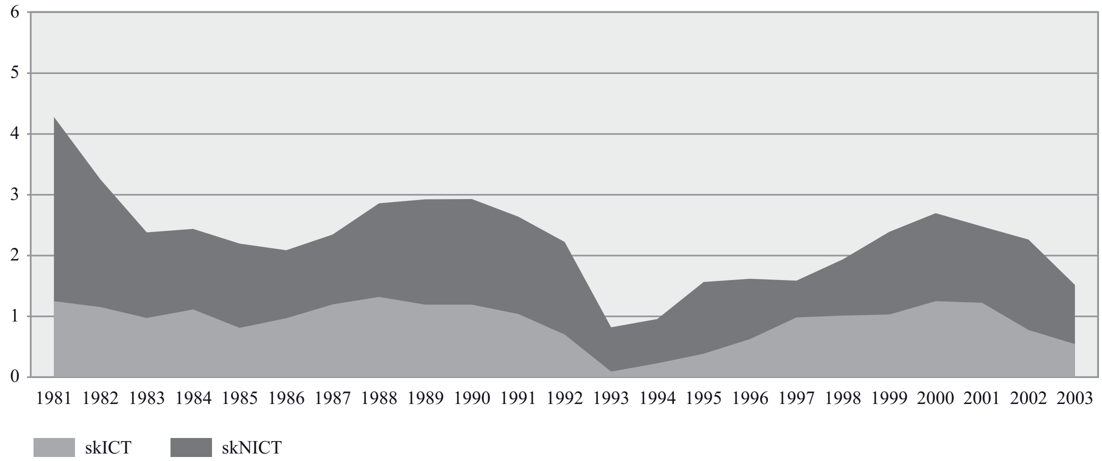
T 17 – 2 Growth of Capital Services (net of residential capital)

Total Economy net of Government
Computed from average annual rates of growth

	80–03	80–85	85–90	90–95	95–00	00–03
1. Growth rate of Capital Services [a]	3.2	4.1	3.9	2.2	3.1	3.0
2. Contributions from [b]:						
ICT Capital Services	0.9	1.1	1.2	0.5	1.0	0.9
Non-ICT Capital Services	2.3	3.0	2.7	1.7	2.1	2.1
2. Shares of the contributions from:						
ICT Capital Services	28%	26%	30%	23%	32%	29%
Non-ICT Capital Services	71%	73%	69%	77%	67%	71%
3. Capital income shares:						
ICT Capital	14.8	14.0	12.9	14.2	15.6	18.1
Non-ICT Capital	85.2	86.0	87.1	85.8	84.4	81.9
4. Growth rates of [a]:						
ICT Capital services	6.6	7.9	9.5	3.5	6.4	4.9
Non-ICT Capital services	2.7	3.5	3.1	1.9	2.5	2.6

[a] Average annual rate of growth in the period shown multiplied by 100
[b] Percentage points

ICT and non-ICT Contributions to the growth of Capital Services: 1980–2003 **G 17–3**



The most remarkable result is that in terms of the relative contribution of technological assets to the growth of total capital services, the 80's were as much "ICT oriented" as the 90's, while in terms of absolute contributions the 80's were even more "ICT oriented". Both in 1985–1990 and in 1995–2000, ICT capital goods accounted for about 30% of the overall growth of capital services, while they accounted for about 20% in 1980–85 and in 1990–95. In the second half of the 80's, ICT capital services recorded the highest absolute contribution (1.2 percentage points), compared to the lowest showed during the first half of the 90's (0.5 percentage points). In 1995–2000 there was a surge in the contribution from ICT, that was only slightly lower than that recorded in the first half of the 80's (1.0 vs. 1.1 percentage points). During the last three years ICT accounted for a smaller share of total capital services (29%).

It should be noticed that the income share of ICT capital grew steadily all over the period (14 percentage points in 1980–1985 and 18.1 percentage points in 2000–2003) and it was considerably higher than the share of ICT over productive capital stock (3.5 percentage points versus 7.5 percentage points all over the period (Table 17–2 and 17–3).

The results reported in graph 17–4 and in Table 17–3 suggest that the contributions to the growth of productive capital stock of both types of assets are quite different.

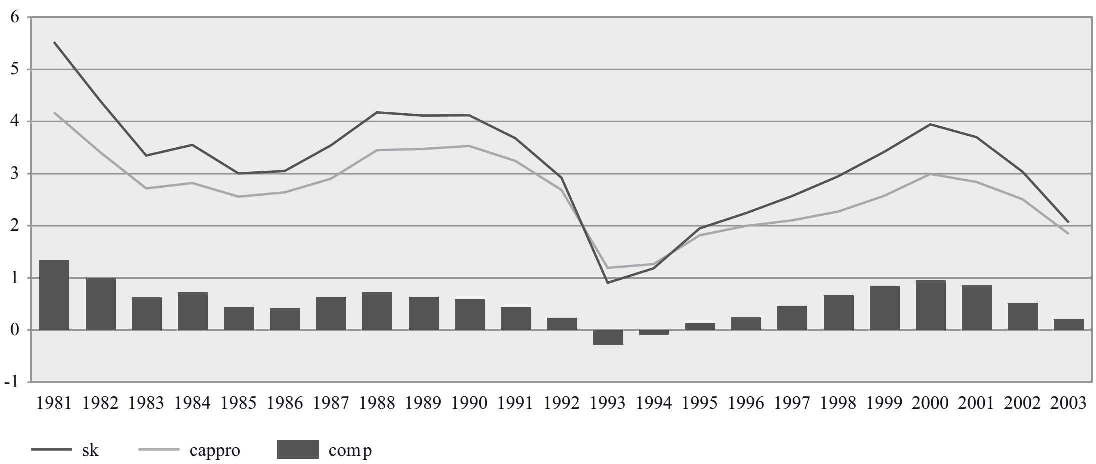
T 17 – 3 Growth of Capital Services (net of residential capital)

Total Economy net of Government Sector

	80–03	80–85	85–90	90–95	95–00	00–03
1. Growth rate of Productive Stock [a]	2.7	3.2	3.3	2.1	2.4	2.4
2. Contributions from [b]:						
ICT Capital	0.3	0.3	0.5	0.2	0.4	0.4
Non-ICT Capital	2.3	2.9	2.8	1.9	2.0	2.1
2. Shares of the contributions from:						
ICT Capital	13%	9%	14%	10%	17%	15%
Non-ICT Capital	87%	91%	86%	90%	83%	85%
3. Capital stock shares (constant prices):						
ICT Capital	5.4	3.5	4.7	5.8	6.5	7.5
Non-ICT Capital	94.6	96.5	95.3	94.2	93.5	92.5
4. Growth rates of [a]:						
ICT Capital	6.8	8.5	10.0	3.6	6.4	5.0
Non-ICT Capital	2.5	3.0	2.9	2.0	2.1	2.2

[a] Average annual rate of growth in the period shown multiplied by 100
[b] Percentage points

Capital Services, Productive Capital Stock and Composition Effect 1980–2003 **G 17–4**



All over the period, but 1993 and 1994, the volume index of capital services grew faster than aggregate capital stock (i.e. the composition effect is positive[266]) and it seems to be more sensitive to the business cycle (see Bassanetti et al, 2004). As stated above, the reason is that

266 The composition effect is positive if there is a substitution effect towards those assets characterized by a relatively higher user cost (marginal productivity).

ICT productive capital stock grows relatively faster and it is more sensitive to the cycle than non-ICT capital. Further the weights of ICT capital goods are relatively higher in capital services measure. Because of their shorter service life and higher depreciation rate, they have a relatively higher user-cost (see the second section).

Additionally, the contribution of ICT to the growth of capital stock is relatively lower than its contribution to the growth of capital services (13% vs. 28% in the whole period 1980-2003) and, when expressed as a percentage of capital stock growth, ICT shows the highest contribution in the second half of the 80's. In absolute term, the contribution of ICT capital services was quite the same in the 80's as well as in the 90's.

Table 17–4 shows the contributions to the growth of capital services in four broad sectors.

T 17 – 4 Growth of Capital Services (net of residential capital)

Sectoral results

Year		Capital Services[a]	Contributions from [b]:			
			ICT		non-ICT	
Manufacturing, Mining, Energy.	1980–1985	3.6	0.5	14%	3.1	86%
	1985–1990	3.2	0.5	17%	2.6	83%
	1990–1995	1.8	0.3	17%	1.5	83%
	1995–2000	2.3	0.9	37%	1.5	63%
	2000–2003	1.9	0.6	30%	1.3	70%
	1980–2003	2.6	0.5	21%	2.1	79%
Constructions.	1980–1985	3.4	0.4	13%	3.0	87%
	1985–1990	1.1	0.3	31%	0.8	69%
	1990–1995	-1.1	0.0	-3%	-1.1	103%
	1995–2000	3.0	0.5	16%	2.5	84%
	2000–2003	5.7	0.6	10%	5.1	89%
	1980–2003	2.1	0.4	17%	1.8	83%
Trade, Transport, Communications.	1980–1985	4.7	1.7	35%	3.0	64%
	1985–1990	5.6	2.4	43%	3.1	56%
	1990–1995	3.6	1.2	32%	2.4	67%
	1995–2000	3.7	0.6	17%	3.1	83%
	2000–2003	3.4	0.3	10%	3.0	90%
	1980–2003	4.3	1.3	31%	2.9	68%
Banking, Finance, Business Services.	1980–1985	6.2	3.3	53%	2.8	46%
	1985–1990	5.7	2.8	49%	2.8	49%
	1990–1995	2.4	0.8	33%	1.6	66%
	1995–2000	4.1	3.0	73%	1.1	26%
	2000–2003	4.0	3.1	77%	0.9	23%
	1980–2003	4.5	2.5	56%	1.9	43%

[a] Average annual rate of growth in the period shown multiplied by 100
[b] percentage points

A great deal of heterogeneity emerges both with respect to the rates of growth of capital services and to the relative contributions of ICT and non-ICT services. The rate of growth of total capital services in Manufacturing, Mining and Energy and in Constructions is always lower than in the two service sectors, and the best performer is Banking, Finance and Business Services (with the exception of 1990–1995 when the highest growth is in Trade, Transport & Communications). Over the whole period, we find the same results both with respect to the absolute and the relative contributions of ICT services, even though with some exceptions in some sub-periods. As expected, the most ICT-oriented sector is Banking, Finance & Business Services, where ICT accounted for about 77% of overall capital services in 2000–2003 and about 56% in the entire period.

In terms of the contributions to the growth of total capital services, Manufacturing, Mining and Energy emerges as a non-ICT oriented sector. In 1980–2003, ICT accounted for 0.5 percentage points, a very modest contribution if compared with Trade, Transport & Communications (1.3 percentage points) and with Banking, Finance and Business Services (2.5 percentage points).

However, it should be noticed that the relative lower contribution of ICT to manufacturing could be partly attributed to measurement problems. Actually, due to the lack of information necessary to obtain a deeper level of disaggregation of machinery and equipment, those capital goods that have a large technological content (semiconductors), but that are not produced by ICT sectors are classified as non-ICT goods. This implies an underestimation of the relative contribution of ICT to the growth of total capital services. Further, it causes a bias in inter sectoral comparisons of the relative contribution of ICT because it is likely that manufacturing would be more affected by the above underestimation problem.

Conclusions

In this paper we show that over 1980–2003, the measure of capital services for the Italian economy is not very sensitive to different assumptions about age-efficiency and age-price profiles and to the choice of the net rate of return. Whereas for shorter horizons the geometric pattern is more sensitive to business cycle fluctuations than the hyperbolic. Over the whole period as well as over shorter horizons, the measures based the on endogenous rate of return records a bit lower average rate of growth than the corresponding based on the exogenous rate. Then we prove that the volume index of capital services grows faster than the aggregate capital stock and that it is more sensitive to the business cycle. The analysis of ICT contribution to the growth of capital services showed that it still represents a small fraction of the total productive capital stock (less than 5%) and it accounted for a modest 12% of the growth of productive capital stock in the 1980–2003 period. The small share of ICT in total investment expenditure and total productive capital stock suggest that its contribution to the growth of total capital input is negligible. But we have shown that when capital input is measured in terms of the flow of capital services, this is not the case. In fact, in Italy, in the last twenty-one years, the flow of total capital services grew on average by 3.2% per year and ICT accounted for a remarkable 28% of that total growth.

Another conventional wisdom is that the importance of ICT capital accumulation for capital input growth in Italy in the second half of the 90s has been much higher than in the previous years. Our results in terms of productive capital stock partially confirm this view. In fact, the relative contribution of ICT to the growth of productive capital stock shows the highest value in the second half of the 90's. However, the analysis undertaken in terms of capital services gives a different picture. Our findings are that in terms of the relative contribution of ICT to the growth of total capital services, the 80's were as much "ICT oriented" as the 90's, while in terms of absolute contributions the 80's were even more "ICT oriented". Both in 1985–1990 and in 1995–2000, ICT capital goods accounted for about 30% of the overall growth of capital services, while they accounted for about 20% in 1980–85 and in 1990–95. The highest absolute contribution of ICT capital services was in the second half of the 80's (1.2 percentage points), while the lowest was in the first half of the 90's (0.5 percentage points). Sectoral results show that the growth of total capital services as well as the contribution of ICT were higher in the service sectors than in Manufacturing, Mining and Energy and Constructions.

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Part 5:

The measure of industry level multi-factor productivity

18. PRODUCTIVITY MEASUREMENT AT STATISTICS NETHERLANDS

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Statistics Netherlands

Introduction

In 2007 the National Accounts of the Netherlands have been expanded with a set of multi factor productivity (MFP) statistics. There are two guiding principles. The first is to construct a system of productivity statistics at the industry branch and macro level that is, to the extent possible, consistent with National Accounts statistics. By doing this we are joining Australia, Canada, New Zealand, Switzerland, and the United States; see OECD (2006) for a summary of all these systems.

The second principle is that the system should not depend on a particular school of thought about the functioning of an economy. In particular we do not adopt the behavioural and structural assumptions of the neo-classical production framework. As a result, MFP change cannot be interpreted as exclusively the result of technological change (progress or regress), but may also be due to scale effects, efficiency improvements, and other factors.

On the basis of these two principles, this paper presents the computation methods and main results. A range of sensitivity analyses were carried out to investigate the effects of various assumptions on the productivity statistics at the industry and macro level. The most important of these assumptions concern the rate of return to capital and the imputed labour income of self-employed persons.

The layout of the paper is as follows. The next section sketches the main principles of the productivity measurement system. The third and fourth sections discuss the issue of capital and labour input cost measurement at current and constant prices. The other inputs and outputs are discussed in the fifth section. Sensitivity analyses are presented in the sixth section. The seventh section addresses the relationship between gross output and value-added based MFP change. The last section winds up with conclusions and indicates directions for future work.

Measuring productivity change

For any production unit (be it an enterprise or an industry) productivity change is generically defined as output quantity change relative to input quantity change. Expressing change by index numbers, a productivity index is defined as an output quantity index divided by an input quantity index. For this to be operational, one has to decide on what is seen as output and what is seen as input. And this in turn depends on the production model chosen. Two models are particularly important.[267]

The first model stays closest to the actual (physical) production process. Output represents the supply of all the goods and/or services that are being produced. This is also called 'gross output'. The input, then, is the consumption of all the goods and services that are necessary for the production. The various items are usually classified into the groups: (private, owned) capital (K), labour (L), energy (E), materials (M), and services (S). The items belonging to groups K and L are called primary input factors, and those belonging to groups E, M, and S are called intermediate input factors.[268]

In this model, the multi factor productivity (MFP) index is defined as a quantity index of gross output divided by a quantity index of combined KLEMS input. A single factor productivity index, such as a labour productivity (LP) index, is defined as a quantity index of gross output divided by a quantity index of labour (L) input.

The second model is more economically oriented. In this model output is defined as the gross output minus the intermediate inputs that are used in the production process. This is called the 'value added output' concept. Value added is defined as revenue (= value of gross output) minus intermediate input cost (= cost of EMS inputs). Notice that, in contradistinction to gross output, there are no well-defined output quantities related to value added. What can be done, however, is decompose the change of value added through time into a price and a quantity component. Expressing change by index numbers, the quantity index of value added is the output quantity index sought.

In this model, there are only two groups of inputs, namely K and L. Hence, the MFP index is defined as a quantity index of value added divided by a quantity index of combined KL input. Similarly, a LP index is defined as a quantity index of value added divided by a quantity index of labour (L) input.

Can anything be said about the relation between a gross-output based MFP index and a value-added based MFP index? Balk (2003b) showed that under the assumption that total cost is equal to gross output (so that there is no profit), for a fairly large class of index formulas, value-added based MFP change (expressed as a percentage) is larger than gross-output based MFP change, the factor of proportionality being given by the ratio of gross output to value added (the so-called Domar factor).[269]

Finally, there is a generic relation between productivity measurement and growth accounting. Recall that a productivity index is defined as an output quantity index divided by an input quantity index. This relation can also be expressed as: output quantity index = productivity index times input quantity index. After transforming index numbers into percentages, one gets a familiar type of growth accounting relation: output quantity change = productivity change + input quantity change. This relation provides the well-known

267 Other models are discussed in Balk (2007).

268 The lease of capital goods is considered as belonging to group S.

269 For a derivation of this result under the usual neo-classical assumptions see, for instance, Jorgenson, Ho and Stiroh (2005), p. 298.

interpretation of productivity change as the unexplained, or residual, part of output quantity change. Of course, depending on the type of productivity index the relation can take on more complicated forms.

It is important, however, to be always aware of the fact that in the growth accounting relation the two right-hand side factors, productivity change and input quantity change, are not independent, since productivity change is *defined* as the residual between output quantity change and input quantity change. Put otherwise, productivity change cannot be seen as a separately operating force in the production process. More insight can only be obtained when one is prepared to make a number of (far-reaching) assumptions on the structure of the production process and the 'behaviour' of the production unit under consideration (see Balk 2003a).

Choice of index formula

For the calculation of aggregate quantity or volume change of inputs and outputs, an index formula must be selected. In the standard growth accounting approach, where MFP change represents technological change, the index formula corresponds to a certain specification of the technology (for instance by means of a production function). However, such an approach depends on strong (neo-classical) assumptions, such as that the technology exhibits constant returns to scale and that there is perfect competition.[270] We don't want to make such strong assumptions, and prefer to select an index formula on the basis of its properties.

Common indices, in the context of productivity measurement, are the Laspeyres index, the Törnqvist index and the Fisher index. Because of their different properties, the selection of a specific index is not inconsequential. Balk (1995) reviewed the various indices and their properties.

For the annual publication of productivity statistics, chained Laspeyres volume index numbers will be used. The reasons are twofold. First, convenience of calculation, given the set-up of the Netherlands' supply and use tables. Second, consistency with the volume index numbers as published in the National Accounts.

Generically, a Laspeyres volume index for period t relative to period t-1 is defined by

$$Q_L^t \equiv \frac{\sum_i p_i^{t-1} q_i^t}{\sum_i p_i^{t-1} q_i^{t-1}} \qquad (1)$$

where q_i^t denotes the quantity of commodity i in period t and p_i^t its unit price. Then, $p_i^t q_i^t$ is the value of commodity i in period t at current prices and $p_i^{t-1} q_i^t$ is the value at prices of the previous period (or, at so-called constant prices). The time periods are calendar years. In the case of labour inputs such values are called (labour) compensation, and in the case of capital inputs one speaks of user cost.

270 See, for instance, Jorgenson, Ho and Stiroh (2005), e.g. p. 37.

Assuming that quantities in year t-1 are non-zero, expression (1) can be rewritten as

$$Q_L^t = \frac{\sum_i p_i^{t-1} q_i^t}{\sum_i p_i^{t-1} q_i^{t-1}} = \frac{\sum_i p_i^{t-1} q_i^{t-1} \frac{q_i^t}{q_i^{t-1}}}{\sum_i p_i^{t-1} q_i^{t-1}} = \sum_i \frac{p_i^{t-1} q_i^{t-1}}{\sum_i p_i^{t-1} q_i^{t-1}} \frac{q_i^t}{q_i^{t-1}} \equiv \sum_i s_i^{t-1} \frac{q_i^t}{q_i^{t-1}} \qquad (2)$$

where s_i^{t-1} is the share of commodity i in the total value in year t-1. Though this is the operational form of the Laspeyres index that is generally used, it appears that the set-up of the supply and use tables makes it easier to work directly with expression (1). This form has also distinct advantages when it comes to (des-) aggregation.

Aggregation

Aggregation means that smaller production units are joined to larger units, for instance, enterprises to industry branches, or industry branches to sectors of the economy. Aggregation, however, is more than simple addition. In order that an aggregate of smaller units can be considered as a single big unit, all supply and use streams between the smaller units must be netted out. This netting-out is also called consolidation.

Aggregation has important consequences for productivity indices. This can be seen as follows. First, gross output of the big unit is less than the sum of the gross output of the smaller units, since all the mutual deliveries between the smaller units must be subtracted. Second, while the K and L input of the big unit is a simple sum of the K and L input of the small units (since K and L are unique to the units), the intermediate EMS consumption of the big unit is less than the sum of the EMS consumption of the small units. Since smaller input and/or output quantities imply nothing about the relative magnitude of quantity *changes*, it may safely be concluded that there is no simple relation between a gross-output based MFP index number of the big unit and the gross-output based MFP index numbers of the small units.

Consider now a value-added based MFP index. Value added of the big unit is a simple sum of value added of the smaller units, and K and L input of the big unit is a simple sum of K and L input of the small units. Put otherwise, by using the value added concept, the small units are considered to be disjunct; that is, relations of supply and use do not exist between them. This implies that there is a simple relation between the MFP index number of the big unit and those of the small units. In fact, MFP change (expressed as a percentage) of the big unit can be expressed as a weighted arithmetic average of MFP change of the small units.

As mentioned previously, Balk (2003b) showed that under the assumption that total cost is equal to gross output (so that there is no profit), for a fairly large class of index formulas, value-added based MFP change (expressed as a percentage) is larger than gross-output based MFP change, the factor of proportionality being given by the ratio of gross output to value added (the so-called Domar factor). It is not obvious what will happen when the assumption about the equality of cost and gross output is dropped. Some empirical evidence will be presented in the seventh chapter.

In any case, the higher the level of aggregation the lesser difference there will be between value added and gross output, and thus the lesser difference between the two MFP measures.

Capital inputs

Production usually requires capital assets (buildings, machinery, tools, etcetera). Apart from new investments, which can happen anytime during a bookkeeping period (year), such assets are available at the start of the period and, apart from wear and tear, still available at the end of the period. The user cost of capital is the cost of using these (private, owned) assets during a year. Using owned assets is, economically seen, like leasing those assets, and unit user costs should therefore be comparable to rental prices. The user cost of capital comprises three components:

1. The revaluation of the assets during the year. This revaluation is defined as the value of the assets at the beginning of the year less their value at the end of the year. Usually capital goods are subject to a reduction in value over time, but some assets, such as dwellings, might increase in value over time.
2. The imputed (opportunity) cost of the money that is tied up in the assets.
3. The sum of all taxes-less-subsidies that the government levies on owning certain assets.

For any industry and institutional sector, the end of period user cost for a certain quantity of assets of type[271] i and age[272] j, which is available at the start of the year, is calculated as

$$U_{i,j}^{*t} \equiv (1+r^{t+,t-})P_{i,j-0.5}^{t-}K_{i,j-0.5}^{t-} - P_{i,j+0.5}^{t+}K_{i,j+0.5}^{t+} + T_{K,i,j}^{t} \equiv U_{i,j}^{t} + T_{K,i,j}^{t} \qquad (3)$$

where:

t denotes the period $[t_-, t_+]$, $t_- = (t\text{-}1)_+$ and $t_+ = (t+1)_-$; hereafter t will also be used to indicate the midpoint of the period;

$r^{t+,t-}$ denotes a (nominal) interest rate over the period $[t_-, t_+]$;

$P_{i,j-0.5}^{t-}$ denotes the price of an asset of age j-0.5 at time t_-;

$K_{i,j-0.5}^{t-}$ denotes the quantity of assets of age j-0.5 at time t_-;

$T_{K,i,j}^{t}$ denotes the sum of taxes-less-subsidies on the assets of age j in year t;

$U_{i,j}^{t}$ denotes the user cost excluding taxes-less-subsidies on assets of age j in year t.

Usually, it is not possible to determine the taxes-less-subsidies at the level of individual assets. Though for some taxes, such as road tax, it is possible to attribute the tax to a specific asset type, generally taxes-less-subsidies are only known at the level of an industry, and not specified by asset type. In practice, taxes-less-subsidies must therefore added to the user cost at a higher aggregation level.

271 For the calculation of the user cost 60 industries, 18 institutional sectors and 20 assets are distinguished.

272 Since it is assumed that investments are made halfway a year, the age of an asset at the beginning or end of a year is always j ± 0.5 year.

The allocation of taxes-less-subsidies is addressed in a later section. In the remainder of this chapter, taxes-less-subsidies will be deleted from the user cost expression. Furthermore, the subscript *i* will be dropped to simplify the expressions. A detailed theoretical derivation of the user cost (apart from taxes-less-subsidies) is given by Balk and van den Bergen (2006). The same framework will be used here.

In the Dutch version of the Perpetual Inventory Method (PIM) it is assumed that trade in second-hand assets and other volume changes of capital occur between the end of a year and the start of the next year. The quantity of capital can therefore be assumed as constant during a year. This implies that expression (3) can be simplified to

$$U_j^t \equiv (1+r^{t+,t-})P_{j-0.5}^{t-}K_j^t - P_{j+0.5}^{t+}K_j^t \tag{4}$$

If the unit user cost is defined as

$$u_j^t \equiv \frac{U_j^t}{K_j^t} = (1+r^{t+,t-})P_{j-0.5}^{t-} - P_{j+0.5}^{t+} \tag{5}$$

,

then the total user cost of period *t* at period *t* prices can be expressed as

$$U^t = \sum_{j=1}^{\infty} \frac{u_j^t}{P_{j-0.5}^t}\left[\frac{P_{j-0.5}^t}{P_{j-0.5}^{t-1}} P_{j-0.5}^{t-1} K_j^t\right] \tag{6}$$

The right-most term in this expression $P_{j-0.5}^{t-1}K_j^t$ is equal to the net capital stock as calculated by the Dutch PIM. Therefore, expression (6) links the user cost of capital directly to the PIM. The characteristics of the Dutch version of the PIM are described in detail by van den Bergen, de Haan, de Heij and Horsten (2005).

Two assumptions are now introduced. First, it is assumed that all asset price changes, other than those related to aging, are equal, irrespective the age *j* of the asset. Second, it is assumed that the price change over a half year is equal to the square root of the price change over a whole year. Together these assumptions imply that

$$\frac{P_{j-0.5}^{t-}}{P_{j-0.5}^t} \cong \frac{P_0^{t-}}{P_0^t} \cong \left(\frac{P_0^t}{P_0^{t-1}}\right)^{-1/2} \tag{6a}$$

$$\frac{P_{j-0.5}^{t+}}{P_{j-0.5}^t} \cong \frac{P_0^{t+}}{P_0^t} \cong \left(\frac{P_0^{t+1}}{P_0^t}\right)^{1/2} \tag{6b}$$

where P_0^t denotes the price of a new asset at time *t*. Next, we define

$$\frac{P_{j+0.5}^t}{P_{j-0.5}^t} \equiv (1-\delta_{K,j}) \tag{6c}$$

where $\delta_{K,j}$ denotes the depreciation rate of assets already in use (as distinct from the rate of newly invested assets)[273]. Then the first term under the summation sign of expression (6) can be approximated by

$$\frac{u_j^t}{P_{j-0.5}^t} = (1+r^{t+,t-})\frac{P_{j-0.5}^{t-}}{P_{j-0.5}^t} - \frac{P_{j+0.5}^{t+}}{P_{j+0.5}^t}\frac{P_{j+0.5}^t}{P_{j-0.5}^t} \cong (1+r^{t+,t-})\left(\frac{P_0^t}{P_0^{t-1}}\right)^{-1/2} - \left(\frac{P_0^{t+1}}{P_0^t}\right)^{1/2}(1-\delta_{K,j}) \qquad (7)$$

The depreciation rate, $\delta_{K,j}$, can be obtained directly from the PIM. The relation between this rate and consumption of fixed capital in the National Accounts is given by

$$\delta_{K,j} = \frac{CFC_{K,j}^t}{P_{j-0.5}^t K_j^t} \cong \left(\frac{P_0^t}{P_0^{t-1}}\right)^{-1} \frac{CFC_{K,j}^t}{P_{j-0.5}^{t-1} K_j^t} \qquad (8)$$

where $CFC_{K,j}^t$ denotes the consumption of assets already in use.
The user cost of period t+1 at prices of the previous period t is calculated as

$$U_{CP}^{t+1} \equiv \sum_{j=1}^{\infty} u_j^t K_j^{t+1} = \sum_{j=1}^{\infty} \frac{u_j^t}{P_{j-0.5}^t} P_{j-0.5}^t K_j^{t+1} \qquad (9)$$

The Laspeyres volume index for capital for period t+1 relative to period t is calculated as the ratio of expression (9) to (6). However, in order to execute this calculation, further assumptions with regard to the interest rate and the price indices have to be introduced.

Interest rate

With regard to the interest rate, which is also called rate of return, the first choice is between an exogenous and an endogenous rate. An endogenous rate is in accordance with the standard neoclassical model. This model is based on the twin assumptions of constant returns to scale and perfect competition. These assumptions imply that profit equals zero. All gross output revenue of an enterprise is used to reward the inputs in the production process. The whole operating surplus / mixed income must therefore be allocated to user cost of capital and labour income of self-employed. When labour income of self-employed persons is estimated exogenously, which is common practice, an endogenous interest rate is required to make the equation fit.

An exogenous rate however is chosen independently of the operating surplus. For example the average interest rate on the capital market could be used. Almost certainly an exogenous rate will lead to a difference between the user cost of capital and the operating surplus. Profit will therefore be non-zero.

Although the usefulness of the neoclassical model is generally recognized, its assumptions seem incompatible with economic reality, especially when there is rapid technological progress (and unbiased measurement of productivity change is more important than ever). To avoid making these assumptions, an exogenous interest rate will be employed.

273 For vessels and barges the depreciation rate is time-dependent, since the depreciation profile of older craft differs from the profile of younger craft. From a conceptual point of view, such an asset type should be split into two (or more) types.

Before an exogenous interest rate can be determined, it has to be determined whether the risk premium belongs in the interest rate or in FISIM. This risk premium is the money that a supplier of capital receives for bearing the risk that the lender defaults on his payments, usually when an enterprise goes bankrupt. There are two ways to interpret this risk premium. First, the premium can be seen as inherent in the lending of money, in which case it should be included in the interest rate. Alternatively, it can be seen as an extra service of the supplier, in which case it should be included in FISIM. A choice between these viewpoints has to be made to assign the risk premium to an input.

This choice however exists only for the banking industry. According to National Accounts standards, FISIM can only be produced by the banking industry. Capital suppliers outside the banking industry[274] produce no FISIM or related services. For these suppliers, the risk premium is therefore included in the interest rate. Since the risk premium should be treated equal for all capital suppliers, for the banking industry the risk premium should also be included in the interest rate and not in FISIM.

However, according to Eurostat regulations, FISIM is calculated as the difference between the paid (or received) interest rate and the internal reference rate (IRR) between banks. This means that, according to these regulations, only the risk premium for lending to a bank should be included in the IRR and therefore in the user cost. As a consequence, for capital borrowed from the banking industry, the difference in risk premium between the banking industry and other industries is included in FISIM. When the risk premium is included in the interest rate, therefore some double-counting is created.

Since the part of capital that is financed by borrowing from the banking industry is probably small, it was decided to accept this double-counting. The risk premium is included in the interest rate, and the National Accounts data on FISIM, which includes some risk premium, is included in the intermediate consumption.

The next question is whether the risk premium should vary across industries. The risk of defaulting varies indeed among industries. However, industries with a larger risk of defaulting[275] usually consist of larger enterprises, which have a smaller defaulting risk. This leads to two opposite effect. For enterprises of the same size, the default risk, and therefore the risk premium, may be smaller for industry A than for industry B. But the fact that the average enterprise in industry B is larger than the average enterprise in industry A should lower the default risk of industry B compared with industry A.

It is unlikely that both effects have the same, but opposite magnitude, so there remains some dispersion in the risk premium between industries. Unfortunately, data about these effects is hardly available. It is therefore not possible to quantify this dispersion. Therefore an industry independent risk premium, and interest rate, is used.

The nominal interest rate is based on the average interest rate that companies must pay on outstanding bonds. To get an estimate of this value, the bonds issued by investment funds are used. The funds use these bonds to invest in outstanding bonds of a wide variation of other companies. A lot of bonds offer an estimated return of 1 to 2 percent above the euribor

274 This includes using the company's own capital to buy assets.

275 These are usually the industries where large initial investments are required, or where expected benefits are either insecure or far into the future.

interest rate. Usually this rate is offered only when there are no defaults on the bonds in which the investment funds invest. When there are a lot of defaults, the return diminishes. This means that the risk premium is included in the offered return.

The average cost that investment funds charge for their services is about 1 percent of the deposit. That indicates that the average interest rate companies have to pay on their outstanding bonds is 2 to 3 percent above the euribor interest rate. Since the euribor interest rate did not exist prior to 1999, the interest rate is linked to the internal reference rate (IRR) between banks. In the period 1999 to 2005, the IRR was about 1 percent above the euribor interest rate. *The nominal interest rate is thus set at IRR plus 1.5 percent.* Table 18–1 shows for a number of years the nominal and the real interest rates.[276]

T 18–1 Interest rates

in percents

	1995	2000	2003	2004	2005	2006
Nominal interest rate	7.3	6.7	4.8	4.7	4.5	5.2
Consumer price index	2.1	4.1	1.7	1.5	2.2	2.3
Real interest rate	5.1	2.5	3.1	3.1	2.2	2.7

Price indices

The price ratios in expressions (6), (7) and (8) require price indices. Since the capital stock is revaluated with producer price indices (PPIs), these PPIs are also used for the calculation of the user costs. An exception is made for transfer costs which, according to a National Accounts convention, belong to the capital stock. Since transfer costs cannot be traded, it seems pointless to include holding gains or losses in user costs thereof. In this case CPIs instead of PPIs are used. With the current data and the current choice of the interest rate, this does not lead to negative user costs.

Summary of expressions

When the above described decisions with regard to the interest rate and price indices are applied, the user cost for all at the start of the year *t* existing assets, excluding taxes-less-subsidies, is calculated as

$$U^t \cong \sum_i \sum_{j=1}^{\infty} \frac{u^t_{i,j}}{P^t_{i,j-0.5}} \frac{PPI^t_i}{PPI^{t-1}_i} P^{t-1}_{i,j-0.5} K^t_{i,j} \tag{10}$$

$$\frac{u^t_{i,j}}{P^t_{i,j-0.5}} \cong (1+r^t)\left(\frac{PPI^t_i}{PPI^{t-1}_i}\right)^{-1/2} - \left(\frac{PPI^{t+1}_i}{PPI^t_i}\right)^{1/2} (1-\delta_{K,i,j}) \tag{11}$$

[276] Real interest rate is defined as nominal interest rate deflated by a headline CPI.

$$\delta_{K,i,j} \cong \left(\frac{PPI_i^t}{PPI_i^{t-1}} \right)^{-1} \frac{CFC_{K,i,j}^t}{P_{i,j-0.5}^{t-1} K_{i,j}^t} \tag{12}$$

$$U_{CP}^{t+1} = \sum_i \sum_{j=1}^{\infty} \frac{u_{i,j}^t}{P_{i,j-0.5}^t} P_{i,j-0.5}^t K_{i,j}^{t+1} \tag{13}$$

For transfer cost, expression (11) is replaced by

$$\frac{u_{i,j}^t}{P_{i,j-0.5}^t} \cong (1+r^t) \left(\frac{PPI_i^t}{PPI_i^{t-1}} \right)^{-1/2} - \left(\frac{CPI^{t+1}}{CPI^{t-1}} \right)^{1/2} \left(\frac{PPI_i^t}{PPI_i^{t-1}} \right)^{-1/2} (1-\delta_{K,i,j}) \tag{14}$$

In expressions (11) and (14), r^t is the nominal interest rate in year *t*.

It is assumed that investments in second-hand assets from abroad and investments in new assets (domestically produced as well as imported) are made halfway a year. Thus, for these assets a different user cost expression must be used. The details of the derivation are provided by Balk and van den Bergen (2006). The user cost for all invested assets is calculated as[277] [278]

$$V^t = \sum_i \sum_{j=0}^{\infty} \frac{v_{i,j}^t}{P_{i,j}^t} P_{i,j}^t I_{i,j}^t \tag{15}$$

$$\frac{v_{i,j}^t}{P_{i,j}^t} \cong \sqrt{1+r^t} - \left(\frac{PPI_i^{t+1}}{PPI_i^t} \right)^{1/2} (1-\delta_{I,i,j}/2) \tag{16}$$

$$\delta_{I,i,j} = 2 \frac{CFC_{I,i,j}^t}{P_{i,j}^t I_{i,j}^t} \tag{17}$$

$$V_{CP}^{t+1} \cong \sum_i \sum_{j=0}^{\infty} \frac{v_{i,j}^t}{P_{i,j}^t} \frac{PPI_i^t}{PPI_i^{t+1}} P_{i,j}^{t+1} I_{i,j}^{t+1} \tag{18}$$

For transfer cost, expression (16) is replaced by

$$\frac{v_{i,j}^t}{P_{i,j}^t} \cong \sqrt{1+r^t} - \left(\frac{CPI_i^{t+1}}{CPI_i^t} \right)^{1/2} (1-\delta_{I,i,j}/2) \tag{19}$$

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277 In order to avoid confusion, user cost for invested assets is represented by the variable *v* instead of *u*.

278 Because figures are rounded off in the calculations of the net capital stock and consumption of fixed capital, $\delta_{K,i,j}$ and $\delta_{I,i,j}$ differ negligibly.

Finally, total user cost[279], including taxes-less-subsidies, at current prices and previous year prices respectively, is calculated as

$$U^{*t} = U^t + V^t + T^t \qquad (20)$$

$$U_{CP}^{*t+1} = U_{CP}^{t+1} + V_{CP}^{t+1} + T_{CP}^{t+1} \qquad (21)$$

where the subscript CP denotes that the variable is valued at the prices of the previous year. The tax component will be discussed in the fifth chapter.

Labour inputs

Production also requires labour. For any industry[280], labour cost is calculated as the sum of three components,

$$W^{*t} = W_E^t + W_S^t + T_L^t \equiv W^t + T_L^t \qquad (22)$$

where: W^{*t} denotes total labour cost;

W_E^t denotes compensation of employees;

W_S^t denotes labour income of self-employed persons;

T_L^t denotes the sum of taxes-less-subsidies on labour;

W^t denotes total labour cost excluding taxes-less-subsidies.

Thus, per industry two types of labour are distinguished. For each type, the unit of measurement is an hour worked.

Compensation of employees

The compensation of employees at current prices is directly available from the National Accounts. However, the same compensation at previous year prices cannot be used because the deflation in the National Accounts is not executed with volume indexes of hours worked. Following international recommendations (OECD 2001), compensation at previous year prices is calculated as

$$W_{E,CP}^{t+1} \equiv w_E^t L_E^{t+1} = w_E^t L_E^t \frac{L_E^{t+1}}{L_E^t} \equiv W_E^t \frac{L_E^{t+1}}{L_E^t} \qquad (23)$$

where w_E^t denotes the compensation per hour and L_E^t denotes the number of hours worked.

279 Non-produced assets (AN.2) and inventories (AN.12) are not included in the capital stock. Livestock for breeding, dairy, draught, etc. (AN.11141) is included but, because of data availability, slightly different formulas had to be used.

280 For the calculation of labour input of both employees and self-employed, 49 different industries are distinguished.

In order to retain a consistent set of supply and use tables, the National Accounts (in constant prices) should be balanced with this newly calculated compensation of employees at prices of the previous year. This can easily be accomplished by adjusting the operating surplus. In this way consistency is retained without changing any other input or output quantity.

Labour income of self-employed persons

Unlike compensation of employees, no explicit estimate of labour income of self-employed is provided in the National Accounts. Labour income of self-employed is, together with the user cost of capital and the profit of the sector households (S.14), part of mixed income.

When gross fixed capital formation, consumption of fixed capital and the capital stock are broken down into institutional sectors, it is possible to directly calculate the user cost of capital of S.14. However, it is not possible to measure directly either profit of S.14 or labour income of self-employed. Therefore, in order to break down mixed income, some assumption with regard to profit of S.14 or labour income of self-employed must be made. Two feasible assumptions are that self-employed have the same income per hour or per year as employees, or that there is no profit for S.14. The last assumption allows labour income of self-employed to be calculated endogenously.

For calculating the labour-income of self-employed endogenously, it is important that the estimates of mixed income, gross fixed capital formation, consumption of fixed capital and the capital stock of S.14 are reliable. Although estimates of these variables are available at Statistics Netherlands, they currently lack the quality required for the calculation of the labour income of self-employed. Thus we turn to exogenous estimation.

Although firm evidence is lacking, most data suggest that self-employed work more hours than employees without earning substantially more money. It is therefore assumed that self-employed have the same labour income per year as employees.

There are a few exceptions to this assumption. In some medical sectors, for instance in the case of dentists and general practitioners, the self-employed generally have a university degree, whereas the employees mostly have a lower educational level. Since educational level is generally positively correlated with earnings, it is expected that in these sectors self-employed have a higher income than employees. Therefore, for the year 2003, in these sectors labour income of self-employed is set at a so-called standard income[281] of these professions. It is further assumed that the development of labour income of the self-employed equals the development of wages of employees in these sectors.

For some professions, e.g. lawyers, accountants and architects, which are included in the financial and business activities branch, it is also expected that self-employed have a higher income than employees. However, there is no data available with regard to some standard income of these professions. It is therefore assumed that these self-employed have the same income per year as employees.[282]

281 This is a rough estimate used to inform medical students about their expected future salaries.

282 When labour is broken down by education, this problem may cease to exist. The expectation that self-employed have a higher income than employees is primarily based on the difference in education between self-employed and employees. It is expected that self-employed in this industry earn the same income as employees with the same education.

From 2001 on, data on compensation of employees and numbers of full-time equivalent jobs (fte) of employees and self-employed is available for 260 industries. For earlier years, however, numbers of fte's are only available at a higher aggregation level (120 industries). Since the proportion of self-employed (in fte's) differs per industry, imputing the same yearly income for self-employed as employees at a higher aggregation level leads to different results than when imputation is done at a lower aggregation level. For this reason, the average ratio α between the labour income of self-employed per fte and the compensation of employees per fte is calculated for the period 2001–2003 and it is assumed that this ratio is constant over time. For the years before 2001, the labour income of self-employed can then be calculated as

$$W_S^t = \alpha W_E^t \frac{LY_S^t}{LY_E^t} = \alpha \frac{W_E^t}{LY_E^t} LY_S^t \tag{24}$$

where LY^t denotes fte's. The labour income of self-employed at prices of the previous year is then calculated by multiplying the hours worked in the current year with the labour income of employees per hour worked in the previous year; that is

$$W_{S,CP}^{t+1} \equiv w_S^t L_S^{t+1} = w_S^t L_S^t \frac{L_S^{t+1}}{L_S^t} \equiv W_S^t \frac{L_S^{t+1}}{L_S^t} \tag{25}$$

Summary of expressions

Per industry, total labour cost is, at current prices, calculated as

$$W^{*t} = W_E^t + W_S^t + T_L^t \tag{26}$$

and, at previous year prices, as

$$W_{CP}^{*t+1} = W_{E,CP}^{t+1} + W_{S,CP}^{t+1} + T_{L,CP}^{t+1} \tag{27}$$

Again, the tax component will be discussed in the next chapter.

Other inputs and output

Gross output, value added and intermediate consumption (with its E, M, and S components) are estimated in the context of the National Accounts. Production surveys, foreign trade statistics, and surveys on consumption and investments are the most important data-sources. Our National Accounts database consists of data for very detailed product groups, which are further subdivided to origin and destination, and which have different valuation layers. From this database, supply and use tables and input-output tables can be derived. Approximately 120 industries and 275 product groups are distinguished. This level of detail is sufficient for measuring productivity change as described in the foregoing. With respect to constant price estimation, a combination of (chained) Paasche price index numbers and Laspeyres volume index numbers is used. The price statistics for production, international trade and private consumption of households are the main sources for the deflators.

Although both value added and gross output (in current prices and prices of the previous year) can be directly derived from the National Accounts, gross output must be consolidated before it can be used for the gross output productivity measures.

The cost components of intermediate consumption can also be derived from the National Accounts. The intermediate consumption that is used for the productivity measures is calculated as the intermediate consumption at basic prices plus the sum of taxes-less-subsidies on products. In contrast with the National Accounts, for productivity measurement trade and transport margins are not attributed to the products on which they are imposed, but they are recorded as a service. This way, energy, materials and services are separated properly. In addition, intermediate consumption must also be consolidated.

Three problems remain to be solved: 1) the consolidation of output and intermediate consumption, 2) the allocation of taxes-less-subsidies on production to the various inputs, and 3) the output of non-market producers. These problems will be addressed in the next sections.

Consolidation

The most detailed National Accounts supply-use database has the following three dimensions: industry of supply × industry of demand × product group. Thus, generally, the amounts of intra-industry deliveries can be determined directly for each product group. Trade and transport margins constitute the only exception to this rule. This is caused by the fact that these margins are registered as so-called valuation layers. They are recorded as part of the purchase value of product groups on which these margins are imposed. As a consequence, in the National Accounts' database, the producer of the product on which the margins are imposed instead of the producer of the margins is registered as the origin of the margins. This implies that the intra-industry deliveries of margins cannot be identified since the original producers of these margins are not identifiable.

As a result a certain assumption must be made about the production of those margins. Since a sensitivity analysis has shown that varying the assumptions has little impact on the final productivity numbers, a relatively simple method can be chosen. For the consolidation of margins, it is assumed that the distribution of margins over the producers is the same for all the consumers of margins.

The value of margin type *m* produced by *k* and consumed by user *l* is calculated as[283]

$$M^t_{k,l,m} = \frac{M^t_{k,\cdot,m}}{\sum_k M^t_{k,\cdot,m}} M^t_{\cdot,l,m} \tag{27a}$$

where $M^t_{k,\cdot,m}$ is the production of margin *m* in year *t* by producer *k* (whereby imports are considered as a "producer");

$M^t_{\cdot,l,m}$ is the consumption of margin *m* in year *t* by user *l*.
Data on production and consumption of margins are taken from the input-output table.

283 Three different kinds of margins are distinguished: wholesale trade margins, retail trade margins and transport margins.

The intra-industry deliveries are subsequently determined as those margins that are consumed by the same industry that produces the margins. These intra-industry deliveries of margins, together with the intra-industry deliveries as determined from the supply-use database, constitute the total intra-industry deliveries in current prices.

In principle, the intra-industry deliveries in prices of the previous year could be determined in a similar way. Unfortunately, due to balancing problems, the price index numbers in the most detailed supply-use database are of insufficient quality for this purpose. Only after aggregating over either users or producers the price index numbers become sufficiently reliable. Thus, intra-industry deliveries in current prices of a certain product group are deflated with the price index of the total consumption of that product group by the industry, to obtain the intra-industry deliveries in prices of the previous year.

All the intra-industry deliveries, both in current prices and in prices of the previous year, are excluded from gross output and intermediate consumption to obtain sectoral output and intermediate input.[284]

Taxes-less-subsidies

Productivity measurement requires output to be valued at basic prices; that is, the prices actually obtained by producers. At the same time, input must be valued at purchasers' prices.

Taxes-less-subsidies on *products* are already included in the costs of the intermediate consumption components. Taxes-less-subsidies on *production* (according to the National Accounts classification), at current prices as well as at prices of the previous year, can be obtained directly from the National Accounts. As far as sensible, the components of this expenditure category should be attributed to the various inputs.

Some of these taxes-less-subsidies can directly be attributed to a specific input. Wage subsidies can be attributed to labour, and road taxes as well as property taxes to capital. Other taxes-less-subsidies, like sewage charges and PBO-levies, cannot be attributed to some single category of inputs. Such taxes-less-subsidies on production could somehow be distributed over all the input categories. A practical difficulty, however, is the fact that it is not always possible to separate the taxes-less-subsidies that can be attributed to capital from the remaining taxes-less-subsidies. A pragmatic solution is to attribute all taxes-less-subsidies on production to capital, with the exception of wage subsidies, which are of course attributed to labour.[285]

Finally, tax deductions should be taken into account in the user cost of capital. In the Netherlands, some costs of capital, e.g. interest paid on mortgages, can be deducted from pre-tax income. In effect therefore, the use of such capital goods is subsidized. For the time being, however, such tax deductions will not be taken into account.

[284] Since this method of deflating the intra-industry deliveries leads to different intra-industry deliveries in prices of the previous year than may be derived directly from the supply-use database, this procedure leads to (usually small) deviations from the official input-output table in prices of the previous year.

[285] We are here following Statistics Canada (2001).

Non-market production

According to the SNA 93, the revenue of non-market producers is defined as the total cost incurred in the production process, the components being intermediate consumption, labour, taxes-less-subsidies, and the consumption of fixed capital (depreciation). Thus, with respect to the user cost of capital SNA 93 implicitly prescribes that the interest rate must be set equal to zero and the non-depreciation part of revaluation must be excluded. This creates an inconsistency in our system, since, as explained in the third section, user cost of capital includes more components than depreciation.

There are several options to resolve the inconsistency. The first is to attribute the full user cost to non-market producers and retain the revenue = cost identity.[286] But this would lead to output value figures that deviate from those in the official National Accounts, which is considered undesirable. It was therefore decided to retain the National Accounts output data for non-market producers.

The polar opposite option is to retain the revenue = cost identity but calculate the user cost of capital for non-market producers according to the implicit SNA 93 prescriptions. In the interest of productivity statistics it is, however, considered important to have for all producers user cost estimates which are calculated in a uniform way.

The third option, which is the option actually chosen, is therefore to drop the revenue = cost identity. At the output side, National Accounts data are used, whereas at the input side the user cost of capital for non-market producers is calculated in the same way as for market producers. The impact of the inconsistency is small since the productivity statistics are restricted to industries which are typically dominated by market producers.

Summary of expressions

Per industry or aggregate of industries, the Laspeyres volume index of the combined KLEMS inputs is calculated as

$$Q_{L,KLEMS}^{t+1} = \frac{U_{CP}^{*t+1} + W_{CP}^{*t+1} + EMS_{CP}^{*t+1}}{U^{*t} + W^{*t} + EMS^{*t}} \tag{28}$$

where

U^{*t} denotes the user cost of capital in year *t*, as given by expression (20);

U_{CP}^{*t+1} denotes the user cost of capital in year *t*+1 valued at prices of year *t*, as given by expression (21);

W^{*t} denotes the labour cost in year *t*, as given by expression (26); W_{CP}^{*t+1} denotes the labour cost in year *t*+1 valued at prices of year *t*, as given by expression (27);

EMS^{*t} denotes the (consolidated) value of energy, materials and services in year *t*;

286 The Advisory Expert Group on National Accounts suggested this to the Statistical Commission (see Inter-Secretariat Working Group on National Accounts (ISWGNA) (2007)), but this was rejected.

EMS_{CP}^{*t+1} denotes the (consolidated) value of energy, materials and services in year t+1 valued at prices of year t.

The Laspeyres volume index of the combined capital and labour inputs is calculated as

$$Q_{L,KL}^{t+1} = \frac{U_{CP}^{*t+1} + W_{CP}^{*t+1}}{U^{*t} + W^{*t}} \tag{29}$$

Since the values of the input components are calculated independently from the value of output, total cost need not be equal to revenue. A new balancing item is created, called net profit. It is defined as

$$NP^{t} = R^{t} - U^{*t} - W^{*t} - EMS^{*t} \tag{30}$$

where R^{t} denotes the value of (consolidated) output (revenue) in year t. Net profit in prices of the previous year is defined as

$$NP_{CP}^{t} = R_{CP}^{t} - U_{CP}^{*t} - W_{CP}^{*t} - EMS_{CP}^{*t} \tag{31}$$

Results and sensitivity analyses

The method described in the previous chapters is used to estimate the official MFP figures for the Netherlands. It will henceforth be called the official method. According to this method gross-output based MFP change and value-added based MFP change are computed for the period 1995–2006. Next, the calculations are repeated using alternative assumptions with regard to the volume index formula, the user cost of capital, and the labour income of self-employed. The productivity changes following from these alternative methods are compared with the results of the official method.

Calculations have been performed at three different levels of aggregation: 36 industries, 9 industries and the commercial sector. The commercial sector is defined as the set of all industries for which consistent and independent measures of input and output exist. In practice, this means that the commercial sector contains the whole economy except general government, defence, subsidized education, real estate activities, renting of movables, and private households with employed persons.[287]

For the sake of readability, the results for the aggregation level of 36 industries are not presented in this paper but available at request.

In Tables 18–2 and 18–3, the gross-output based and value-added based MFP change as calculated with the official method are presented. The average (1996/2006) gross-output based MFP change for the commercial sector turns out to be 0.88 percent, and the average value-added based MFP change 1.35 percent.

287 The name ‘commercial sector’ must not be taken too literal. Real estate activities, renting of movables, and private households with employed persons contain activities which are at least partially commercial. On the other hand, industries like research and development services, and sewage and refuse disposal contain non-market (and thus non-commercial) activities.

T 18 – 2 Gross output based MFP change using the official method
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.2	1.0	0.5	2.7	0.5	0.8
Mining and quarrying	-3.3	0.3	-1.7	7.3	-6.5	-2.8
Manufacturing	0.8	0.7	0.7	1.9	0.7	0.7
Electricity, gas and water supply	-0.1	1.5	0.7	0.8	1.1	0.4
Construction	-0.3	-0.2	-0.2	0.2	1.0	0.6
Trade, hotels, restaurants and repair	2.0	0.9	1.6	1.8	1.8	2.9
Transport, storage and communication	2.0	1.8	1.9	2.1	2.2	1.5
Financial and business activities[1]	-0.4	0.9	0.2	3.0	1.1	0.1
Care and other service activities[2]	-0.3	-0.3	-0.3	0.1	-0.2	-0.0
Commercial sector	0.80	0.91	0.88	2.46	1.16	1.14

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18 – 3 Value added based MFP change using the official method
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.3	2.1	0.9	5.3	1.0	1.3
Mining and quarrying	-3.5	0.5	-1.7	10.2	-8.4	-3.0
Manufacturing	2.7	2.1	2.4	6.1	2.6	2.8
Electricity, gas and water supply	-0.4	4.6	2.0	2.8	3.3	1.7
Construction	-0.6	-0.5	-0.3	0.5	2.1	1.4
Trade, hotels, restaurants and repair	3.7	1.5	2.8	3.2	3.4	5.3
Transport, storage and communication	3.8	3.6	3.7	4.1	4.4	3.3
Financial and business activities[1]	-0.5	1.3	0.4	4.5	1.7	0.1
Care and other service activities[2]	-0.4	-0.4	-0.4	0.1	-0.3	-0.0
Commercial sector	1.27	1.35	1.35	3.69	1.80	1.79

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

Paasche volume index

In the official method, Laspeyres volume indices are used, together with Paasche price indices. In order to judge the sensitivity of the outcomes with respect to the index formulas used, MFP change is also calculated with Paasche volume indices and Laspeyres price indices. Generically, the Paasche volume index is given by

$$Q_P^t \equiv \frac{\sum_i p_i^t q_i^t}{\sum_i p_i^t q_i^{t-1}} \tag{32}$$

This expression can be rewritten as

$$Q_P^t \equiv \frac{\sum_i (p_i^t / p_i^{t-1}) p_i^{t-1} q_i^t}{\sum_i (p_i^t / p_i^{t-1}) p_i^{t-1} q_i^{t-1}} \tag{33}$$

from which it becomes clear, by comparison to expression (1), that such an index requires the same building blocks as the Laspeyres volume index. But additionally, price relatives p_i^t / p_i^{t-1} are required. Here we encounter a problem.

As already mentioned, the price index numbers at the most detailed level of the supply-use database are of insufficient quality. Thus the Paasche volume index computations must start at a higher aggregation level. For gross output this is 118 producers and 207 commodities, whereas for intermediate consumption this is 118 users and 207 commodities.

The resulting gross-output based MFP and value-added based MFP change are presented in tables 18–4 and 18–5. For most industries, using a Paasche volume index leads to higher average MFP change. For the commercial sector, average gross-output based MFP is 0.03 percentage points higher, while value-added based MFP is 0.05 percentage points higher. From 2004 on however, using a Paasche volume index leads to lower MFP change.

The biggest differences in average gross-output based MFP occur in financial and business activities and in care and other service activities. In these industries, average gross-output based MFP is 0.13 percentage points higher. For individual years, the biggest differences are found in agriculture, forestry and fishing and in mining and quarrying. In these industries, differences are up to 0.8 percentage point. In the other industries, the maximum difference is 0.3 percentage point. For value-added based MFP, next to agriculture, forestry and fishing and mining and quarrying there are also large differences in electricity, gas and water supply. For individual years, the maximum differences in these three industries are between 1 and 1.4 percentage point.

T 18 – 4 Gross output based MFP change using a Paasche volume index

in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.2	0.9	0.4	2.2	0.4	0.5
Mining and quarrying	-3.5	0.3	-1.7	7.1	-6.9	-2.9
Manufacturing	0.9	0.7	0.8	2.0	0.7	0.7
Electricity, gas and water supply	0.0	1.6	0.8	1.0	1.2	0.3
Construction	-0.2	-0.1	-0.1	0.3	1.0	0.6
Trade, hotels, restaurants and repair	2.1	0.9	1.6	1.9	1.9	2.9
Transport, storage and communication	2.0	1.9	1.9	2.2	2.2	1.6
Financial and business activities[1]	-0.2	0.9	0.3	2.9	0.9	0.1
Care and other service activities[2]	-0.1	-0.1	-0.1	0.2	-0.0	0.1
Commercial sector	0.88	0.92	0.92	2.40	1.05	1.08

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18 – 5 Value added based MFP change using a Paasche volume index
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.5	1.8	0.7	4.6	1.0	0.9
Mining and quarrying	-3.2	0.6	-1.5	10.1	-8.4	-3.0
Manufacturing	3.0	2.3	2.7	6.4	2.7	2.8
Electricity, gas and water supply	0.1	4.8	2.3	3.0	3.9	1.6
Construction	-0.4	-0.3	-0.2	0.7	2.2	1.5
Trade, hotels, restaurants and repair	3.8	1.7	3.0	3.3	3.5	5.3
Transport, storage and communication	3.8	3.7	3.7	4.3	4.5	3.3
Financial and business activities[1]	-0.2	1.4	0.5	4.4	1.5	0.1
Care and other service activities[2]	-0.2	-0.2	-0.2	0.2	-0.1	0.1
Commercial sector	1.38	1.37	1.41	3.62	1.67	1.71

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

Fisher volume index

In addition to productivity calculations with a Laspeyres and a Paasche volume index, one can construct a productivity index with a Fisher volume index. This index is, in one-step form, given by

$$Q_F^t \equiv \left(Q_L^t Q_P^t\right)^{1/2} = \left(\frac{\sum_i p_i^{t-1} q_i^t}{\sum_i p_i^{t-1} q_i^{t-1}} \frac{\sum_i p_i^t q_i^t}{\sum_i p_i^t q_i^{t-1}} \right)^{1/2} \tag{34}$$

Results are presented in tables 18–6 and 18–7. As expected, differences between the Fisher index and the Laspeyres index are about half the differences between the Paasche index and the Laspeyres index. For the commercial sector, the average difference in gross-output based MFP is 0.02 percentage point, while the difference in value-added based MFP is 0.03 percentage point.

Other labour income for self-employed

In the official method, it is assumed that the annual labour income of self-employed is equal to the annual labour income of employees. In the literature, for example the OECD manual Measuring Productivity (2001), it is often advised to assume that self-employed have the same *hourly* labour income as employees. Therefore, MFP changes are recalculated under the last assumption.

To calculate the labour income of self-employed under this assumption an approach similar to the official method is employed. Like the full-time equivalent jobs, from 2001 on, hours worked are available for 260 different industries, whereas for other years hours worked are only available at a higher aggregation level (49 industries). At this higher aggregation level, the average ratio β between the labour income of self-employed per hour and the compensation of employees per hour is calculated for the period 2001–2003. It is next assumed that this ratio is constant over time. For the years before 2001 the labour income of self-employed is then calculated as

T 18 – 6 Gross output based MFP change using a Fisher volume index

in percent

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.2	1.0	0.4	2.4	0.5	0.6
Mining and quarrying	-3.4	0.3	-1.7	7.2	-6.7	-2.9
Manufacturing	0.9	0.7	0.8	1.9	0.7	0.7
Electricity, gas and water supply	-0.1	1.6	0.7	0.9	1.2	0.4
Construction	-0.3	-0.2	-0.1	0.2	1.0	0.6
Trade, hotels, restaurants and repair	2.0	0.9	1.6	1.9	1.9	2.9
Transport, storage and communication	2.0	1.8	1.9	2.1	2.2	1.5
Financial and business activities[1]	-0.3	0.9	0.3	3.0	1.0	0.1
Care and other service activities[2]	-0.2	-0.2	-0.2	0.1	-0.1	0.0
Commercial sector	0.84	0.91	0.90	2.43	1.11	1.11

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18 – 7 Value added based MFP change using a Fisher volume index

in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.4	1.9	0.8	4.9	1.0	1.1
Mining and quarrying	-3.4	0.5	-1.6	10.1	-8.4	-3.0
Manufacturing	2.9	2.2	2.6	6.2	2.6	2.8
Electricity, gas and water supply	-0.2	4.7	2.2	2.9	3.6	1.6
Construction	-0.5	-0.4	-0.3	0.6	2.2	1.5
Trade, hotels, restaurants and repair	3.8	1.6	2.9	3.3	3.5	5.3
Transport, storage and communication	3.8	3.6	3.7	4.2	4.5	3.3
Financial and business activities[1]	-0.4	1.3	0.5	4.4	1.6	0.1
Care and other service activities[2]	-0.3	-0.3	-0.3	0.2	-0.2	0.1
Commercial sector	1.33	1.36	1.38	3.66	1.73	1.75

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

$$W_S^t = W_E^t \beta \frac{L_S^t}{L_E^t} = \beta \frac{W_E^t}{L_E^t} L_S^t \tag{35}$$

The labour income of self-employed valued at prices of the previous year is, in line with the official method, calculated according to expression (25).

In tables 18–8 and 18–9, the resulting gross-output based MFP changes and value-added based MFP changes are presented. In all industries except construction, the average MFP change is higher than the results of the official method. Agriculture, forestry and fishing, construction and trade, hotels, restaurants and repair are the only industries showing a difference of more than 0.1 of a percentage point in average gross-output based MFP change. The average difference in construction is -0.35 percentage point. This difference is caused by a large shift in labour from employees to self-employed in recent years.

At the level of the commercial sector, average gross-output based MFP change increases with 0.05 percentage points, whereas the average value-added based MFP change increases with 0.06 percentage points. In contrast with these average increases, the MFP change (both gross-output based and value-added based) shows a small decrease in 1996, 2004, 2005 and 2006 as compared to the results of the official method.

T 18 – 8 Gross output based MFP change when giving self-employed the same hourly labour compensation as employees

in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.2	1.3	0.6	3.0	0.6	1.0
Mining and quarrying	-3.3	0.3	-1.7	7.3	-6.5	-2.8
Manufacturing	0.8	0.7	0.8	1.9	0.7	0.7
Electricity, gas and water supply	-0.1	1.5	0.7	0.8	1.1	0.4
Construction	-0.4	-0.4	-0.3	-0.1	0.6	0.2
Trade, hotels, restaurants and repair	2.3	0.9	1.7	1.8	1.8	2.9
Transport, storage and communication	2.1	1.8	1.9	2.1	2.2	1.5
Financial and business activities[1]	-0.3	0.9	0.3	2.9	1.1	0.0
Care and other service activities[2]	-0.3	-0.2	-0.2	0.1	-0.1	0.1
Commercial sector	0.90	0.94	0.94	2.44	1.12	1.11

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18 – 9 Value added based MFP change when giving self-employed the same hourly labour compensation as employees

in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.4	2.5	1.1	5.8	1.2	1.4
Mining and quarrying	-3.5	0.5	-1.7	10.2	-8.4	-3.1
Manufacturing	2.7	2.1	2.4	6.0	2.6	2.7
Electricity, gas and water supply	-0.4	4.6	2.0	2.8	3.3	1.7
Construction	-0.8	-0.8	-0.7	-0.1	1.2	0.4
Trade, hotels, restaurants and repair	4.1	1.6	3.1	3.1	3.3	5.3
Transport, storage and communication	4.0	3.6	3.7	4.1	4.4	3.2
Financial and business activities[1]	-0.4	1.3	0.4	4.4	1.6	0.0
Care and other service activities[2]	-0.4	-0.3	-0.3	0.2	-0.1	0.1
Commercial sector	1.38	1.39	1.42	3.64	1.72	1.72

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

No holding gains and losses

In the official method, holding gains and losses are included in the user cost of all assets except transfer of ownership. Alternative calculations of MFP change are made under the assumption that holding gains and losses are excluded from the user cost. Results are presented in tables 18–10 and 18–11.

When holding gains and losses are excluded, the MFP change increases relatively much in comparison to the official method. For the commercial sector, the average gross-output based MFP change increases with 0.10 percentage points and the average value-added based MFP change increases with 0.16 percentage points.

The difference with the official method is the largest in the period 1997–1999. Since then, the difference is steadily declining. In 2005 and 2006, the differences in gross-output based MFP change are reduced to about 0.02 percentage points. The industry where the differences in the average gross-output based MFP change are the largest is financial and business activities, but even in this industry the differences in 2005 and 2006 are only 0.05 percentage points.

T 18–10 Gross output based MFP change when holding gains are excluded from the user cost
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	0.1	1.0	0.5	2.7	0.5	-0.1
Mining and quarrying	-3.3	0.2	-1.7	7.3	-6.5	-2.9
Manufacturing	0.9	0.7	0.8	1.9	0.7	0.6
Electricity, gas and water supply	-0.0	1.5	0.7	0.8	1.1	0.1
Construction	-0.2	-0.2	-0.1	0.2	1.0	0.5
Trade, hotels, restaurants and repair	2.1	0.9	1.6	1.8	1.9	2.7
Transport, storage and communication	2.1	1.8	1.9	2.1	2.2	1.3
Financial and business activities[1]	-0.2	1.0	0.4	3.0	1.1	-0.2
Care and other service activities[2]	-0.2	-0.2	-0.2	0.1	-0.2	0.1
Commercial sector	0.96	0.97	0.98	2.49	1.18	1.17

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

Other exogenous interest rate

In the official method the interest rate is based on the internal reference rate between banks. This rate varies through time. The implied real interest rate varies also through time, as table 18–1 shows. The question now is: what happens to MFP change when the real interest rate is fixed? We considered two cases, 4 and 10 percent respectively.

In tables 18–12 and 18–13, the results for a real interest rate of 4 percent are presented. The differences in MFP change as compared to the official method are very small. For most years and most industries, the differences in either gross-output based or value-added based

T 18–11 Value added based MFP change when holding gains are excluded from the user cost
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	0.3	2.0	1.1	5.4	1.0	0.2
Mining and quarrying	-3.4	0.5	-1.4	10.2	-8.4	-1.2
Manufacturing	2.9	2.2	2.6	6.2	2.7	3.1
Electricity, gas and water supply	-0.2	4.7	2.2	2.9	3.3	2.3
Construction	-0.4	-0.4	-0.3	0.5	2.1	1.2
Trade, hotels, restaurants and repair	3.9	1.6	3.0	3.2	3.4	5.1
Transport, storage and communication	4.0	3.6	3.8	4.2	4.4	3.8
Financial and business activities[1]	-0.1	1.5	0.6	4.6	1.8	-0.4
Care and other service activities[2]	-0.3	-0.3	-0.3	0.1	-0.2	0.1
Commercial sector	1.53	1.44	1.51	3.75	1.83	1.83

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

MFP change are smaller than 0.1 percentage point. For the market sector, differences are even smaller. The differences are negligible in all years except 2006. In this year, gross-output based MFP change is 0.05 percentage point higher and value-added based MFP change is 0.06 percentage point higher.

T 18–12 Gross output based MFP change when the real interest rate is set at 4 percent
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.1	1.0	0.5	2.7	0.5	0.7
Mining and quarrying	-3.3	0.3	-1.6	7.4	-6.5	-2.8
Manufacturing	0.8	0.7	0.7	1.9	0.7	0.8
Electricity, gas and water supply	-0.1	1.6	0.7	0.9	1.2	0.5
Construction	-0.3	-0.2	-0.2	0.2	1.0	0.6
Trade, hotels, restaurants and repair	2.0	0.9	1.6	1.8	1.9	2.9
Transport, storage and communication	2.0	1.8	1.9	2.1	2.2	1.6
Financial and business activities[1]	-0.4	0.9	0.2	3.0	1.1	0.2
Care and other service activities[2]	-0.3	-0.3	-0.3	0.0	-0.2	-0.0
Commercial sector	0.81	0.91	0.89	2.46	1.17	1.20

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18 –13 Value added based MFP change when setting the real interest rate at 4 percent

in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.2	2.0	0.9	5.3	1.0	1.1
Mining and quarrying	-3.5	0.5	-1.7	10.2	-8.4	-3.1
Manufacturing	2.7	2.1	2.4	6.1	2.6	2.8
Electricity, gas and water supply	-0.4	4.6	2.1	2.8	3.2	1.7
Construction	-0.6	-0.5	-0.4	0.5	2.1	1.5
Trade, hotels, restaurants and repair	3.7	1.5	2.8	3.2	3.4	5.3
Transport, storage and communication	3.8	3.5	3.6	4.1	4.4	3.2
Financial and business activities[1]	-0.5	1.3	0.4	4.5	1.7	0.2
Care and other service activities[2]	-0.4	-0.4	-0.4	0.0	-0.3	-0.0
Commercial sector	1.27	1.34	1.36	3.68	1.80	1.86

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

In tables 18–14 and 18–15, the results for a real interest rate of 10 percent are presented. As expected, differences are larger. For the commercial sector, on average gross-output based MFP change is 0.06 percentage point higher than in the official method, whereas value-added based MFP change is on average 0.03 percentage point higher. In 2006, differences in both gross-output based MFP change and value-added based MFP change are over 0.2 percentage points.

T 18 –14 Gross output based MFP change when the real interest rate is set at 10 percent

in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.0	0.9	0.4	2.8	0.4	0.6
Mining and quarrying	-2.9	0.4	-1.4	7.6	-6.5	-2.7
Manufacturing	0.9	0.6	0.8	2.0	0.8	0.9
Electricity, gas and water supply	0.0	1.8	0.9	1.2	1.2	0.7
Construction	-0.3	-0.2	-0.2	0.1	1.0	0.7
Trade, hotels, restaurants and repair	2.0	0.8	1.6	1.9	1.9	3.0
Transport, storage and communication	2.2	1.7	1.9	2.2	2.3	1.7
Financial and business activities[1]	-0.3	1.0	0.3	3.1	1.3	0.4
Care and other service activities[2]	-0.3	-0.2	-0.2	-0.1	-0.3	-0.1
Commercial sector	0.90	0.90	0.94	2.50	1.25	1.36

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18–15 Value added based MFP change when setting the real interest rate at 10 percent
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.0	1.7	0.8	5.3	0.9	0.7
Mining and quarrying	-3.4	0.6	-1.6	10.3	-8.4	-3.1
Manufacturing	2.5	1.8	2.2	5.8	2.3	2.7
Electricity, gas and water supply	-0.6	4.7	2.0	2.6	3.1	1.8
Construction	-0.7	-0.5	-0.4	0.4	2.2	1.6
Trade, hotels, restaurants and repair	3.7	1.4	2.8	3.2	3.4	5.4
Transport, storage and communication	3.8	3.3	3.5	4.0	4.2	3.2
Financial and business activities[1]	-0.5	1.4	0.5	4.6	2.0	0.6
Care and other service activities[2]	-0.4	-0.3	-0.4	-0.1	-0.4	-0.1
Commercial sector	1.32	1.31	1.38	3.63	1.85	2.04

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

For agriculture, forestry and fishing, the 1997 and 1998 value-added based MFP change differences are +2.1 and –2.7 percentage point respectively. This can be related to the occurrence of swine fever. In 1997, this led to large-scale "destructions" of pigs, and therefore to high user cost. When the real interest rate is fixed at 10 percent, these once-only cost become a smaller part of total cost, leading to a smaller change in the volume index of the input, and thus to less extreme MFP changes.

Endogenous interest rates

MFP changes are also calculated by using endogenous interest rates. An endogenous interest rate for each industry and year is determined under the condition that

$$U^{*t} + W^{*t} = VA^t \tag{36}$$

where U^{*t} is given by expression (20), W^{*t} by expression (22), and VA^t is value added of year t. Solving r^t from equation (36) gives the so-called endogenous interest rate, and deflating by a headline CPI gives the real rates.

Two different scenarios have been studied. In the first scenario, it is assumed that self-employed persons receive the same *annual* labour income as employees, whereas in the second scenario it is assumed that self-employed persons receive the same *hourly* labour income as employees.

In tables 18–16 and 18–17, the resulting real interest rates are presented. Some of the rates, especially in table 18–16, seem extremely high. For mining and quarrying, wholesale trade and to a lesser extent for trade and repair of motor vehicles/cycles, a plausible explanation for this is the incompleteness of the capital inputs. Natural resources and inventories are still excluded from the capital inputs, and since they are very important in these industries, this exclusion leads to excessively high endogenous interest rates. For some other industries, like construction and computer and related activities, at the end of the nineties, self-employed may have had a higher hourly labour income than employees. The excessive interest rates are in these cases probably caused by an underestimation of labour income of self-employed.

T 18–16 Endogenous real interest rates, using for self-employed the same yearly labour compensation as for employees
in percents

	1995	2000	2003	2004	2005	2006
Agriculture, forestry and fishing	2.4	0.7	-1.4	-2.3	-1.9	0.5
Mining and quarrying	22.7	21.6	23.8	26.0	31.9	40.9
Manufacture of food products, beverages and tobacco	14.3	13.0	16.4	17.1	15.4	13.5
Manufacture of textile and leather products	6.0	7.0	4.5	2.3	2.6	4.0
Manufacture of paper and paper products	2.0	3.0	3.0	4.4	1.9	0.1
Publishing and printing	15.8	17.0	11.5	15.8	17.9	17.8
Manufacture of petroleum products	-2.1	6.2	18.0	27.2	44.4	28.6
Manufacture of basic chemicals and chemical products	12.6	10.1	10.8	13.6	12.1	12.1
Manufacture of rubber and plastic products	7.4	6.7	5.6	5.0	2.8	1.0
Manufacture of basic metals	9.0	8.2	3.3	12.3	19.4	19.7
Manufacture of fabricated metal products	10.9	9.6	3.2	5.3	6.9	6.8
Manufacture of machinery and equipment n.e.c.	10.8	16.3	12.9	18.1	20.6	23.9
Manufacture of electrical and optical equipment	-0.7	6.0	-14.8	-15.0	-16.7	-19.6
Manufacture of transport equipment	2.0	12.7	9.2	12.6	10.7	11.4
Other manufacturing	4.0	7.2	5.1	5.5	6.2	7.0
Electricity, gas and water supply	3.3	2.3	6.4	5.5	6.4	9.1
Construction	21.6	26.1	27.2	24.4	27.7	33.0
Trade and repair of motor vehicles/cycles	6.7	20.3	20.7	19.9	16.9	18.7
Wholesale trade (excl. motor vehicles/cycles)	19.1	41.4	38.8	43.7	48.6	57.2
Retail trade and repair (excl. motor vehicles/cycles)	13.4	14.4	9.1	4.1	-3.3	-5.9
Hotels and restaurants	20.2	33.1	30.9	30.9	29.9	31.3
Land transport	4.1	7.4	7.7	6.5	6.9	8.9
Water transport	-1.8	-1.7	2.1	3.2	2.0	1.7
Air transport	-0.6	-2.5	-11.4	-9.5	-10.6	-9.8
Supporting transport activities	2.6	3.1	2.4	2.2	2.5	3.6
Post and telecommunications	9.6	5.5	15.1	15.5	15.7	15.1
Banking	26.6	7.2	22.3	25.0	26.0	7.0
Insurance and pension funding	10.7	9.2	21.0	22.4	31.6	32.3
Activities auxiliary to financial intermediation	7.8	50.2	27.5	30.3	28.8	41.7
Computer and related activities	5.7	67.8	33.4	43.7	47.4	63.4
Research and development	3.6	-8.7	-6.6	-0.3	3.5	-1.1
Other business activities	33.1	29.1	16.3	16.1	23.2	26.0
Health and social work activities	9.1	9.6	12.8	11.7	10.9	9.5
Sewage and refuse disposal services	0.9	2.5	4.2	2.5	2.8	3.9
Recreational, cultural and sporting activities	-11.9	2.4	5.3	6.2	6.4	8.9
Other service activities n.e.c.	2.4	5.3	6.0	5.5	5.8	6.0

T18–17 Endogenous real interest rates, using for self-employed the same hourly labour compensation as for employees

in percents

	1995	2000	2003	2004	2005	2006
Agriculture, forestry and fishing	-1.2	-6.5	-7.5	-8.7	-8.1	-5.4
Mining and quarrying	22.7	21.6	23.8	26.0	31.9	40.9
Manufacture of food products, beverages and tobacco	13.7	12.4	16.0	16.7	15.0	13.1
Manufacture of textile and leather products	4.7	5.9	3.0	0.6	0.9	2.4
Manufacture of paper and paper products	2.0	2.9	2.9	4.4	1.9	0.1
Publishing and printing	13.8	15.8	10.6	14.6	16.7	16.6
Manufacture of petroleum products	-2.1	6.2	18.0	27.2	44.4	28.6
Manufacture of basic chemicals and chemical products	12.6	10.1	10.8	13.6	12.1	12.0
Manufacture of rubber and plastic products	6.9	6.5	5.5	4.9	2.7	1.0
Manufacture of basic metals	9.0	8.2	3.3	12.3	19.4	19.7
Manufacture of fabricated metal products	9.7	8.1	2.1	4.1	5.6	5.3
Manufacture of machinery and equipment n.e.c.	9.8	15.2	12.5	17.7	20.1	23.4
Manufacture of electrical and optical equipment	-1.2	5.3	-15.4	-15.6	-17.4	-20.3
Manufacture of transport equipment	1.4	12.3	8.5	11.8	9.8	10.7
Other manufacturing	2.4	5.4	3.9	4.1	4.9	5.6
Electricity, gas and water supply	3.3	2.3	6.4	5.5	6.4	9.1
Construction	13.6	14.9	15.7	11.5	13.0	15.6
Trade and repair of motor vehicles/cycles	-0.2	14.5	15.7	14.5	11.5	13.2
Wholesale trade (excl. motor vehicles/cycles)	13.7	37.9	36.2	41.1	45.9	54.3
Retail trade and repair (excl. motor vehicles/cycles)	4.8	7.5	2.9	-1.9	-9.6	-12.1
Hotels and restaurants	4.8	16.2	16.4	16.7	15.5	17.3
Land transport	3.2	6.4	7.0	5.7	6.1	8.1
Water transport	-5.3	-4.4	0.6	1.7	0.4	0.1
Air transport	-0.6	-2.5	-11.4	-9.5	-10.7	-9.9
Supporting transport activities	2.3	2.8	2.3	2.0	2.3	3.4
Post and telecommunications	9.4	5.3	14.9	15.2	15.4	14.7
Banking	26.6	7.2	22.3	25.0	26.0	7.0
Insurance and pension funding	10.7	9.2	21.0	22.4	31.6	32.3
Activities auxiliary to financial intermediation	-6.5	39.5	20.3	23.8	22.2	34.7
Computer and related activities	-9.8	56.8	21.6	32.0	36.2	49.3
Research and development	3.4	-9.4	-7.3	-1.0	2.7	-2.1
Other business activities	22.0	18.6	7.2	6.2	12.5	14.1
Health and social work activities	9.7	10.2	13.9	12.8	12.1	10.8
Sewage and refuse disposal services	0.9	2.5	4.2	2.5	2.8	3.9
Recreational, cultural and sporting activities	-22.1	-6.4	-3.3	-2.0	-1.3	1.5
Other service activities n.e.c.	-1.2	-0.7	-1.6	-2.1	-1.9	-2.1

The calculations resulted in some instances in negative endogenous interest rates. Furthermore, negative user cost values occurred for some combinations of industry and asset type. In cases where the operating surplus of an industry is negative, the total user cost of capital must be negative as well. However, for the purpose of getting some sensitivity results, MFP change has been calculated in all these instances, disregarding theoretical problems with negative interest rates or negative user cost of capital values.

In tables 18–18 and 18–19, MFP change is presented under the assumption that self-employed persons receive the same *annual* income as employees. In tables 18–20 and 18–21, MFP change is presented under the assumption that self-employed receive the same *hourly* income as employees.

T 18–18 Gross output based MFP change when using an endogenous interest rate
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.2	1.1	0.5	2.6	0.5	0.9
Mining and quarrying	-2.6	0.5	-1.2	8.0	-6.5	-2.5
Manufacturing	0.9	0.6	0.7	1.9	0.7	0.8
Electricity, gas and water supply	-0.1	1.6	0.7	1.0	1.2	0.6
Construction	-0.3	-0.3	-0.2	0.1	1.1	0.9
Trade, hotels, restaurants and repair	2.1	0.8	1.6	2.0	2.0	3.3
Transport, storage and communication	1.9	1.9	1.9	2.4	2.3	1.7
Financial and business activities[1]	-0.5	0.9	0.3	3.2	1.7	1.0
Care and other service activities[2]	-0.3	-0.3	-0.3	-0.1	-0.3	-0.1
Commercial sector	0.77	0.89	0.89	2.55	1.34	1.51

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18–19 Value added based MFP change when using an endogenous interest rate
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.3	2.3	1.1	5.3	1.1	1.9
Mining and quarrying	-3.3	0.7	-1.5	10.4	-8.3	-3.2
Manufacturing	2.6	1.8	2.2	5.7	2.2	2.7
Electricity, gas and water supply	-0.4	4.6	2.1	2.7	3.2	1.8
Construction	-0.8	-0.7	-0.5	0.3	2.4	1.8
Trade, hotels, restaurants and repair	3.6	1.3	2.8	3.3	3.5	5.6
Transport, storage and communication	3.6	3.7	3.6	4.6	4.5	3.4
Financial and business activities[1]	-0.7	1.4	0.4	4.7	2.4	1.5
Care and other service activities[2]	-0.4	-0.4	-0.4	-0.2	-0.5	-0.1
Commercial sector	1.12	1.28	1.30	3.68	1.95	2.23

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18–20 Gross output based MFP change when using an endogenous interest rate and giving self-employed the same hourly labour compensation as employees
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.3	1.7	0.7	2.9	0.7	1.2
Mining and quarrying	-2.6	0.5	-1.2	8.0	-6.5	-2.5
Manufacturing	0.9	0.6	0.8	1.9	0.7	0.8
Electricity, gas and water supply	-0.1	1.6	0.7	1.0	1.2	0.6
Construction	-0.4	-0.4	-0.3	-0.1	0.7	0.3
Trade, hotels, restaurants and repair	2.3	0.9	1.7	1.9	2.0	3.2
Transport, storage and communication	1.9	1.9	1.9	2.4	2.3	1.7
Financial and business activities[1]	-0.3	1.0	0.4	3.2	1.6	0.9
Care and other service activities[2]	-0.2	-0.2	-0.2	-0.1	-0.2	-0.0
Commercial sector	0.85	0.94	0.95	2.53	1.29	1.44

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18–21 Value added based MFP change when using an endogenous interest rate and giving self-employed the same hourly labour compensation as employees
in percents

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.5	3.5	1.6	6.0	1.6	2.8
Mining and quarrying	-3.3	0.7	-1.5	10.4	-8.3	-3.2
Manufacturing	2.6	1.8	2.3	5.7	2.2	2.6
Electricity, gas and water supply	-0.4	4.6	2.1	2.7	3.2	1.8
Construction	-0.9	-1.0	-0.8	-0.2	1.4	0.6
Trade, hotels, restaurants and repair	4.0	1.4	3.0	3.3	3.4	5.6
Transport, storage and communication	3.6	3.7	3.7	4.5	4.5	3.4
Financial and business activities[1]	-0.5	1.4	0.5	4.6	2.4	1.3
Care and other service activities[2]	-0.3	-0.4	-0.3	-0.1	-0.3	-0.0
Commercial sector	1.25	1.36	1.38	3.65	1.87	2.12

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

For mining and quarrying the differences in average MFP change, as compared with the results of the official method, are very large. As already mentioned when discussing the high interest rates in this industry, this is probably due to the exclusion of natural resources as capital input. Endogenous interest rates are only meaningful when all inputs in the production process are accounted for. For mining and quarrying, natural resource extraction constitutes quite likely the most important production factor. By using endogenous interest rates, these production costs are completely assigned to the other capital services.

Apart from mining and quarrying, the most extreme differences with the official method occur in agriculture, forestry and fishing. When endogenous interest rates are used and self-employed persons are given the same hourly labour income as employees, the differences with the official method in value-added MFP change are up to 4 percentage points. This volatility is probably caused by the large share of self-employed in this industry, inducing a large uncertainty with respect to the compensation of self-employed persons and therefore also a large uncertainty in the endogenously determined user cost of capital. The combination of the assumption that the hourly labour income for self-employed persons is the same as that for employees with the assumption of endogenous interest rates causes the compensation of the self-employed to be much higher and the user cost of capital to be much smaller than in the official method.

From 2005 on, differences are increasing. In 2006, for the commercial sector the difference in gross-output based MFP change between the official method and the method using an endogenous interest rate is 0.4 percentage points. For financial and business activities, the difference is even 0.9 percentage points. These large differences are caused by a change in capital input that differs substantially from the change in the other inputs, combined with large profits. When large profits occur, the share of capital in the total cost changes a lot when using an endogenous instead of an exogenous interest rate. Since the change in capital input is much lower than the change in the other inputs, the differences in the share of capital in the total cost lead to large differences in the total input change, so differences in MFP change are also large.

Sensitivity analyses: main conclusions

From the sensitivity analyses presented in the preceding subsections, it follows that for the commercial sector, MFP change is fairly insensitive to variations of the method of calculation. Only when holding gains are excluded from the user cost (and thus the effect of computers and software is downplayed), differences in average MFP change exceed 0.1 percentage point. However, almost all alternatives result in a higher average MFP change than the official method. Only with an endogenous instead of an exogenous interest rate, average value-added based MFP change is lower than in the official model. For gross-output based MFP, all the alternatives give a higher average MFP change.

The insensitivity to variations of the calculation method is confirmed when comparing our results with findings by EU-KLEMS as reported by van Ark, O'Mahony and Ypma (2007). EU-KLEMS, where different choices were made for the volume index, the labour income of self-employed, and the interest rate, estimates the average value-added based MFP change for the Dutch market sector[288] in the period 1995–2004 at 1.0 percent. After including the effect of labour composition this becomes 1.2 percent, which is comparable to our 1.26 percent.

288 The EU-KLEMS definition of the market sector differs from what we called the commercial sector. EU-KLEMS excludes care from the market sector but includes real estate activities, renting of movables, and private households with employed persons. Results are therefore not completely comparable.

In 2006, however, alternative assumptions on the user cost have larger effects on MFP change. Setting the interest rate at 10 percent or using an endogenous interest rate leads to differences for the commercial sector exceeding 0.2 percentage point. The reason is that in 2006 the volume change of capital input differs appreciatively from the volume change of the other inputs. Changing then the cost share of capital has consequences for MFP change.

At the industry level, the insensitivity is less. Average differences in gross-output based MFP change may be up to 0.15 percentage points, whereas average differences in value-added based MFP change may be up to 0.3 percentage points. With an endogenous instead of an exogenous interest rate, results for mining and quarrying show large differences. This can be explained by the incompleteness of the capital inputs in the accounting exercise.

Domar factors

As mentioned in the second section, Balk (2003b) showed that under the assumption of zero profit, for a fairly large class of index formulas, the ratio of value-added to gross- output based MFP change (each expressed as the logarithm of an index number) is proportional to the ratio of gross output to value added, which is the so-called Domar factor. Thus, the Domar factor can be approximated by dividing the value-added based MFP change by the gross-output based MFP change as in

$$D_1^t = \frac{\ln(\Pi_{VA,KL}^t)}{\ln(\Pi_{GO,KLEMS}^t)} \tag{37}$$

where $\Pi_{VA,KL}^t$ denotes the value-added based MFP index and $\Pi_{O,KLEMS}^t$ the gross-output based MFP index. The original computation method for the Domar factor is by dividing (consolidated) gross output by value added; that is, using year t – 1 values,

$$D_2^t = \frac{R^{t-1}}{VA^{t-1}} \tag{38}$$

where R^{t-1} denotes the value of (consolidated) gross output (revenue) in year t–1 and VA^{t-1} denotes value added in year t–1 (both in current prices).

Since in the official method it is not assumed that total cost is equal to gross output, these two approaches to the Domar factor do not necessary deliver the same results. In table 18–22, Domar factors are presented as calculated according to expression (37), and in table 18–23 according to expression (38). Their ratios are presented in table 18–24.

Though many of the ratios are near unity, sometimes the two approaches differ quite a lot. This happens mostly when the MFP change is small. In such cases, small changes in MFP change may lead to large changes in the ratio between the two estimates of the Domar factor. Extreme values of this ratio do therefore not necessarily correspond with large differences between the two measures of MFP change.

T 18 – 22 Domar factor calculated as the ratio between value added based MFP change and gross output based multi-factor productivity change

	1996	2000	2003	2004	2005	2006
Agriculture, forestry and fishing	1.58	1.88	2.02	1.97	2.19	1.71
Mining and quarrying	2.33	0.94	2.83	1.38	1.31	1.07
Manufacturing	3.27	3.03	3.00	3.12	3.58	3.71
Electricity, gas and water supply	2.37	2.68	0.98	3.45	2.85	3.97
Construction	2.20	4.37	2.03	3.28	2.22	2.34
Trade, hotels, restaurants and repair	1.98	1.97	1.46	1.73	1.84	1.80
Transport, storage and communication	1.70	1.94	1.86	1.93	2.01	2.13
Financial and business activities[1]	1.27	1.28	1.37	1.49	1.55	1.18
Care and other service activities[2]	1.50	1.56	1.46	1.47	1.49	1.90
Commercial sector	1.51	1.66	1.36	1.49	1.54	1.56

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

T 18 – 23 Domar factor calculated as the ratio between gross output and value added

	1996	2000	2003	2004	2005	2006
Agriculture, forestry and fishing	1.90	2.02	2.09	2.04	2.15	2.13
Mining and quarrying	1.24	1.36	1.32	1.30	1.29	1.26
Manufacturing	2.79	2.92	2.96	2.89	2.94	3.09
Electricity, gas and water supply	2.55	2.60	2.54	2.54	2.68	2.90
Construction	2.23	2.25	2.11	2.09	2.10	2.11
Trade, hotels, restaurants and repair	1.66	1.69	1.69	1.68	1.69	1.72
Transport, storage and communication	1.82	1.93	1.92	1.88	1.90	1.97
Financial and business activities[1]	1.43	1.44	1.45	1.43	1.44	1.43
Care and other service activities[2]	1.47	1.49	1.45	1.45	1.44	1.44
Commercial sector	1.44	1.45	1.45	1.43	1.44	1.46

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

To test this, value-added based MFP change is calculated from output-based MFP change and the Domar factor; that is, by

$$\Pi^{*t}_{VA,KL} = \exp(\ln(\Pi^{t}_{GO,KLEMS})D^{t}_{2}) \qquad (39)$$

The results of expression (39) are presented in table 18–25. For mining and quarrying, this leads to differences of up to 2.5 percentage points with value-added based MFP change as calculated with the official method (table 18–3). This may be due to the exclusion of natural resources as input factors, which causes gross output to be much larger than cost. For the other industries, as well as for the commercial sector as a whole, the differences with value-

T 18 – 24 Ratio between the two versions of the Domar factor

	1996	2000	2003	2004	2005	2006
Agriculture, forestry and fishing	0.83	0.93	0.97	0.97	1.02	0.80
Mining and quarrying	1.87	0.69	2.15	1.06	1.02	0.85
Manufacturing	1.17	1.04	1.01	1.08	1.22	1.20
Electricity, gas and water supply	0.93	1.03	0.39	1.36	1.06	1.37
Construction	0.99	1.94	0.96	1.57	1.06	1.11
Trade, hotels, restaurants and repair	1.19	1.17	0.86	1.03	1.09	1.05
Transport, storage and communication	0.93	1.01	0.97	1.02	1.06	1.08
Financial and business activities[1]	0.89	0.89	0.94	1.04	1.08	0.83
Care and other service activities[2]	1.02	1.05	1.01	1.01	1.03	1.31
Commercial sector	1.05	1.15	0.94	1.05	1.07	1.07

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

added based MFP change as calculated with the official method are much smaller. The largest difference, 0.8 percentage points, is found in electricity, gas and water supply in 2004. For care and other service activities, the differences are the smallest. The largest difference found in this industry is 0.04 percentage points in 2000.

T 18 – 25 Value added based multi-factor productivity change based on gross output based multi-factor productivity change and the Domar factor

	1996/2000	2000/2005	1996/2006	2004	2005	2006
Agriculture, forestry and fishing	-0.5	2.2	0.9	5.5	1.0	1.7
Mining and quarrying	-4.3	0.4	-2.1	9.6	-8.3	-3.6
Manufacturing	2.4	2.0	2.2	5.6	2.1	2.3
Electricity, gas and water supply	-0.3	4.5	2.0	2.1	3.1	1.2
Construction	-0.7	-0.5	-0.4	0.3	2.0	1.3
Trade, hotels, restaurants and repair	3.4	1.5	2.7	3.1	3.1	5.0
Transport, storage and communication	3.8	3.5	3.6	4.0	4.2	3.0
Financial and business activities[1]	-0.6	1.3	0.3	4.3	1.5	0.1
Care and other service activities[2]	-0.4	-0.4	-0.4	0.1	-0.3	-0.0
Commercial sector	1.17	1.31	1.28	3.53	1.68	1.68

[1] excluding real estate services and renting of movables
[2] excluding private households with employed persons

Conclusions and future work

In the foregoing we discussed the main results of the Netherlands' system of productivity statistics. The model has been explained, its various assumptions discussed, and a large number of sensitivity analyses executed.

Although official figures were presented, the system is far from final. Further improvement is expected from an extension of the National Accounts in the following three directions:

- The inclusion in the calculation of hours worked and the compensation of employees by industry branch of a breakdown by educational attainment. This means that in the near future quality changes in labour will be covered better in the productivity statistics.
- The annual production of a so-called knowledge module[289] will provide statistics on knowledge related inputs such as the capital services of R&D and ICT. The representation of R&D capital services in the National Accounts constitutes yet another deviation from mainstream national accounting.
- It is scheduled to construct complete balance sheets for non-financial assets. For productivity measurement this implies that the coverage of assets will be extended to inventories and non-produced assets such as land and subsoil assets.

289 See for details De Haan and Horsten (2007) and Tanriseven et al. (2007).

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19. SECTORAL PRODUCTIVITY IN THE UNITED STATES
Recent Developments and the Role of IT

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Introduction

As the step-up in U.S. productivity growth in the mid-1990s became evident, research on productivity surged. Initially, the new work concentrated on estimating the contribution of information technology (IT) to the productivity pickup, with similar results obtained using industry-level or broad macroeconomic time-series data (Jorgenson and Stiroh 2000, Oliner and Sichel 2000, respectively). Later, studies exploited more detailed data and showed that, while multi-factor productivity (MFP) growth in the IT-producing industries was very high, many services industries also had substantial MFP growth in the late 1990s (Triplett and Bosworth 2004; Jorgenson, Ho, and Stiroh 2005a, 2005b).

It is not surprising that disaggregate data were needed to establish that the resurgence in U.S. productivity growth in the late 1990s went beyond the production of IT and was based, at least in part, in increases in MFP growth in some services industries.[291] Detailed analysis had previously documented that many services industries had flat or declining trends in labor productivity for twenty or more years before the pickup in the late 1990s became evident (Corrado and Slifman 1999). The discovery that the "use of IT" story was mostly a services phenomenon (Stiroh 1998, Triplett 1999) also required disaggregate data to determine which industries were investing in the newer technologies. In some sense, the well documented variability in the diffusion of new technology and innovation across ranges of products

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291 This refers to the conventional representation of IT in the neoclassical growth accounting framework, which does not rule out the existence of externalities (or network effects) from IT. If such effects are present, the conventional framework will attribute them to MFP.

(Mansfield 1968, Gort and Klepper 1982) has long suggested that the available industry data should be studied to detect and identify changes in productivity.

This paper presents key trends and developments in productivity growth at an intermediate level of aggregation in the United States, and shows links between the acceleration of MFP and IT. Six custom-made sectors were aggregated up from detailed disaggregated data using a framework that has some nice theoretical properties. Further, the six sectors were defined to provide a more meaningful view of productivity growth than can be found using standard industry hierarchies. The six sectors have highly divergent trends in MFP growth, a result that we believe, in itself, strongly suggests disaggregate data are extremely useful for determining the current trend in aggregate MFP.

Similar to previous studies of sectoral productivity, we find that the U.S. productivity resurgence in the late 1990s was a sectoral story, with notable increases in the rate of change in MFP for some sectors partly offset by small step-downs in others. In terms of the sources of growth since 2000, our results show that productivity (MFP) has been the major contributor. We estimate that the rate of change in aggregate MFP picked up notably since 2000, and we now show that this was driven primarily by striking results for finance and business services. Although the major players in the productivity pickup in late 1990s – the tech sector and retail and wholesale trade – were not players in the *acceleration* since then, we estimate that the rate of MFP growth in these sectors continued to be robust. All told, using our newly developed NAICS-based dataset, we find that by 2004 the resurgence in productivity growth that started in the mid-1990s was relatively broad-based by major producing sector.

The plan of this paper is as follows: The next section of this paper spells out our theoretical framework and reviews the basic elements in our system: measures for industry-level growth accounting, measures of sectoral output and purchased inputs for aggregates of industries, and a structure for aggregating industries to sectors and to the total economy. We then present our results on developments and trends in sectoral productivity and on the role of IT.

Data and Methodology

This section consists of three parts that summarize detailed discussions presented in a methodological working paper (Corrado et al., 2006b). The first part describes the procedure used to define six sectors, or 'intermediate aggregates' made up of groups of underlying disaggregated industries. The next part is an overview of the methods used to construct productivity measures at each level of aggregation as well as decompositions of output growth for the aggregate economy and the six sectors. Finally, the construction of consistent time series on outputs, inputs, and prices for disaggregated U.S. industries is presented.

Grouping industries into sectors for productivity analysis

A novel feature of our work is the construction of custom-made sectors, or groupings of disaggregated industries. We do not define sectors according to the hierarchy implied in the industrial classification system, NAICS. Instead, we view aggregates of industries as vertically-integrated entities and group "upstream" industries with related "downstream" industries using I-O relationships. A detailed description of the methodology used to group industries in sectors is given in Corrado et al. (2006b). Grouping industries according to this approach minimizes int*er*sectoral flows across a given number of groups. Further, the aggregation minimizes time series breaks that occur in underlying disaggregated data. Finally, the defined sectors allow looking at welfare-theoretically consistent measures of productivity for deliveries to subsets of final demand.

Our first sector, the "high-tech" sector, includes producers of IT goods as well as IT services. To group the key IT-producing industries (semiconductors, computers, communications equipment, computer software, telecommunications services, and internet services) in a single sector, it was necessary to cut across three major NAICS groupings and to further disaggregate three industries in BEA's industry hierarchy. We did not map the entire new NAICS information sector to our high-tech sector because the NAICS information sector includes producers of cultural products (a NAICS term for newspapers, books, popular music, movies, TV programs, etc.) in addition to producers of IT products. Because cultural products are primarily consumed by persons, we assigned the industries that produced them with personal services. Overall, the productivity measures for our high-tech sector maps more closely to IT producing industries than in other sectoral productivity studies.

In addition to high-tech, the other sectors we identified were: construction, industrial, distribution, finance and business, and other (mostly personal) services. The construction sector is isolated because the sector plays an important role in economic fluctuations. The other four groupings of industries had a *primary* producing function that can be viewed as follows: producers of goods (industrial), merchandisers and transporters of goods (distribution), providers of services to businesses (finance and business), and providers of services and cultural products to persons (personal and cultural).

The resulting six sectors and their relative sizes according to several metrics are illustrated in table 19–1. The bottom half of column 1 shows the 'Domar' weights, the weights used for aggregating MFP for each sector to obtain MFP for the total private nonfarm business sector, as described in the following section. As may be seen, the industrial and the finance and business sectors have relatively large Domar weights, and the sum of the Domar weights for all sectors exceeds one by 40 percent (as explained in the next section). The Domar weights have shifted only slightly over time, with the

weight for the industrial sector (which excludes high-tech manufacturing) dropping a bit, and weights for the high-tech and the finance and business sectors increasing.

Table 19–1 also shows that in 2004, whether measured as sectoral output, deliveries-to-final demand, or value added, four sectors – industrial, distribution, finance and business, and personal and cultural – dominate U.S. business activity. The industrial sector is the largest in terms of gross output and shipments to final demand, but it is the smallest of the four – by a wide margin – in terms of employment share and does not dominate in terms of value added. The finance and business services sector is the largest in terms of value added.

T 19–1 The Private Nonfarm Business Sectors and their Relative Sizes, 2004

Billions of dollars	Total Sectoral Output1 (1)	Deliveries to Final Users2 (2)	Deliveries to PNFB Sectors (3)	Gross Output (4)	Value Added (5)	Employ-ment3 (6)
Private nonfarm business	9,504	9,504	0	16,480	8,616	97,949
High-tech	995	715	280	1,187	562	3,713
Excluding high-tech	9,169	8,789	380	15,293	8,054	94,236
Construction	1,050	991	59	1,051	550	8,250
Industrial	3,299	2,436	863	4,687	1,735	14,579
Distribution	2,660	1,899	761	2,835	1,791	23,644
Finance and business	3,308	1,773	1,535	4,525	2,730	25,206
Personal and cultural	2,014	1,691	323	2,197	1,249	22,557
Shares (percent)						
High-tech	10.5	7.5	---	7.2	6.5	3.8
Construction	11.0	10.4	---	6.4	6.4	8.4
Industrial	34.7	25.6	---	28.4	20.1	14.9
Distribution	28.0	20.0	---	17.2	20.8	24.2
Finance and business	34.8	18.7	---	27.5	31.7	25.7
Personal and cultural	21.2	17.8	---	13.3	14.5	23.0
Sum of six sectors	140.2	100.0	---	100.0	100.0	100.0

--- not applicable.
1. The shares in the lower half of column (1) are Domar weights.
2. Final users is final demand plus industries excluded from private nonfarm business.
3. Thousands, persons engaged in production (full-time equivalent workers plus self-employed workers).
Note—The industry composition of each sector is reported in Corrado et al. (2006b).

Productivity aggregation and growth decompositions

Productivity for an aggregate and productivity for component industries are related using the framework of Domar (1961). This framework enables MFP growth at any level of aggregation to be decomposed into contributions from underlying sectors or industries. Hulten (1978) and Gollop (1979, 1983) further developed the framework, and it has been used in several prominent studies of U.S. productivity growth (e.g., Jorgenson, Gollop, and Fraumeni 1987, and Gullickson and Harper 1999).

The Domar framework uses the concept of sectoral output – defined as the gross output of an industry or sector less the amount produced and consumed within the industry or sector – to model production for an industry or a sector. This output concept has an interesting property: Although it is very close to gross output at the detailed industry level, as we move up an aggregation hierarchy of producing units, sectoral output strips out what each aggregate *collectively* uses up in production and moves closer and closer to value added. Because the output of an industry, a collection of industries, or the whole economy is viewed, in effect, as production by a single vertically-integrated firm, the Domar or sectoral framework has come to be called the "deliveries-to-final demand" framework for studying industry productivity (Gollop 1979).

As shown by Hulten (1978), productivity growth defined in this way has nice theoretical properties, as productivity can be mapped into the growth of welfare of purchasers minus growth in primary inputs used in the required stages of production. As a practical matter, defining productivity in this framework means that researchers do not need to make the often-violated assumptions necessary for either value added or gross output productivity measures.

The definitions and notation we employ in this paper are grounded in industry-by-industry input-output (I-O) relationships as laid out in table 19–2. Note that bolded letters denote growth rates in real terms and non-bold capital letters denote nominal expenditure flows. The items defined in table 19–2 are used to illustrate the basic Domar/Hulten result that the rate of change in multi-factor productivity at any level of aggregation (MFPk) can be expressed as a weighted average of the rates of change in multi-factor productivity of underlying or disaggregated industries (MFPi).

$$\text{MFPk} = \sum_{i \in k} d_i^k \ \text{MFPi}, \qquad (1a)$$

The 'Domar' weights are defined as, $d_i^k = \frac{S_i}{S_k}$, which depends on the composition of both the underlying industries and the aggregate industry being created. The "Domar" weights have the following property, $\sum_{i \in k} d_i^k > 1$, and reveal the effect that a change in each industry's productivity has on the change in aggregate productivity. Each industry i contributes to productivity of industry k, directly through its deliveries to customers of k (i.e. deliveries of k to other using industries and to final demand), and indirectly through its deliveries to other component industries of k that purchase its output.

T 19 – 2 Sources of growth in sectoral output for major and "intermediate" sectors of the U.S. economy (1)

	Sectoral Output (1)	MFP (2)	IT Capital2 (3)	Other Capital3 (4)	Labor (5)	Purchased Inputs4 (6)
A. 1995 to 2000						
1. Private nonfarm business	5.4	1.1	1.0	.8	1.5	1.0
2. Excl. high-tech	4.6	.4	.8	.8	1.2	1.4
3. Construction	4.8	-.8	.2	.3	1.8	3.3
4. Industrial	2.6	.2	.3	.3	-.1	1.9
5. Distribution	5.3	2.3	.5	.6	.7	1.1
6. Finance and business	6.6	-.6	1.5	1.1	1.8	2.8
7. Personal and cultural	3.6	-.6	.3	.4	1.1	2.3
8. High-tech	17.6	6.8	1.5	.6	2.4	6.4

	Sectoral Output (1)	MFP (2)	IT Capital2 (3)	Other Capital3 (4)	Labor (5)	Purchased Inputs4 (6)
B. 2000 to 2004						
1. Private nonfarm business	2.3	2.3	.4	.3	-.8	.0
2. Excl. high-tech	2.0	1.8	.4	.3	-.5	-.0
3. Construction	.9	-.2	.1	.2	-.1	1.0
4. Industrial	.6	1.1	.1	.1	-1.2	.5
5. Distribution	3.1	2.5	.2	.1	-.4	.7
6. Finance and business	2.8	1.9	.7	.4	-.3	.1
7. Personal and cultural	2.1	.2	.2	.3	.6	.8
8. High-tech	3.2	5.3	.4	.2	-2.3	-.3
C. Difference in Annual Averages, (1995 to 2000) vs. (1987 to 1995)						
1. Private nonfarm business	2.4	.3	.5	.2	.7	.7
2. Excl. high-tech	2.0	-.1	.4	.2	.5	.9
3. Construction	4.6	-.5	.1	.3	1.3	3.4
4. Industrial	.8	-.4	.1	.1	-.0	1.0
5. Distribution	1.2	.7	.3	.3	.2	-.3
6. Finance and business	3.2	-.2	.7	.1	.9	1.7
7. Personal and cultural	.8	.1	.1	-.0	-.3	.8
8. High-tech	8.0	2.6	.9	.0	2.0	2.6
D. Difference in Annual Averages, (2000 to 2004) vs. (1995 to 2000)						
1. Private nonfarm business	-3.1	1.2	-.5	-.5	-2.2	-1.0
2. Excl. high-tech	-2.6	1.5	-.4	-.5	-1.8	-1.4
4. Construction	-3.9	.6	-.1	-.2	-1.9	-2.3
3. Industrial	-2.0	.9	-.2	-.2	-1.1	-1.4
5. Distribution	-2.2	.2	-.3	-.5	-1.1	-.5
6. Finance and business	-3.8	2.5	-.8	-.7	-2.1	-2.7
7. Personal and cultural	-1.5	.8	-.1	-.1	-.5	-1.6
8. High-tech	-14.4	-1.6	-1.1	-.4	-4.7	-6.7

1. Average annual rate for period shown. Column (1) is percent change. Columns (2) through (6) are percentage points.
2. Computers and peripheral equipment, software, and communication equipment.
3. Non-IT equipment, structures, and inventories.
4. Combined contribution of domestic and imported purchased inputs.
Note—For each row, column (1) equals the sum of columns (2) through (6).

As Domar/Hulten show, productivity growth at any level of industry detail also may be calculated residually as the difference between changes in Divisia quantity indexes for the industry's appropriately defined output ($\boldsymbol{S}_{k\cdot}$) and share-weighted inputs ($\boldsymbol{I}_{k\cdot}$):

$$\mathbf{MFP}_k = \mathbf{S}_{k\cdot} \quad \mathbf{I}_{k\cdot}, \qquad (1b)$$

which allows the standard Solow-Jorgenson-Griliches decomposition of the sources of aggregate economic growth (Hulten 1978). Also, the framework permits an assessment of the role of "intermediate" aggregates, or sectors, in the productivity performance of the overall economy.

The decomposition of sectoral output growth is written in terms of contributions of domestic inputs from outside the sector, and a Domar-weighted sum of growth accounting contributions of primary inputs and MFP of underlying industries:

$$\boldsymbol{S}_{k\bullet} = s_k^N \boldsymbol{N}_{k\bullet} + \sum_{i \in k} d_i^k \; [\boldsymbol{MFP}_i + s_i^L \boldsymbol{L}_i + s_i^K \boldsymbol{K}_i + s_i^R \boldsymbol{R}_i \quad . \tag{2}$$

The subscript k in (2) denotes a (sub)aggregate of industries, and the first term is the share-weighted growth of domestically-produced inputs purchased from outside the sector k. As with the Domar weights, accounting for these purchases is specific to the subaggregate and is based on industry-by-industry I-O relationships.

In our work we calculate detailed industry-level MFP using equation (1b) and aggregate MFP using equation (1a). We then use the results in equations (2) to obtain sources-of-growth decompositions for the total nonfarm business sector and for the six sectors. In this decomposition, the contribution of real growth of intermediates from outside the sector, s_k^N $\boldsymbol{N}_{k\bullet}$, is calculated residually.

Measures of output and inputs for individual industries

The estimation of industry-level multifactor productivity requires the following empirical elements: growth rates of real sectoral output for each industry ($\boldsymbol{S}_{k\bullet}$), growth rates of the inputs to production (labor, capital, imported inputs, and inputs from other domestic industries) for each industry ($\boldsymbol{L}_k$, $\boldsymbol{K}_k$, $\boldsymbol{R}_k$, and $\boldsymbol{N}_{k\bullet}$), and income shares for each input for each industry (s_k^L , s_k^K , s_k^R ,and s_k^N).

The nominal values of sectoral output for each industry ($S_{k\bullet}$) were determined by subtracting estimates of own-industry intermediate use ($X_{k\bullet}$) calculated using BEA's input-output accounts from the data on gross output (Q_k) in BEA's industry accounts dataset. The estimates of $X_{k\bullet}$ were also subtracted from BEA's data on total intermediate inputs (M_k) to determine the value of an industry's purchased inputs from *other* industries, that is, the sum of purchased inputs from other domestic industries and the "import" industry ($N_{k\bullet} + R_k$); see table 19–2. The details of these computations owing to missing data and other issues are discussed in Corrado et al. (2006b).

The growth of real industry-level sectoral output ($\boldsymbol{S}_{k\bullet}$) is determined from quantity indexes constructed by assuming the real value of each input produced and consumed within the industry ($\boldsymbol{X}_{k\bullet}$) has the same price index as each of the outputs produced within the industry. The growth rate of imported intermediates purchased from the 'import industry ($\boldsymbol{R}_k$) is calculated by deflating the estimated the value of imports for an industry with an industry-specific import deflator. Finally, the growth rate of intermediates purchased from other industries ($\boldsymbol{N}_{k\bullet}$) is calculated by chain stripping the real values of $X_{k\bullet}$ and R_k from the real value of M_k for which price and quantity measures are available in BEA's industry accounts.

Changes in industry capital input measures (K_k) were derived using BEA's detailed asset-by-industry net stocks. We follow the Jorgenson-Griliches approach taken by the BLS and aggregate asset-by-industry capital stocks using *ex post* rental prices. The BEA's capital stocks differ from the "productive" stocks compiled by the BLS, however, because the two agencies use different models of capital depreciation. We are comfortable adopting the BEA model because the differences between the two approaches are very small (see U.S. Department of Labor, 1983, pp. 56–59). Following numerous productivity studies, we aggregate the many detailed asset types into three aggregates for our sources-of-growth analysis: information technology (IT) capital, other equipment, and structures.[292]

Changes in industry labor input measures (L_k) are changes in hours worked of all persons (employees and the self-employed) with no explicit differentiation by characteristics of workers. Implicitly, some account is taken of worker heterogeneity by using the very detailed information on industry-level employment, hours and payrolls from the *County Business Patterns* (CBP) series issued by the Census Bureau. As indicated previously, the underlying source data on employment and hours contain serious breaks. A fairly complicated procedure, involving numerous assumptions, was needed to create a consistent time series for hours worked; see Corrado et al. (2006b).

Sectoral decomposition of output and productivity growth

The empirical decomposition of output and productivity growth for the six sectors is shown in table 19–3 and table 19–4. The tables each have three panels. The first two panels (panels A and B) show results for subperiods – 1995 to 2000, and 2000 to 2004. The next two panels (C and D) shows changes (in growth rates or contributions to growth) for the 1995–2000 relative to 1987–1995 (Panel C), and for the 2000 to 2004 period relative to the late 1990s (panel D).

Each **row** of table 19–3 is a sources-of-growth decomposition using equation (2). Thus, the contributions from MFP and each production factor (columns 3–8) sum across the row to equal sectoral output growth (column 2). The first row in each panel reports the decomposition for private nonfarm business; the subsequent rows in the panel show decompositions for major producing sectors. As may be seen in row 1 of panel A, we estimate that aggregate sectoral output growth for the private nonfarm business sector averaged about 5.4 percent from 1995 to 2000, with contributions from MFP, capital, labor, and purchased inputs all playing important roles. Because our "total" economy aggregate falls short of complete coverage of the U.S. economy, accounting for the growth in its purchased inputs from other domestic producers as well as the rest-of-world sector (imports) is important: During the late 1990s nearly 20 percent of private nonfarm business sectoral output *growth* was accounted for by purchased inputs.

Although contributions from MFP, capital, labor, and purchased inputs are all important for understanding aggregate economic growth, the sectoral sources-of-growth results (panel A, rows 3 through 8) indicate that the importance of productivity and contributions of factor

292 IT capital is defined as computers, communications equipment, and software.

inputs varies notably by sector. For construction, measured productivity change is negative, and the contribution of labor and purchased inputs more than account for the real output growth of this sector. By contrast, in the industrial sector, the contribution of labor input is negative, on average, and the contribution of productivity increases and purchased inputs account for much of its real output growth. Purchased inputs also contribute noticeably to output growth in the finance and business sector and in the personal and cultural sector (mainly purchases by industries in the NAICS food and accommodation sector), whereas purchased inputs contribute much less to growth in the distribution sector.

T 19 – 3 Sectoral decomposition of sources of growth for private nonfarm business (1)

	MFP	IT Capital2	Other Capital3	Labor	Memo: Domar Wght.
	(1)	(2)	(3)	(4)	(5)
A. 1995 to 2000					
1. Private nonfarm business	1.11	.98	.84	1.46	-----
2. Excl. high-tech	.34	.81	.77	1.19	95.3
3. Construction	-.09	.02	.03	.19	10.3
4. Industrial	.07	.11	.12	-.02	37.8
5. Distribution	.66	.14	.17	.21	28.3
6. Finance and business	-.19	.48	.36	.60	32.3
7. Personal and cultural	-.12	.06	.09	.22	20.2
8. High-tech	.78	.17	.07	.27	11.5
B. 2000 to 2004					
1. Private nonfarm business	2.34	.44	.30	-.76	-----
2. Excl. high-tech	1.76	.39	.28	-.50	95.9
3. Construction	-.03	.01	.02	-.01	10.9
4. Industrial	.38	.04	.03	-.42	34.6
5. Distribution	.70	.06	.03	-.11	27.6
6. Finance and business	.66	.24	.14	-.09	34.5
7. Personal and cultural	.04	.04	.07	.14	21.1
8. High-tech	.56	.05	.02	-.25	10.9
C. Difference in Annual Averages, (1995 to 2000) vs. (1987 to 1995)					
1. Private nonfarm business	.30	.52	.21	.69	-----
2. Excl. high-tech	-.09	.41	.20	.45	-1.6
3. Construction	-.06	.01	.03	.13	0.2
4. Industrial	-.19	.04	.03	-.01	-5.2
5. Distribution	.20	.08	.09	.04	-0.6
6. Finance and business	-.07	.26	.06	.33	3.4
7. Personal and cultural	.02	.02	-.00	-.04	0.5
8. High-tech	.39	.11	.01	.24	2.3

	MFP (1)	IT Capital2 (2)	Other Capital3 (3)	Labor (4)	Memo: Domar Wght. (5)
D. Difference in Annual Averages, (2000 to 2004) vs. (1995 to 2000)					
1. Private nonfarm business	1.23	-.54	-.54	-2.22	-----
2. Excl. high-tech	1.42	-.42	-.49	-1.69	0.5
3. Construction	.06	-.01	-.02	-.20	0.6
4. Industrial	.31	-.07	-.08	-.39	-3.2
5. Distribution	.04	-.08	-.14	-.32	-0.6
6. Finance and business	.84	-.23	-.23	-.69	2.2
7. Personal and cultural	.17	-.02	-.02	-.09	1.0
8. High-tech	-.22	-.13	-.05	-.52	-0.6

---- not applicable

1. Average annual rate for period shown. All entries (except memo item) are percentage point contributions to the growth of private nonfarm business sectoral output.
2. Computers and peripheral equipment, software, and communication equipment.
3. Non-IT equipment, structures, and inventories.

Note – In each panel, row (1) equals the sum of rows (3) through (8).

Each **column** of table 19–4 shows the sectoral decomposition of the contribution of primary factors and MFP to aggregate growth. Thus, the contribution of MFP or one of the production factors to sectoral growth in private nonfarm business, shown in line 1, is split into contributions from the high-tech (line 8) and excl. high-tech sectors (line2), while the contribution from the excl high-tech sector can be decomposed into contributions from the sectors in lines 3–7. In this decomposition, the role of the high-tech sector in the late 1990s resurgence in productivity growth, can be seen by the substantial difference between MFP for the private nonfarm business sector and the contribution of MFP in the "excl. high-tech" subaggregate (panel A, column 2, compare rows 1 and 2). It would therefore appear that, no matter how one looks at this period, the late 1990s productivity pickup story is a sectoral story: Notable increases in the rates of change in MFP in the high-tech and distribution sectors drove the aggregate results, but their strong performance was partially offset by negative contributions from the industrial, construction, and finance and business sectors.

With regard to factor inputs, our results show that faster growth in IT capital services contributed importantly to the pickup in economic growth in the late 1990s (panel C, row 1, column 3), consistent with previous studies and the official macro productivity data. As may be seen looking down column 3, the faster growth in IT capital services was concentrated primarily in industries in the distribution and finance and business sectors. All told, therefore, our results line up very well with the analysis and conclusions of many previous studies of the industries and factors that contributed to productivity growth in the United States in the late 1990s (Jorgenson and Stiroh 2000, Oliner and Sichel 2000, Triplett and Bosworth 2004).

Panel B reports our new results for the sources of the gains in output since 2000. As may be seen, productivity has been the major driver of recent economic growth (row 1), with most sectors contributing to the increase (column 2, rows 3 through 8). As shown in panel D, column 2, there is a notable sectoral variation in the results for the *pickup* in productivity since 2000, however. This faster growth in MFP in recent years is sizeable – more than 1 percent per year, on average – but the major sectoral players in the late 1990s (high-tech and distribution) are *not* contributors to the more recent pickup. Rather, very strong MFP gains in the finance and business sector, a resurgence in MFP growth in the industrial sector, and an end to the drops in MFP in the personal and cultural sector more than account for U.S. economic growth since 2000.

In terms of primary factor inputs, a notable result is that the post-2000 gains in output occurred as businesses pulled back on labor input (row 1 of panel B), leaving capital deepening (whose effect must be inferred from the results shown in row 1) and increasing MFP as the unambiguous sources of the post-2000 average gain in U.S. labor productivity. This result is pretty widespread by sector, although increases in hourly labor input in the personal and cultural sector continued to contribute to the economic growth of the post-2000 period.

In summary, we have found that by 2004 the resurgence in productivity growth that started in the mid-1990s was relatively broad-based across major producing sectors. However, the timing of the increases in sectoral MFP growth rates varied notably within this period. More fundamentally, the underlying trends in sectoral productivity growth rates themselves are highly divergent. In the high tech sector, MFP growth averaged 6 percent per year between 1995 and 2004; elsewhere, the underlying trends ranged from -3/4 percent per year for construction to 2-1/2 percent per year for distribution. We believe these findings can be exploited for forecasting changes in the current/prospective trend in MFP growth.

What is the underlying trend in MFP growth and what is the role of IT?

In this section, we explore two simple examples of how our findings can be used. The first example exploits only the *divergent pattern in sectoral MFP trends* just discussed and attempts to determine the current/prospective trend in aggregate MFP growth using a time-series approach.

The underlying variation in MFP growth across sectors and over time is displayed in graph 19–1. On the left, each panel displays the index level of actual MFP for a sector and an estimate of its trend based on the Hodrick-Prescott (HP) filter. The HP trends were generated using the smoothing parameter suggested by Ravn and Uhlig (2002) for annual data and have been calculated for three periods beyond the last observation on actual MFP.[293] The panel to the right shows percent changes in the actual and trend estimates of MFP, along with the

293 The projected trends were obtained by first extending the underlying data for five periods using forecasts from an ARIMA model and then applying the HP filter to the extended time series. This procedure minimizes the well-known end-of-sample problem with the HP filter. We thank our colleagues Charles Gilbert and Norman Morin for developing this routine.

period averages of MFP growth rates reported in table 19–3. Note that the changes in the estimated trends do not necessarily coincide with the averaged rates of actual productivity growth for the sub-periods analyzed in table 19–3.

We aggregate the HP-filtered sectoral trends shown in graph 19–1 using actual values of the Domar weights.. Because Corrado *et al* (2006b) determined that changes in these weights did not contribute significantly to recent productivity developments, we use a simple average of the two most recent actual values as Domar weights for the extension period, which in this example covers the years 2005 to 2007.[294] The results are shown in table 19–5. As may be seen, although the estimate of the trend in MFP growth from 2000 to 2004 in table 19–5 picks up less than the increase in its actual average rate in table 19–3 (also shown in the memo in table 19–5), the acceleration is still very notable – from 1.1 percent per year to 1.9 percent per year. The estimated current/prospective trends during 2005, 2006, and 2007 – though at lower rates than during the preceding period – remain robust and average nearly 1-3/4 percent per year.

As seen in graph 19–1, the continued robust pace of aggregate productivity growth occurs primarily because most sectors are expected to continue to contribute to the overall gain. This is seen especially for the high-tech sector, in which the prospective trend in MFP growth continues to be relatively strong. Quality-adjusted price measures are important for gauging the pace of technological innovation in this sector. As a result, confidence in the estimated prospective MFP trend depends in large part on believing that the sector's price measures are capturing recent developments in technology. In future work we plan to further disaggregate this sector so that we may incorporate the results of more recent research on price measures for communications equipment that are not in BEA's figures but are included in the annual price indexes used to benchmark the Federal Reserve's industrial production index.[295] The Federal Reserve's measures attempt to capture the effects of relatively recent developments, such as fiber optics, wireless networking, and IP (internet protocol)-based telephony.

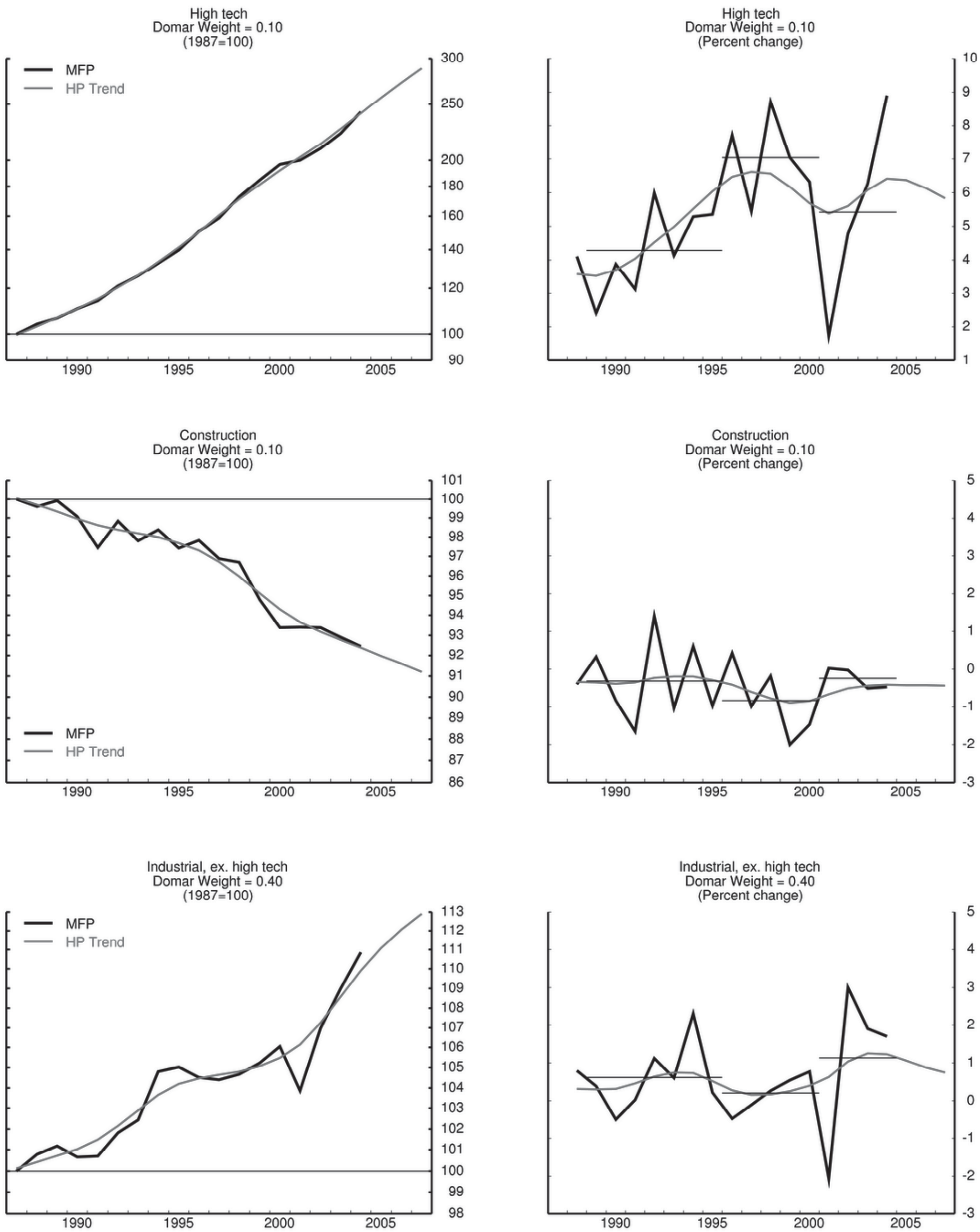
The prospective trends in MFP for the aggregate economy would be even higher were it not for the projected step-down in trend MFP for finance and business and the persistently negative – almost implausible – change in actual MFP for the construction sector.

With regard to the finance and business sector, the large turnaround in post-2000 MFP growth is striking. Moreover, the result appears to be widespread by industry within the sector (see detailed tables in Corrado 2006b). The largest contributions are from the banking

294 Of course, for additional precision in a practical forecasting setting, the sectoral weights could be developed from elements of macroeconomic data and/or a forecast in conjunction with the latest information on I-O relationships. Additionally, actual MFP at the sectoral level could be estimated for another year (in this case, 2005) using the methods described in Beaulieu and Bartelsman (2005) for estimating industry output using information on final demand components and adapting simplified methods for estimating capital input (e.g., Oliner and Sichel 2000, Meyer and Harper 2005) for use in a sectoral format.

295 These price indexes are based on research reported in Doms and Foreman (2005) and Doms (2005). Corrado (2001, 2003) and Bayard and Gilbert (2006) report on what has been developed, updated, and included in industrial production.

Multifactor Productivity ; Major Producing Sectors **G 19–1-1**



and commercial real estate industries; increases in MFP growth in these industries, along with an increase for the broad business services group, more than account for the step-up in the sector.[296] Because the sector's demand drivers would appear to be relatively diverse and its measurement long a subject of debate, the specific productivity stories within this sector are deserving of much further scrutiny and study.

As for construction, recall that we isolated the sector because it is an important driver of aggregate demand. In addition, our input-output analysis did not strongly suggest that the sector should be integrated with industries in the BEA hierarchy that primarily produce its inputs. However, given the materials-using nature of the sector's production (and the fact that real gross output grows substantially faster than real value added), a more detailed representation of supplying industries would be needed to create a more vertically-integrated construction sector. Another possibility would be to integrate the real estate industry with the construction sector. All told, therefore, the productivity of a more integrated construction (or construction and real estate) sector might look more plausible than the results for the construction industry alone.[297]

A second example uses only the *cross-sectional variation in MFP at the industry level* to analyze recent productivity developments.[298] Specifically, we ask whether the recent strong results for MFP are partly a reflection of earlier investments in IT. As noted in the introduction, the neoclassical growth accounting framework that we use may attribute part of what we think of "the use of" IT effects to MFP to the extent that network effects (and other externalities) are present. Furthermore, if firms experience adjustment costs (or must engage in learning) prior to factoring newly acquired IT technologies in production processes, the waning of those effects will have a temporary "accelerating" effect on MFP. Anecdotal and other information suggest that some of the recent productivity gains reflect firms making better use of existing capital and improving business processes, especially as they discover new and better methods for using IT (Basu, et al. 2003, Gordon 2004, Bies 2006).

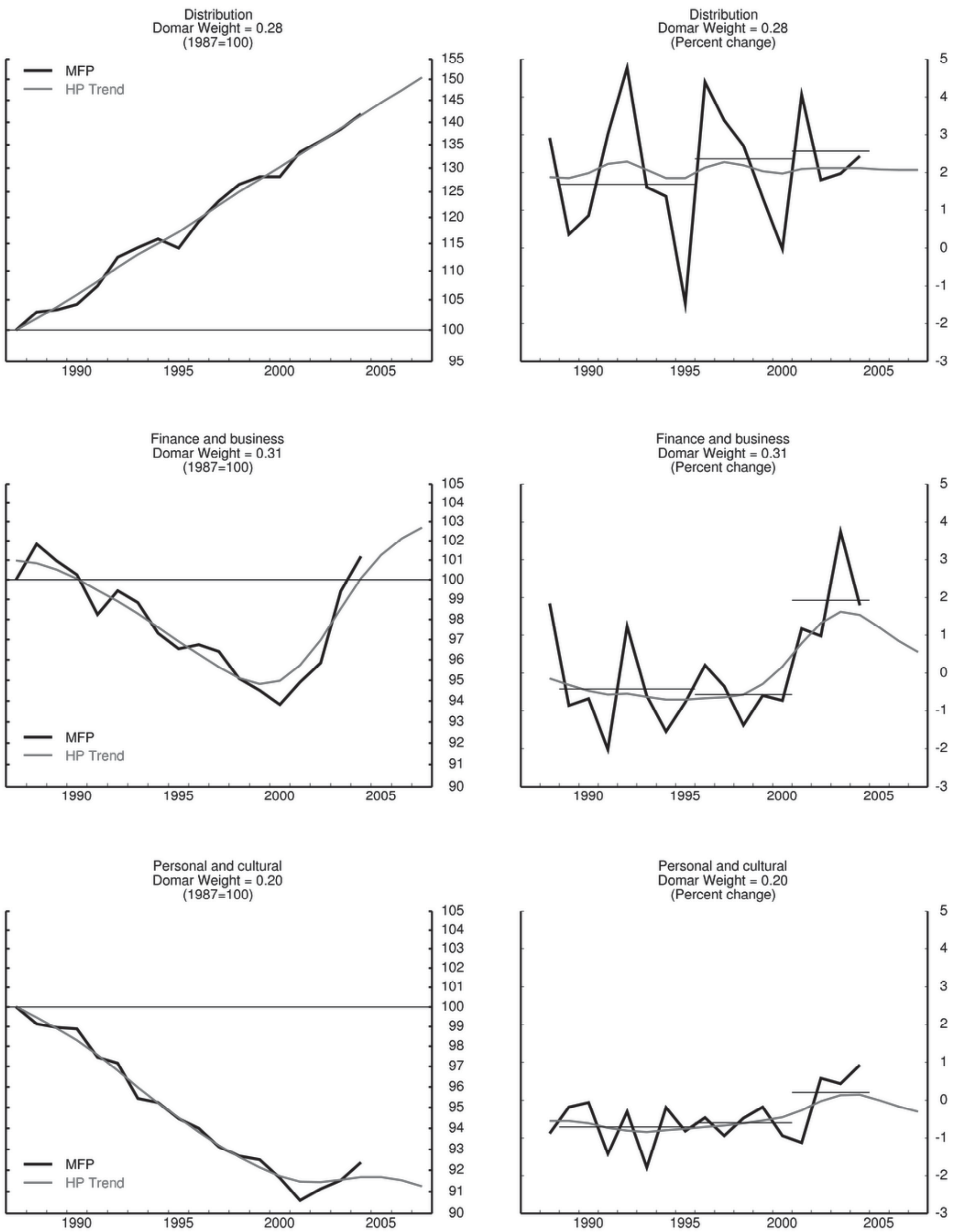
If some of the recent productivity gains are a lagged realization of the large run-up in IT investment in earlier years, then we would expect to see a pattern in which MFP growth for industries that invested especially heavily in IT in the late 1990s accelerated more strongly than did MFP growth for industries whose IT investments were not especially strong. Graph 19–2 shows a simple scatter plot and regression relationship between the *acceleration* in MFP growth by industry in 2000 to 2004 (relative to 1995 to 2000) and the extent to which IT investment by industry was above trend in the late 1990s. As may be seen, the relationship is statistically significant. Furthermore, although the regression explains only a small portion

296 Using SIC-based data, Triplett and Bosworth (2004) found that the securities industry posted a notable acceleration in productivity in the late 1990s. We estimate that MFP for this industry continued to expand post-2000, although the rate of growth was not nearly as rapid as in the late 1990s.

297 Of course, the results for productivity of the aggregate economy would be different only if the output price of the construction sector was mismeasured. Construction prices received much attention as a possible "culprit" for mismeasurement during the 1970s and 1980s period of lackluster productivity growth (e.g., Baily and Gordon 1988). The BEA recently revisited the measurement of construction prices, but the new results did not materially change the picture (Grimm 2003).

298 We are grateful to Larry Slifman for suggesting this example to us.

Multifactor Productivity ; Major Producing Sectors **G 19–1–2**



of the cross-sectional variance in productivity gains by industry in recent years, the effect appears despite the fact that the period analyzed contains a recession.

All told, the result shown in graph 19–2 suggests that the productivity-enhancing effects of installed IT capital (above and beyond the usual attribution in growth accounting) may still have been part of the story of the remarkable pace of U.S. economic growth since 2000. Because this "above and beyond" effect should only prove temporary, the result is consistent with the time-series analysis in suggesting that the underlying growth rate of aggregate productivity is likely to slow, albeit to a pace that would still be quite strong by historical standards.

Conclusion

This paper introduces new estimates of aggregate, sectoral, and industry productivity. The estimates are based on an appropriate theoretical framework for how industry and sectoral MFP feed into aggregate MFP, and are developed using industry data classified according to NAICS from 1987 on.

The six sectors we studied were designed to highlight differences among groups of industries in terms of their deliveries to final demand. Using this approach, we were able to provide new decompositions of economic growth and paint a rich picture of recent productivity developments in the United States. Our results indicate that the six sectors have had very different trends in multifactor productivity growth and made contributions to aggregate productivity that varied notably within the period from 1995 to the present. Nonetheless, by 2004 the resurgence in productivity growth that started in the mid-1990s was found to have been relatively broad-based and likely still driven by IT.

Given the macroeconomic importance of productivity, along with our finding that productivity has been the major source of the output gains since 2000, we believe it is especially important to understand the sources of productivity and to assess their implications for the period going forward. This paper has taken a modest step in this direction, but our work also raises questions, such as how the finance and business services sector experienced such a remarkable turnaround in productivity in recent years. The role of IT capital is often discussed in the context of productivity in financial services (e.g., Triplett and Bosworth), but it is important to remember that human capital also is an important input in the financial and business services industries more broadly (Jorgenson, Ho, and Stiroh 2005). Our results do not include an explicit adjustment to account for the role of human capital in business sector productivity statistics. Furthermore, if the economy's aggregate production depends on uncounted intangible capital as in Corrado, Hulten, and Sichel (2005, 2006a), the expanded view heightens the importance of this sector. Uncounted investments in innovation (R&D, for example), organizational practices, and business strategies are not just inputs to production in the finance and business sector as in other sectors. Many of these intangibles are part of *the output* of this sector.

Stepping back from our specific results, an inherent advantage of approaching productivity at an "intermediate" level of aggregation is that the effects of the underlying economic mechanisms may be discerned. In this paper, we chose to construct intermediate aggregates using vertical chains as a grouping principle. As mentioned in section 4, our interpretation of productivity developments in, for example, construction may change if the construction sector were to be grouped with construction materials, real estate, and mortgage finance. Other aggregations of the same underlying industry productivity estimates are possible in the Domar framework used in this paper. For example, one could combine industries into aggregates that reflect the cyclicality of final demand (i.e., industries that supply consumer durables, cyclical business equipment, exports, intermediates, and so on), the cyclical sensitivity of productivity, the level of innovative activity, the dependence on suppliers, purchases of IT capital, the competitiveness of markets, the average quality of labor input, the sensitivity to energy prices, and so on. These explorations remain the topic for future work.

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20. ESTIMATES OF INDUSTRY LEVEL MULTIFACTOR PRODUCTIVITY IN AUSTRALIA
Measurement Initiatives and Issues

By Paul Roberts
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Introduction

The ABS has been producing productivity estimates for approximately 20 years. Considerable development work took place during the 1980s leading to the publication of the first estimates of multi-factor productivity (MFP) in 1985. Since then MFP estimates for the market sector have been produced each year and released in conjunction with the annual national accounts.

Over recent years, interest in productivity has increased significantly with particular interest in the productivity performance of individual industries and the performance of the Australian economy relative to other countries. In response to this increased demand, the ABS commenced a project in 2002 aimed at developing industry level estimates of MFP. Estimates were released in a research paper in 2005 (Zheng, 2005) and confirmed that while there were some limitations in the available data, meaningful estimates could be developed.

Following on from that positive finding, the ABS was funded to develop and release annual industry level MFP estimates. A small team has been established to complete this work and investigate a range of other productivity related topics. Other areas in the ABS are also undertaking analysis and compilation associated with productivity.

This paper discusses the current state of work on the measurement of multifactor productivity (MFP) at the industry level for Australia. To a large extent the work has uncovered additional questions and issues and as a result this paper is not conclusive but hopefully can stimulate discussion towards better solutions. It is noted that the estimates presented still in the early stage of development, and as such they are experimental, not official.

As part of the process of estimating industry MFP a reference group was established to assist the ABS in this work. The reference group comprises individuals from government, private enterprise, industry bodies and academia who are both interested in, and experts in, productivity measurement. Part of the work presented here has been presented to the reference group, whose members have been instrumental in taking the ABS's productivity work forward.

The paper discusses the following:

- the methodology and the results of industry MFP estimates for Australia.
- the issues in creating data series for capital and labour.

- the issues in aggregating industry level MFP based on value added.
- the issues of interpretation of industry MFP. One aspect is the need to look at the underlying reasons behind the measured trends in each industry. A case study of the Mining industry is presented as an example.
- future directions in measuring industry level MFP that the ABS is undertaking.

Industry MFP

The ABS has compiled MFP indexes for 12 separate market sector industries. The market sector industries as defined by the ABS are:

- Agriculture, forestry & fishing,
- Mining,
- Manufacturing,
- Electricity, gas & water,
- Construction,
- Wholesale trade,
- Retail trade,
- Accommodation, cafes & restaurants,
- Transport & storage,
- Communication services,
- Finance & insurance, and
- Cultural & recreational services

Methodology

The ABS uses a value added approach to measure industry MFP. That is, for MFP, the changes are measured as the growth in the rates of real value added to the combination of two factor inputs, capital and labour. The industry value added index is a Laspeyres index, which is used because it is consistent with aggregate market sector output and GDP. The industry capital services index is a Tornqvist index based on weighted changes in productive capital stock that are formed from the perpetual inventory method. The labour input is based on data from the Labour Force Survey (LFS), which is a household survey providing hours worked by industry. The aggregate labour and capital indexes are combined using their respective income shares to form an aggregate input index using a Tornqvist methodology. The calculation of MFP is output divided by the combined capital labour input index.

Forming MFP growth cycle estimates by industry

Data are available from 1984–85 to 2004–05. Tables 1 and 2 present annual average growth rates of value added MFP for the market sector industries, and Figure 1 presents the entire MFP series for each industry.

Table 20–1 shows the average annual growth rates of MFP by industry where the years selected correspond to the productivity growth cycles of the market sector. These growth cycles are constructed by forming a long-term trend using an 11-term Henderson moving average with the difference between the original series and the long-term trend used to detect peaks. When comparing average growth rates between peaks, it is important to compare peaks that are assumed to have similar levels of capacity utilisation.

T 20–1 Annual average growth in MFP for the market sector industries, market sector productivity growth cycle (Experimental estimates)

Per cent per year

	1985–86 to 1988–89	1988–89 to 1993–94	1993–94 to 1998–99	1998–99 to 2003–04	1985–86 to 2003–04
Agriculture, forestry & fishing	-0.1	3.9	3.8	3.8	3.2
Mining	2.3	2.4	0.2	-0.5	1.0
Manufacturing	2.2	1.8	0.7	2.2	1.7
Electricity, gas & water	6.2	4.1	2.2	-2.6	2.0
Construction	-1.8	-0.2	2.7	0.9	0.6
Wholesale trade	1.8	-2.4	5.5	1.9	1.6
Retail trade	-2.3	0.9	1.8	1.3	0.7
Accommodation, cafes & restaurants	-3.1	-1.5	1.6	0.8	-0.3
Transport & storage	1.4	1.3	2.1	2.6	1.9
Communication services	5.5	5.6	3.9	-1.0	3.2
Finance & insurance	4.1	1.4	2.3	-0.3	1.6
Cultural & recreational services	-2.3	-0.8	-1.6	1.3	-0.7
Market sector [(a)]	0.7	0.9	2.1	1.0	1.2

[a] Market sector is from 1984-85

One important issue that arises here is that the industries will not necessarily have the same cycles as the market sector, or the same as each other. When constructing trend MFP estimates for the individual industries using an 11 term Henderson moving average the results showed that not one industry had all of the same peaks as the aggregate for the market sector. However, most industries had at least one peak that was the same as the market sector.

Table 20–2 presents industry MFP growth over five year cycles from 1984–85 to 2004–05. The estimates show a mixed story in comparison with table 20–1. This highlights that the growth rates for particular industries are sensitive to the choice of years. While there are minimal differences at the aggregate market sector level, different pictures emerge for a number of industries depending on the choice of year to measure the average growth rate. That is, the choice of start and end year used to determine the growth cycle period affects the growth rate. Agriculture, forestry & fishing and Wholesale trade show two contrasting results, with growth in opposite directions for similar periods in some instances. Another example where a different picture emerges is for Manufacturing, which shows a relatively constant, albeit slower, growth rate in table 20–2 over the different periods. This is a different story from table 20–1, which shows that the Manufacturing industry had a slowdown in MFP growth over the second half of the 1990s.

T 20 – 2 Annual average growth in MFP for the market sector industries, five year cycles (Experimental estimates)
Per cent per year

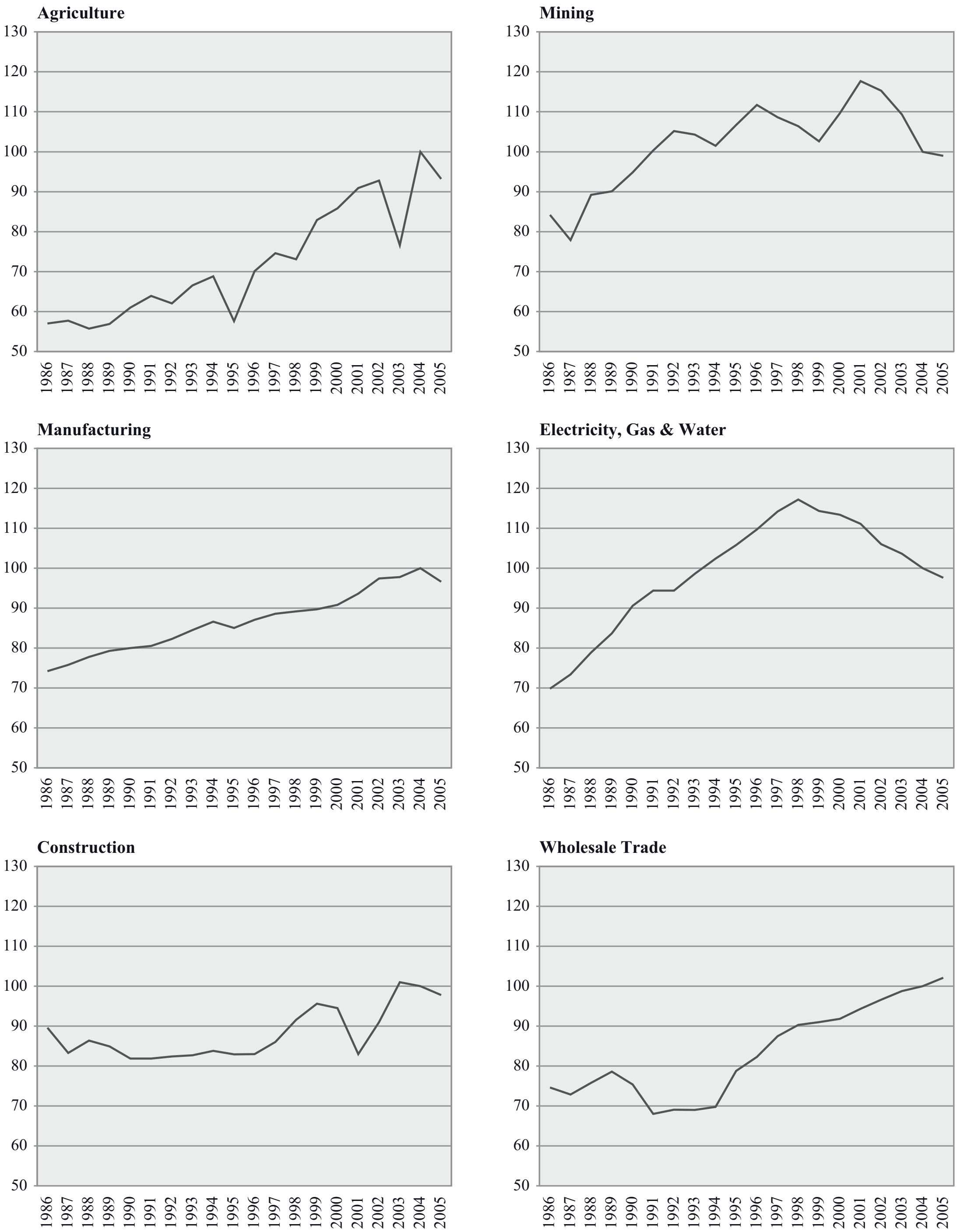
1985–86 to 1988–89	1989–90 to 1994–95	1994–95 to 1999–00	1999–00 to 2004–05	1985–86 to 2004–05
1.7	-1.1	8.3	1.7	2.6
3	2.4	0.5	-2	0.9
1.9	1.2	1.3	1.2	1.4
6.7	3.2	1.4	-3	1.8
-2.2	0.3	2.6	0.7	0.5
0.3	0.9	3.1	2.2	1.7
-1.7	0.5	2.3	0.9	0.6
-2.7	-0.8	0.7	1.2	-0.3
0.7	2.1	2.2	2.4	1.9
5.8	4.5	2.5	0.2	3.1
3.3	2	2	-1.5	1.4
-3	-0.8	-0.5	1.3	-0.6
1	**1**	**2**	**0.6**	**1.1**

Graph 20–1 presents the annual MFP indexes for all the market sector industries. This figure further highlights the disparities in movements and peaks across industries and the difficulty in determining similar productivity cycles.

The next phase of the ABS's research is to analyse in detail the plausibility of the results for each industry. This will involve examining the data series that form the MFP estimates for each industry. For instance, investigations will involve looking at the quality of the current output and sales data, the quality of the output deflators used to get volume estimates. The ABS will also examine the intermediate input structures, the quality of the labour input series, the quality of the capital data, and the quality of the income shares. The following sections highlight the key investigations that have been undertaken to date in understanding the industry MFP estimates.

MFP for the market sector industries (Experimental estimates)
Index 2003–04=100

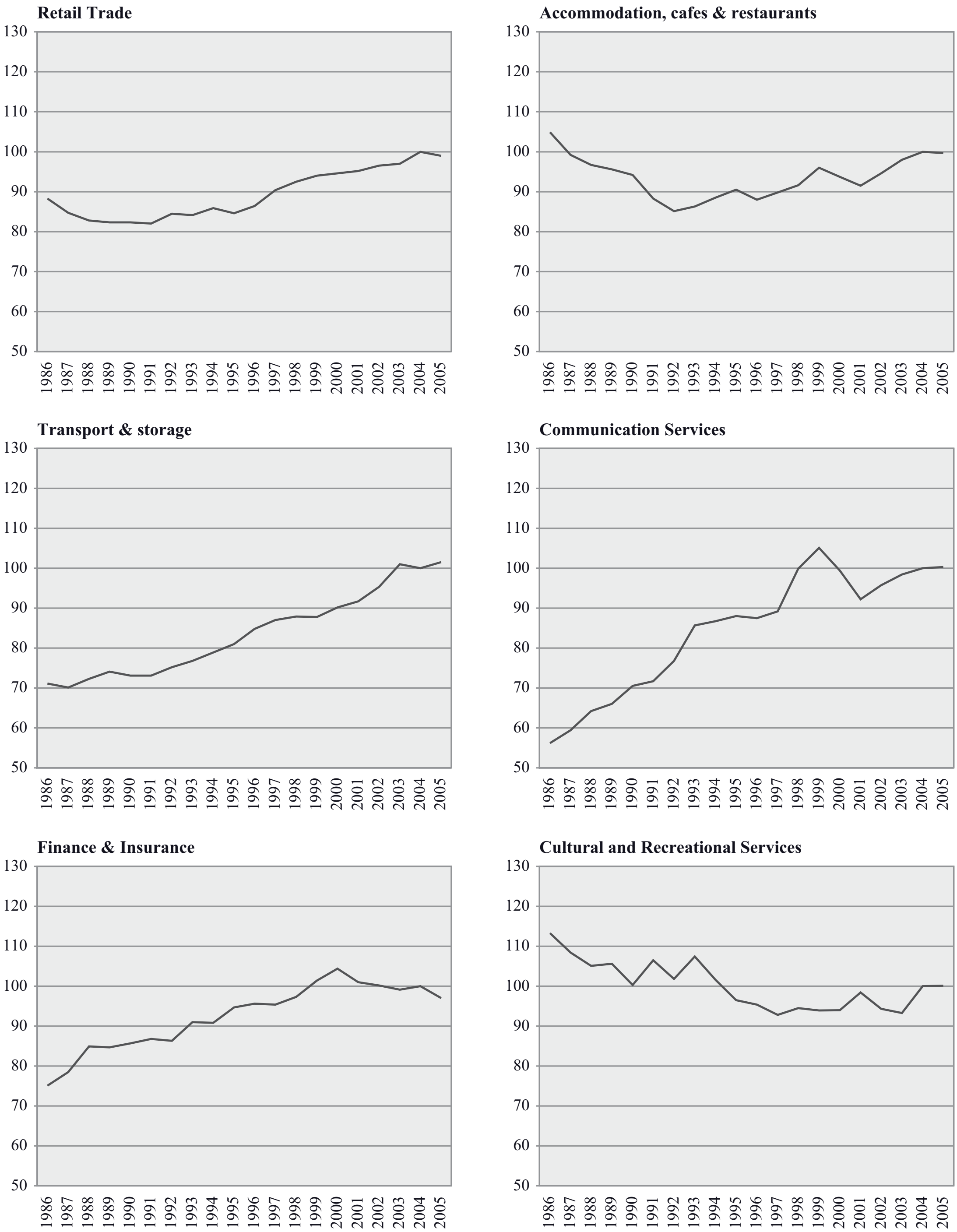
G 20–1–1



MFP for the market sector industries (Experimental estimates)

Index 2003–04=100

G 20–1–2



Measuring capital inputs

Currently the ABS produces industry level capital services indexes and these capital services indexes are used as the capital input for industry level and market sector MFP estimates. The following section describes the issues involved with creating capital services indexes and the implications for industry level MFP estimates. More specifically, the focus is on the user cost of capital equation and the sensitivity of capital services indexes to changes in the rate of return component of the equation. The ABS currently uses a combination of endogenous and exogenous rates of return in the user cost of capital equation.

Capital services are a flow measure based on the productive capacity of capital. The capital services produced by an asset over its life are not usually observed, however, they may be approximated by assuming that capital services are directly proportional to the productive capital value of the asset. This relationship is fixed over the asset's life, but does vary between asset types and even between different vintages of the same asset, since it depends on the expected life of the asset, the discount rate and the rate of decline in the asset's efficiency. Aggregate capital services indexes are created by aggregating different vintages of the same type of asset, and then aggregating different assets using rental prices as weights to form an aggregate index.

These rental prices are analogous with user costs as they represent the price of capital. This is a significant issue in compiling the aggregate index of capital services. Given that rental prices are not observable for all assets, they must be estimated in another manner. The user cost of capital equation is the method used by the ABS to calculate rental prices.

The user cost of capital equation in its most basic form is comprised of three components: depreciation of the asset, a rate of return reflecting financing costs, and a capital gain/loss component. The ABS also includes a corporate income tax component, tax depreciation allowances, investment credits and indirect taxes. The user cost equation is as follows:

$$UC_{ijt} = T_{ijt}(r_{it}.p_{ijt} + d_{ijt}.p_{ijt} - p_{ijt} + p_{ij(t-1)}) + p_{ijt}.x_{it}, \text{ where}$$

i = industry
j = asset type
t = discrete time period
T = income tax parameter
r = rate of return
p = price deflator for new capital goods
d = depreciation rate
x = effective average non-income tax rate on production

The primary focus of ABS's work to date has been on the calculation of the rate of return, r, and its implications for capital services calculations and corresponding industry level MFP estimates.

Rates of Return

Rates of return may be calculated in one of two ways. Firstly, we can use an endogenous rate of return which is represented by the internal rate of return for the industry. Using an endogenous rate of return to calculate user costs of capital imposes some implicit assumptions, namely that the underlying production function exhibits constant returns to scale, that markets are competitive, and that the expected return is the same as the realised return. Also, using an endogenous rate of return imposes the same rate of return for all asset types within an industry. The endogenous rate of return is derived using the Hall and Jorgenson (1967) approach, which equates the capital income to its cost for a particular asset, where the total capital income equals all non-labour income. A practical issue involved in using an endogenous rate of return is that when capital income is small, the associated internal rate of return will be small.

An alternative approach to calculating rates of return is to use an exogenous rate of return such as the interest rate on government bonds. Using an exogenous rate may lead to a difference between the calculated capital rent, defined as the rental prices multiplied by the productive capital stock, and capital income, defined in the national accounts as gross operating surplus (GOS). This difference may be attributed to returns to other assets such as intangibles that would be included in the GOS used to derive endogenous rates of return but these assets are not in the productive capital stock on which the capital rent is calculated. As well, GOS is an ex-post measure of the return to capital. To the extent that expected and realised returns differ, inconsistencies in average rates of return will exist.

Currently the ABS uses a combination of endogenous and exogenous rates of return when creating MFP estimates. To help overcome the problem of a negative user cost, the ABS applies a floor to the rate of return of 4 percent plus the consumer price index (CPI) rate. If the endogenous rate is greater than or equal to this floor then the endogenous rate is used in the user cost equation. However, if the derived endogenous rate is less than the set exogenous rate of 4 percent plus the CPI rate, then the exogenous rate is used. Using this approach no adjustment is made when the endogenous rate is greater than the exogenous rate.

Tables 20–3 and 20–4 show the average rates of return by industry for the three approaches and the deviations from the average exogenous rate of return of the other two approaches. The tables are split into two periods covering roughly the last 40 years, where table 20–3 is from 1964–65 to 1984–85 and table 20–4 is from 1984–85 to 2004–05

The tables show that the average return for each approach can differ substantially for each industry. Most variation occurs between the exogenous rate of return and the endogenous rate of return, as shown by large deviations of the endogenous rate of return from the exogenous rate of return. Also, the average endogenous rate of return is, for the majority of industries, less than the average exogenous rate or return. By definition, the current approach used by the ABS produces average rates of return that are higher than the exogenous rate of return, however, for the majority of industries, the deviations from the exogenous rate of return are not significantly large.

T20–3 Average rates of return and deviations from the exogenous rate of return, by market sector industry, 1964-65 to 1984-85

per cent

	Average rates of return			Deviations from exogenous rate of return	
	Exogenous	Endogenous	Current	Endogenous	Current
Agriculture, forestry & fishing	11.78	7.12	13.29	-4.66	1.51
Mining	11.78	14.99	15.26	3.21	3.48
Manufacturing	11.78	14	15.19	2.22	3.41
Electricity, gas & water	11.78	7.28	11.78	-4.5	0
Construction	11.78	11.81	13.1	0.03	1.32
Wholesale trade	11.78	11	12.43	-0.78	0.66
Retail trade	11.78	10.65	12.23	-1.13	0.45
Accommodation, cafes & restaurants	11.78	7.72	11.78	-4.06	0
Transport & storage	11.78	5.97	11.78	-5.81	0
Communication services	11.78	11.47	12.79	-0.31	1.01
Finance & insurance	11.78	14.99	16.46	3.21	4.68
Cultural & recreational services	11.78	8.9	11.78	-2.88	0

T20–4 Average rates of return and deviations from the exogenous rate of return, by market sector industry, 1984-85 to 2004-05

per cent

	Average rates of return			Deviations from exogenous rate of return	
	Exogenous	Endogenous	Current	Endogenous	Current
Agriculture, forestry & fishing	7.99	1.30	8.39	-6.69	0.40
Mining	7.99	6.42	8.38	-1.58	0.39
Manufacturing	7.99	6.86	8.55	-1.13	0.56
Electricity, gas & water	7.99	3.77	7.99	-4.22	0.00
Construction	7.99	9.63	11.34	1.63	3.35
Wholesale trade	7.99	5.78	8.13	-2.21	0.14
Retail trade	7.99	6.85	8.43	-1.14	0.44
Accommodation, cafes & restaurants	7.99	3.41	8.01	-4.59	0.01
Transport & storage	7.99	1.11	7.99	-6.89	0.00
Communication services	7.99	8.13	8.94	0.14	0.95
Finance & insurance	7.99	8.31	10.50	0.32	2.50
Cultural & recreational services	7.99	1.76	7.99	-6.23	0.00

Another key component of the user cost equation is the choice of price deflator. Currently, the ABS uses specific asset deflators in estimating rental prices but in some cases this has led to negative rental prices for particular assets and in extreme cases in the aggregate. To avoid this issue the current practice is to set any negative rental price to a very small positive number (0.001). By adjusting the negative rental prices in this way the capital stock weights return to 'reasonable' levels and the weights of the remaining assets are also adjusted. As a consequence, the corresponding capital services index also returns to a "reasonable" level. However, the question remains as to how to appropriately deal with negative rental prices.

One alternative approach that might overcome the negative rental prices is to recognise that the user cost equation is an expectations model. However, the ABS's current approach is that the variables are measured ex poste rather than ex ante. Shifting to an ex ante approach and assuming that businesses base their general inflationary expectations on movements in the CPI, then the CPI would be the price deflator (p_{ijt}) in the user cost of capital equation above. For a complete ex ante model the rate of return should be an exogenous rate.

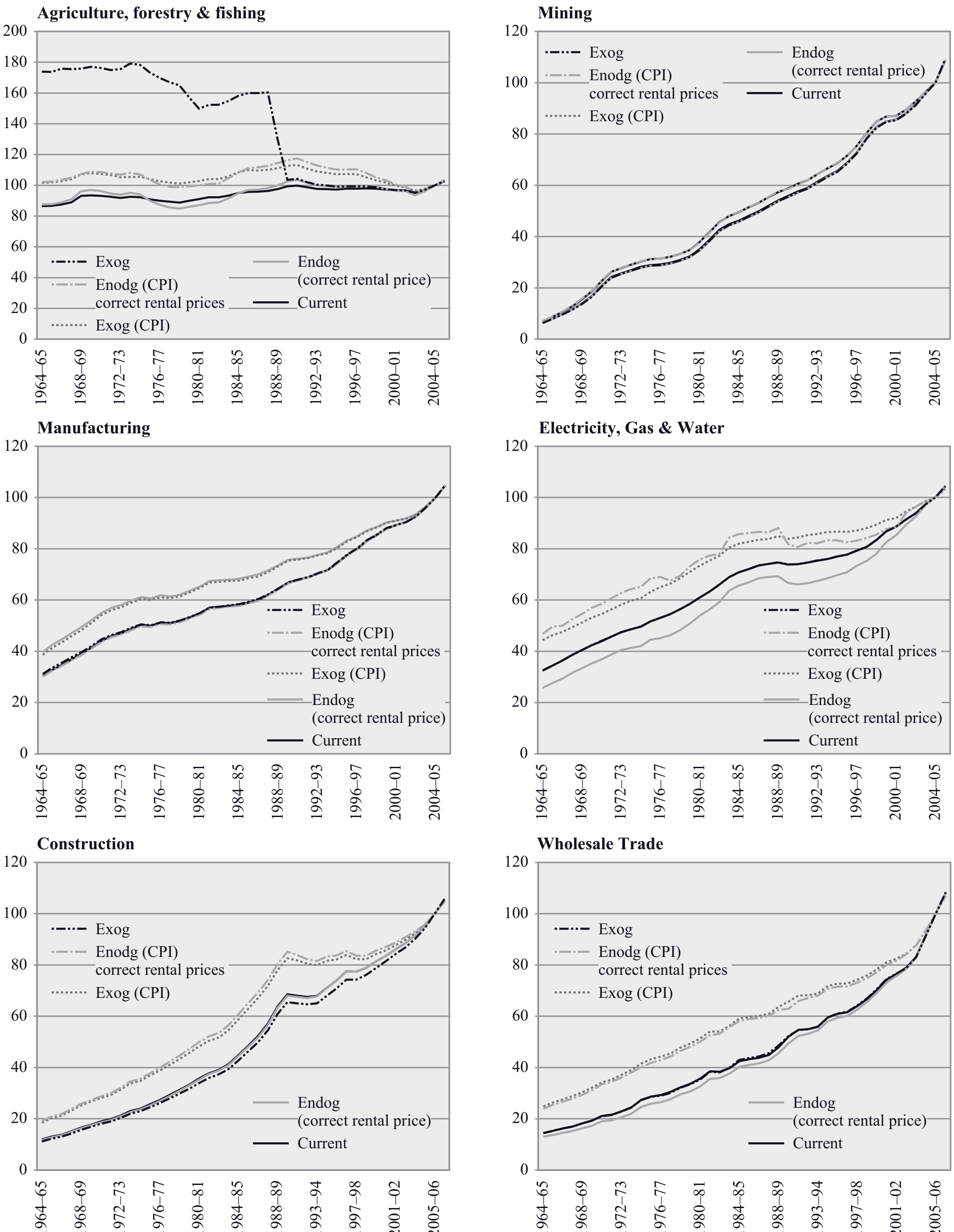
Given the possible combinations of rates of return and price deflators we have tested the following combinations – the results of which are shown in graph 20–2

- Current ABS approach (as defined above);
- Exogenous rate of return with separate asset price deflators;
- Exogenous rate of return with the CPI as the price deflator;
- Endogenous rate of return with separate asset price deflators; and
- Endogenous rate of return with the CPI as the price deflator.

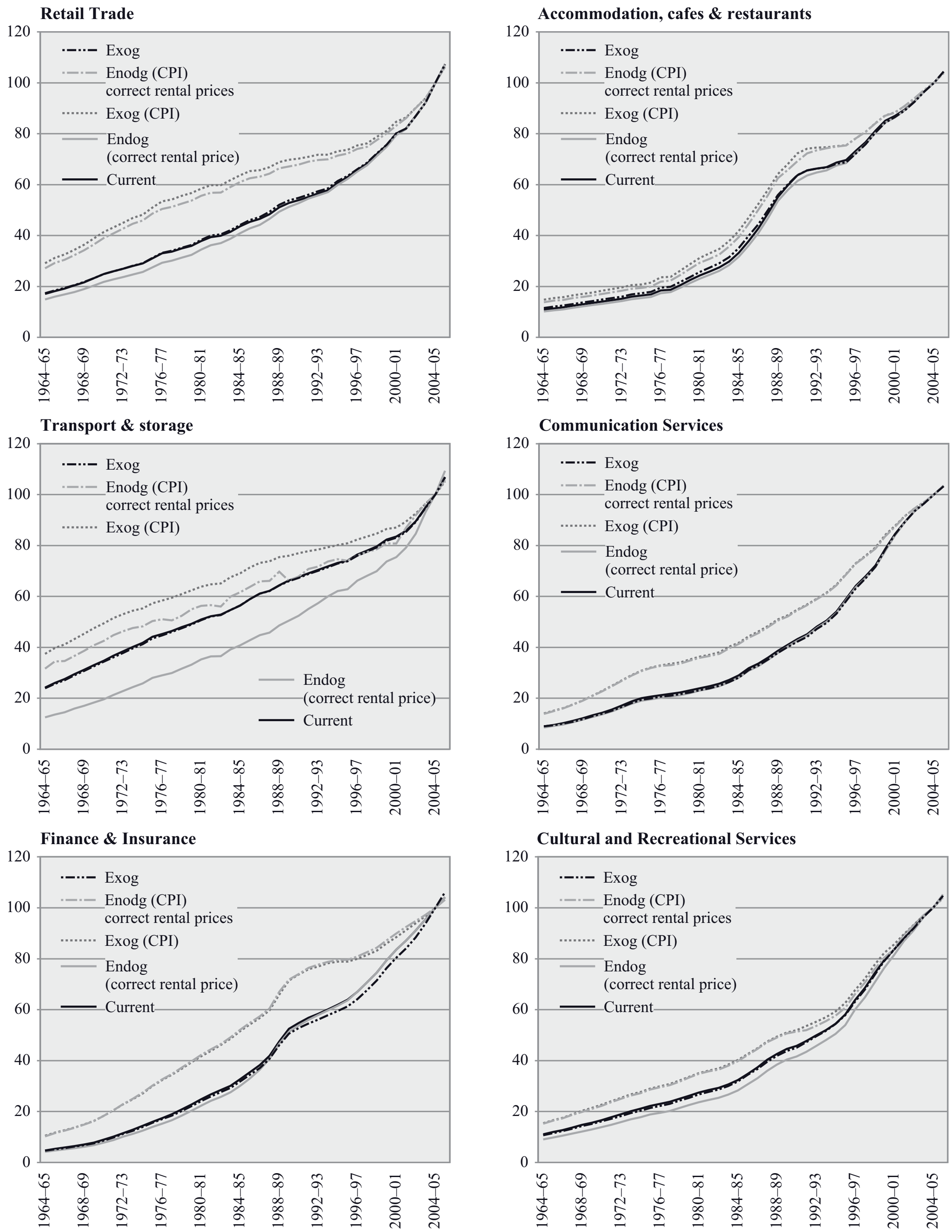
The data show that for Mining and to a lesser degree Manufacturing that the choice of approach has little effect on the capital services index. With the exception of Agriculture, forestry & fishing and Transport & storage, the rest of the industries also show little difference other than when the CPI price deflator is used. For Agriculture, forestry & fishing and Transport & storage the graphs highlight problems with negative rental prices.

In the figure for Agriculture the exogenous capital services curve does not exhibit the same pattern as the other series. The reason behind this is that there is volatility in land prices that leads to a negative rental price for land in a number of years when an exogenous rate of return equal to 4 per cent plus the CPI is used. For Agriculture, forestry & fishing, land contributes significantly to the overall capital stock and has fallen in price over the period. Consequently, the aggregation to total gross rentals (rental price multiplied by productive capital stock) gives a negative value for land and for total assets. This means that the asset weights for all assets other than land become negative. However, land does not contribute to the capital services index as the productive capital stock of land does not change over time. Therefore, it is not the large weights for land themselves that lead to the wayward capital services index such as the one shown in figure 2 but their distorting effect on the weights for other assets. While this effect is shown occurring for exogenous rates it also occurs for endogenous rates but a further adjustment has been made to the rental price.

Capital services for the market sector industries, 1964–65 to 2004–05
Index 2003–04=100 **G 20–2–1**



Capital services for the market sector industries, 1964–65 to 2004–05
Index 2003–04=100 **G 20–2–2**



For the Transport & storage industry negative rental prices occur using an endogenous rate of return whether price deflator is the CPI or an asset price deflator. The negative rental price occurs across a number of assets over various years, with the most common being land and non-dwelling construction. Despite the negative rental prices occurring for both endogenous estimates, the index using the asset price deflators produces a seemingly plausible estimate. Further investigation is aimed at using a mix of asset price deflators and the CPI, with the idea being to form a better ex ante measure of producer's asset inflation expectations, not just for this industry but across all industries.

Table 20–5 shows the growth rates of capital services index for selected time periods based on different rates of return. For the majority of time periods and industries, the growth rates do not differ substantially with the choice of rate of return. However, some differences do exist. For example, for Transport & storage, the growth rate based on an endogenous rate of return is higher than the growth rate based on an exogenous rate of return. This is also reflected in the graph in graph 20–2, where there is evidence of convergence of the indexes from 1990 onwards.

With the exception of the two series within Agriculture, forestry & fishing, and Transport & storage the growth rates of the capital services indices do not differ substantially with the choice of rate of return or the asset price deflator. Thus the subsequent impact on growth rates of MFP estimates should also not differ substantially, assuming every thing else remains constant. However, the use of the CPI appears to show that for the majority of industries growth in the capital services index was slower, which would lead to faster growth in MFP as opposed to using the asset price deflators. While the differences are likely to be small, they still can influence how MFP is interpreted.

T20–5 Annual average growth in capital services index for the market sector industries

per cent per year

	1964–65 to 1994–95		1994–95 to 2004–05		1964–65 to 2004–05	
	Exogenous	Endog-enous	Exogenous	Endog-enous	Exogenous	Endog-enous
Agriculture, forestry & fishing	-1.59	1.01	0.01	0.11	-1.19	0.78
Mining	7.87	7.78	4.11	4.13	6.93	6.87
Manufacturing	2.94	2.96	3.14	3.17	2.99	3.01
Electricity, gas & water	3.02	3.55	2.94	3.78	3.00	3.61
Construction	5.64	5.76	3.50	3.19	5.10	5.12
Wholesale trade	4.74	4.95	4.62	4.89	4.71	4.93
Retail trade	4.45	4.69	5.03	5.03	4.60	4.78
Accommodation, cafes & restaurants	5.40	5.82	4.84	5.18	5.26	5.66
Transport & storage	3.53	5.43	2.84	4.15	3.36	5.11
Communication services	6.29	6.40	6.98	6.91	6.46	6.53
Finance & insurance	8.33	8.54	6.41	5.53	7.85	7.79
Cultural & recreational services	5.86	5.93	7.24	7.60	6.21	6.35

Future Work for Capital Services

The future work on capital services is to undertake further sensitivity analysis on various aspects of capital services measurement. One area is to examine other components of the user cost of capital equation such as the rate of depreciation, and capital gains. Further to this, we will examine how different methods of depreciation, different age-efficiency profiles, and mean asset lives impact on capital services, and the corresponding MFP estimates.

The choice of age efficiency profile impacts capital services estimates through the Perpetual Inventory Method (PIM). Currently, the ABS uses a hyperbolic age efficiency profile in the calculation of capital services. A hyperbolic profile implies that the productive services of an asset decrease slowly at the beginning of the asset's life and then decreases at an increasing rate in later periods. While there is no strong evidence against using a hyperbolic age efficiency profile, investigating alternative profiles may still be beneficial. A geometric age efficiency profile is the most common alternative to a hyperbolic profile. A geometric age efficiency profile implies the efficiency of an asset decreases at a constant rate.

Another area for exploration in the age-efficiency profiles is the efficiency parameters used in the hyperbolic profile equation. The efficiency parameters currently used by the ABS are 0.5 for equipment, software and livestock, 0.75 for construction, 1 for mineral exploration, and 0 for artistic originals. If the hyperbolic age efficiency profile is continued to be used, then further investigation into the efficiency parameters may be warranted. In particular, the sensitivity of MFP estimates to changes in the parameters may be of interest.

The choice of age efficiency profile determines the age price profile of an asset. The choice of age price profile has an impact on the depreciation rate. An age price profile is used to determine the net capital stock, which in turn is used to derive the depreciation rate.

Mean asset lives are an important component in the measurement of capital stock and vary by asset type. Asset lives are influenced by a number of variables including changes in technology, quality changes, and changes in the rate of use. While the ABS has adjusted mean asset lives for some assets as more information has become available, the mean asset lives used currently are based on asset lives from 1996–97 which may not accurately reflect current mean asset lives. For example, in 1996–97, the mean asset life for computers was 4.9 years, which may be too high for the current period. An investigation into the sensitivity of MFP estimates to changes in mean asset lives may be warranted.

One final aspect of capital services estimation to consider is asset life distributions. Asset life distributions are the extent to which assets are retired before, on, or after the mean asset lives. The approach used by the ABS assumes that for most asset types, the lives of assets vary about the mean according to a Winfrey S3 probability distribution – a bell-shaped symmetric function, with about 75 % of assets retiring within 30% of the mean life. While a number of distributions exist, the only other plausible alternatives to the Winfrey S3 pattern are other bell-shaped curves, or delayed linear patterns. It may be beneficial to investigate the impact of various mortality patterns on MFP estimates.

Measuring labour inputs

An important aspect in measuring industry productivity is accurate estimates of hours worked by industry. As part of the ABS's work program to enhance its productivity measures, it is reviewing measures of hours worked by industry. The productivity measures presented in section 2 use hours worked by industry from the Labour Force Survey (LFS). The total hours worked estimates by industry are the product of industry employment and average hours worked per person.

There has been discussion of the quality of the industry employment figures in the Labour Force Survey (LFS), which form part of the hours worked estimate, noting that the concern lies with the accuracy of the industry employment numbers, not total employment which are considered to be of a high quality. The main reason for the concern around the industry employment numbers is that the LFS is not stratified by industry, hence movements in the industry employment numbers can be subject to notable sampling error.

However, using the LFS for industry hours worked does have some strong advantages. Business surveys tend not to record hours worked information. The LFS records full hours worked and employment information for employees and the self employed whilst business surveys tend only to have employment data for employees. Since the self-employed constitute around 15% of the Australian work force and have different patterns of work than employees the availability of hours worked data including the self-employed is a significant benefit of LFS data over business surveys. The LFS also has a consistent uninterrupted time series and if the ABS were to use business surveys a hybrid of two different data sources would be needed.

Business surveys on the other hand, tend to provide more accurate industry allocation due to industry stratification and the linking of industry to a business register. Even where inaccuracies exist since the industry definition is consistent between the employment and data used to measure GDP and capital formation there is a greater likelihood of consistency between the components of the productivity equation.

In this section a new methodology is explained using business survey data from the Survey of Employment and Earnings (SEE) and modelled employment data based on data from the linked Economic Activity Survey (EAS) and Business Income Tax (BIT) dataset. These business survey based estimates are used to estimate total hours worked for the industry, using industry average hours worked from the LFS. These industry hours worked are benchmarked with the total LFS hours worked as it is more reliable at the aggregate level. The hypothesis is that by utilising a more appropriate industry allocation methodology there should be more reliable measures of industry multifactor and labour productivity.

The ABS is also researching estimates of aggregate hours worked, which are derived from average hours worked per person. Currently the ABS uses only the four reference weeks from the LFS in the mid-month of each quarter. A new methodology adopting the Statistics Canada approach of using the full 12 LFS reference weeks is likely to be used in the next annual national accounts. This new approach has little impact on growth rates in hours worked but has significantly changed the level of hours worked which matters in international comparisons.

Alternative methodology

The alternative estimates of industry employment use data from SEE up until 2000–01 and the modelled employment dataset for subsequent years. Total hours worked from the LFS is used as a benchmark and the industry shares from SEE and modelled employment data are applied to this. There are two main methodological issues:

- the business survey based employment data only include employees, therefore the employer and self-employed counts by industry from the LFS are prorated to the employment SEE data.
- there are no data for Agriculture, forestry & fishing, or Finance & insurance in the EAS dataset, and hence LFS data are used for these industries throughout the time series. The shares of total hours worked using SEE and modelled employment data are then applied to the LFS aggregate hours benchmark.

The modelled employment estimates are based on wages and employment data in EAS data set to provide an estimated equation that can impute employee numbers for establishments on the BIT dataset, which contains only wages data.

Comparison of Employment Proportions by Industry

Table 20–6 below is a comparison of employment percentages by industry using different data sources for the start and end points of the time series. The first series is the linked SEE and modelled employment data series. The second series is the LFS. Despite the differences in the methodologies there appear to be no significant differences in industry shares.

T20–6 Employment share by industry for SEE and modelled employment data and LFS for 1985-86 and 2003-04
per cent

	1985–86		2003–04	
	SEE & ModEmp	LFS	SEE & ModEmp	LFS
Agriculture, forestry & fishing	7.8	8.9	6	6.3
Mining	2.1	2.4	1.4	1.6
Manufacturing	24.4	24.5	17.9	18
Electricity, gas & Water	2.9	2.8	1	1.3
Construction	10.1	10.4	12.8	13.3
Wholesale trade	7.5	7.7	8.4	7.5
Retail trade	21.1	19.3	25.7	24.2
Accommodation, cafes & restaurants	6.3	4.7	7.8	7.9
Transport & storage	7.5	7.3	7.5	7.2
Communication services	2.7	3.1	2.3	2.8
Finance & insurance	5.4	6.1	5.5	5.8
Cultural & recreational services	2.3	2.7	3.7	4

Comparison of Growth Rates for Hours Worked

Table 20–7 below is a comparison of annual average growth rates for hours worked from 1985–86 to 1994–95 and 1994–95 to 2003–04 for the linked SEE and modelled employment dataset, and the LFS.

T20–7 Average annual growth rates in hours worked for SEE & modelled employment data and LFS, selected periods

per cent per year

	1985–86 to 1994–95		1994–95 to 2003–04	
	SEE & ModEmp	LFS	SEE & ModEmp	LFS
Agriculture, forestry & fishing	-0.5	-1.0	-1.5	-1.3
Mining	-0.3	-0.4	0.6	1.7
Manufacturing	0.2	0.5	-1.4	-0.6
Electricity, gas & Water	-5.0	-4.6	-4.1	-1.3
Construction	2.9	2.7	2.2	3.2
Wholesale trade	2.1	2.1	1.2	-1.3
Retail trade	1.5	1.9	1.0	1.2
Accommodation, cafes & restaurants	2.9	5.3	0.8	2.2
Transport & storage	1.4	1.1	1.0	1.4
Communication services	0.2	0.7	1.0	1.8
Finance & insurance	1.9	1.0	-0.5	1.2
Cultural & recreational services	5.0	4.3	1.5	2.0

The data in table 20–7 shows that there are some significant differences in the both periods, the most notable being Accommodation, cafes & restaurants. In the first period the other big difference occurs in the Finance & insurance industry. In the latter decade there are larger differences across a range of industries.

Preliminary analysis comparing the effect the two series has on MFP growth shows that MFP using the LFS series as the labour input has slower growth for most industries. The only exceptions are Agriculture, forestry and fishing, Finance & insurance, Transport & storage, which had similar growth rates, and Wholesale trade where MFP using LFS was faster than the SEE / modelled series. Work will continue towards defining the most appropriate measures of labour input by industry.

Aggregation issues

Concurrent with measuring industry level MFP, the ABS will continue to estimate aggregate market sector MFP. This aggregate measure can be estimated directly or by summing the individual MFP estimates, but different results would be obtained. The motivation for this is that if the ABS is to publish industry level MFP estimates then there is the issue of consistency between the current method and any alternative set of results. Compiling the industry level estimates would raise analytical questions as to their contributions to aggregate MFP growth. This section reviews the current methodology, and discusses an alternative methodology.

The focus is on a value added based measure of MFP. An alternative to a value added based measure of MFP is a gross output based measure. That is, where gross output is the ‘output’ variable in the MFP calculation. The gross output measure is not examined here as an alternative in considering an aggregate measure of MFP for three reasons. First, the focus is on issues that relate to value added based MFP because this is what is currently used for the market sector. Any comparisons between gross output and value added based measures may conjure up further issues to consider in the realm of an aggregate MFP measure. Thus, for brevity the focus will remain on value added.

The second issue is that there has been no further work on gross output based measures of MFP by the ABS at this stage. However, this is on the forward work program. Finally, any productivity measure based on gross output only has data available from 1994–95, whereas value added data are available from 1964–65 for the market sector and from 1984–85 for industry data.

Current methodology

The ABS currently publishes productivity estimates for the market sector. The current method that the ABS uses for estimating market sector MFP is commonly termed the 'top-down' approach.

Put simply, the approach involves estimating aggregate indexes for output, capital and labour and then estimating an aggregate MFP estimate. The aggregate index for output involves summing individual volume estimates of value added for market sector industries and constructing an aggregate volume index from this. The aggregate index for labour inputs for the market sector is obtained by deducting estimates of total hours worked for the non-market sector from the 'All industries' estimate of total hours worked.

The aggregate capital services index is calculated using a two stage process. The first stage produces industry level capital services, based on the perpetual inventory method. The second stage involves weighting the industry capital services indexes to form an aggregate capital services index. Industry gross operating surplus shares form the weights and are applied to the industry capital services indexes to form an aggregate Tornqvist.

The aggregate labour and capital indexes are then combined using their respective income shares to form an aggregate input index using a Tornqvist methodology.

The final step is the calculation of MFP, which is output divided by input. One point to note is that the index for output, value added in this instance, for the market sector is a Laspeyres index as opposed to the Tornqvist index used for the inputs. The use of a Laspeyres index makes it consistent with the economy-wide volume measure of output, namely GDP.

Alternative value added methodology

The alternative method for estimating an aggregate measure for MFP involves using industry level estimates of MFP weighted together to form a market sector MFP. This method is commonly termed the 'bottom-up' approach.

One approach is to aggregate each industry's MFP by the industry's current price share of value added, since the current price industry-level value added sums to the market sector value added. However, growth in this form of aggregate MFP will not generally be equal to an aggregate MFP measure based on the 'top down' approach. This is because the top down approach captures changes in the distribution of industry value added and in the industry distribution of capital and labour.

This method of weighting industry MFP means that an aggregate MFP measure is dependent on the distribution of industry value added. Thus, the interpretation for market sector MFP growth would depend on industry productivity growth and on changes in the distribution of value added. To some extent this is Baumol's disease, that is, aggregate MFP growth will be reduced if the value added shares of the low productivity industries are increasing in the economy.

An alternative weight to use is employment, but the issues of distribution remain, but with the focus on industry employment distribution.

Reconciling the two approaches

Methodological differences between the two measures mean that the top down approach captures the changes in the industry distribution of value added, capital and labour. That is, the industry reallocation of all three of these affects aggregate productivity growth. Zheng (2005) in his paper decomposes the top-down approach into (i) the industry-level approach (bottom-up), (ii) the reallocation of value added and (iii) the reallocation of primary inputs. Simply:

Aggregate approach = Industry-approach + contribution of reallocation of
industry value added + contribution of reallocation of industry primary inputs.

Zheng has followed the approach in Jorgenson, Gollop and Fraumeni (1987), which is also discussed in Oulton and O'Mahony (1994).

Overall, there needs to be consideration as to the approach to take, as well as the interpretation of the aggregate MFP measures.

Issues around interpretation

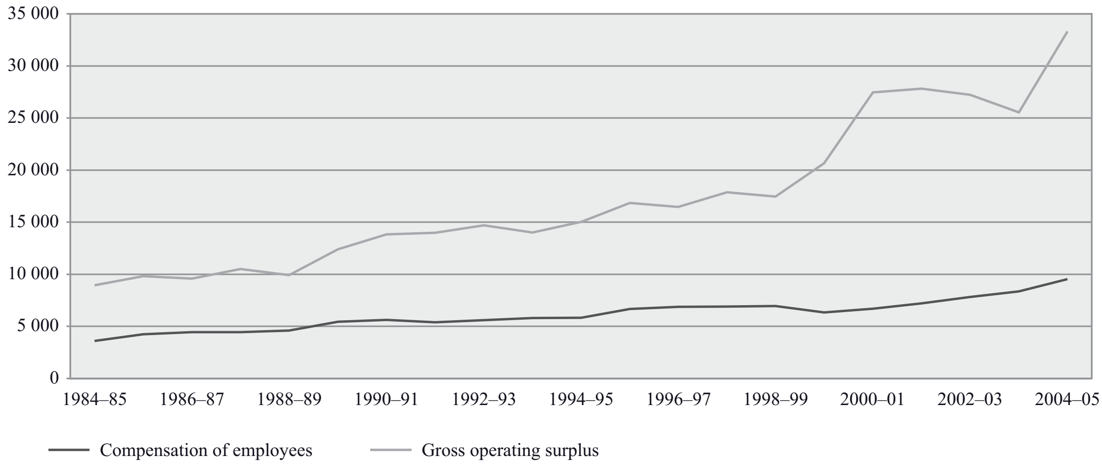
Further to the issues surrounding the data for use in measuring industry level productivity there is the issue of interpreting the results. That is, does the MFP estimate accurately reflect what is really occurring? To do this properly requires in depth investigations of each industry. A brief look at the Mining industry was chosen because of its current high profile in Australia due to the recent resources boom that is occurring.

Mining case study

MFP for the Mining industry grew steadily in the years to 2001, but has subsequently declined (see graph 20–3). However, since 2001 the Mining industry has had significance increases in income. To some extent this is shown in the graph 20–4 in the gross operating surplus series. This increase in income comes from higher prices for exports of Australian resources, which can be seen in Australia's rising terms of trade. These gains in income have raised the question as to why productivity has not followed suit. To answer this question the MFP results need to be deconstructed.

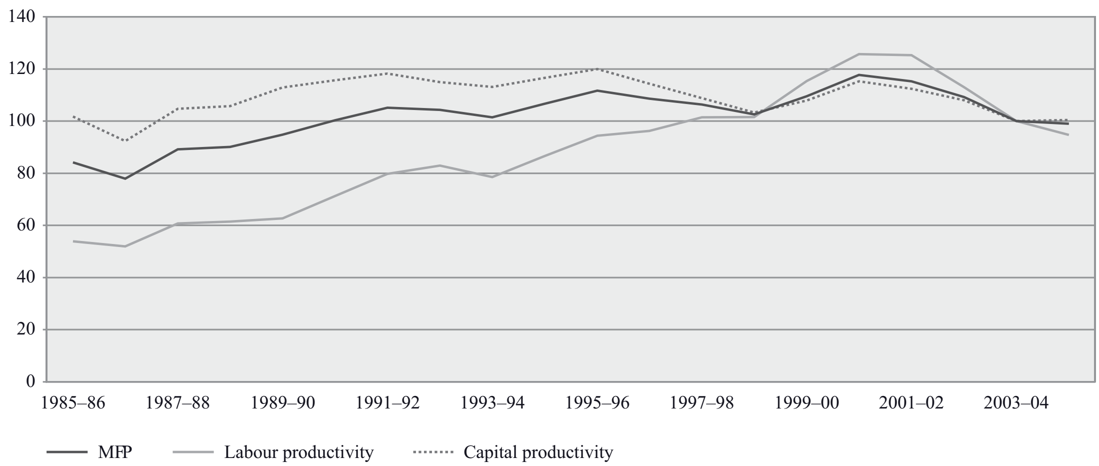
Gross operating surplus and compensation of employees for the Mining industry, 1984–85 to 2004–05
$ million

G 20–4



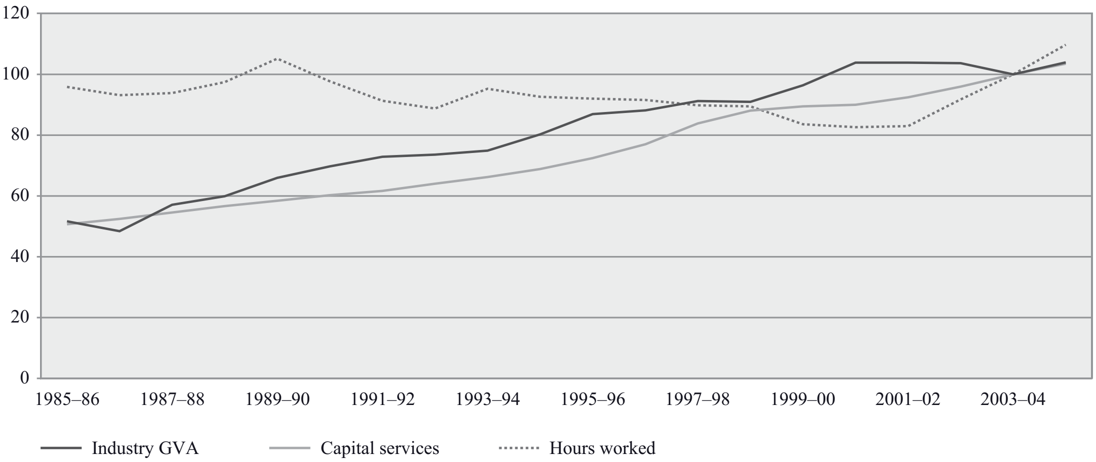
MFP, labour productivity, and capital productivity for the Mining industry, 1985–86 to 2004–05 (Experimental estimates)
Index 2003–04=100

G 20–3



The first component of MFP to examine is output. Graph 20–5 shows that there has been no growth in output since 2000, which means that the decline in MFP has come from increasing growth in inputs. For capital services it appears that there was a slight slowdown in 2000, but it resumed trend growth in the following years. The growth in labour inputs is another possible explanation for the decline in MFP. The data shows labour employment, and hence total hours worked, has increased rapidly over the last few years, increasing by more than 30 per cent since 2001–02. However, the labour share is relatively small compared to capital. Overall, the decline in Mining MFP over recent years is due to a combination of a return to trend growth in capital services, relatively strong growth in labour inputs and no growth in output.

Output, labour and capital inputs for the Mining industry, 1985–86 to 2004–05
Index 2003–04=100 **G 20–5**

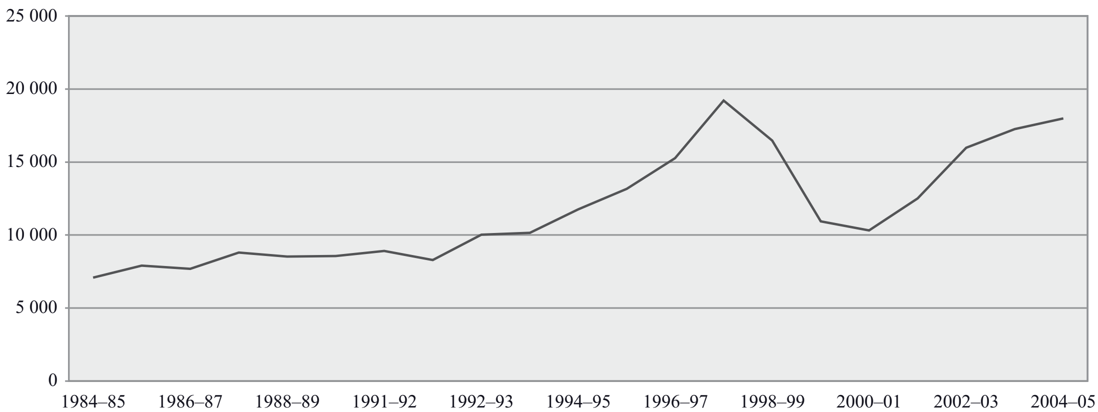


If, as the data shows, that there have been significant increases in income then it would be expected that investment would follow suit to capture these gains. The slowdown in capital services in 2000 was due to a significant fall in investment in 1999–00, but has since rebounded, although in volume terms this rebound seems to have returned the series to a trend growth rate (see graph 20–6).

Even though investment has been increasing in recent years there may be a lag until there is any production as another reason that might explain the slowdown in productivity. That is, gross fixed capital formation is recorded when the expenditure is made, but there may be some time before anything is produced from this investment, which means that inputs are growing but without any growth in output. At present, this matter is not adjusted for in the capital service estimates.

There is some anecdotal evidence that might suggest that MFP in the Mining industry is either declining or its growth is flat. For instance, less efficient mines come online when a resource reaches a particular price. That is, the mine became cost efficient to engage in production. If this is widespread then there is likely to be a compositional effect that reduces productivity for the Mining industry. However, further investigation is required to examine the extent that this is occurring.

Gross fixed capital formation volume for the mining industry
in $ 2003–04 million **G 20–6**



Two final issues to consider when interpreting Mining MFP estimates are the scope of assets and the treatment of mineral exploration. Subsoil assets are not included in the capital services measure for Mining at present and further work in this area is required. The second issue is the treatment of the efficiency decline for mineral exploration. The ABS treatment is such that it is assumed that there is no decline in the efficiency of mineral exploration, that is, the assets efficiency decline is represented as a one-hoss shay. The assumption is that there is no decline in exploration knowledge.

In summing up it appears that there is no necessary reason why Mining MFP should have increased even though incomes have increased. The evidence appears to point to MFP declining or having very little growth. There was no growth in output accompanying the growth in inputs. There is the significant increase in labour inputs, which has come from an increase in employment. While investment volumes have been increasing they have yet to reach the previous high levels in the late 1990s. There is also the possibility that there are lags in new investment becoming productive as a reason why productivity is declining but this requires further investigation to provide information on the extent that this is occurring. Despite not being able to draw any absolute conclusions, the evidence to date appears to show that the MFP results for the Mining industry appear plausible.

Future directions

Future directions for industry MFP measures will be to build on the Mining case study with further industry case studies. Further questions could be asked of the data such as, what is the quality of the current coding of units to these industries on the business register? What is the quality of the current output and sales data for wholesale and retail? What is the quality of the output deflators used to get volume estimates for the industries? What is the quality of the intermediate input structures? What is the quality of the income shares for these industries?

What is the quality of the labour input data for these industries? What is the quality of the capital data for these industries considering in particular the implied return on capital and the current asset mix? Further work will also test the sensitivity of all results.

The ABS is also investigating growth cycle issues. The aim is to try and get a good way of comparing productivity over time. This requires developing appropriate estimates of productivity numbers, and likewise, appropriate methods of determining the productivity cycle. The work will examine the questions of what method is best for determining a productivity cycle (that is, determining peaks in the productivity series); how industries' contribution to the observed productivity cycle differ; and how capacity utilisation may be taken into account when comparing productivity peaks. The immediate concern is reviewing (and explaining the choice of) the current method for estimating growth cycles in the productivity series.

Overall, the ABS's productivity work is progressing well but a significant amount of investigation and testing is still required. Although the work poses challenges and questions core elements of the national accounts data set, the application of a growth accounting framework at the industry level will help to increase the overall coherence and quality of the accounts.

For further information on the ABS' productivity work program contact Paul Roberts on 02 6252 5360 or email paul.roberts@abs.gov.au

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21. SHOPPING WITH FRIENDS GIVE MORE FUN; HOW COMPETITION, INNOVATION AND PRODUCTIVITY RELATE IN DUTCH RETAIL TRADE

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Introduction

This study focuses on the relation between competition, innovation and productivity in the Dutch retail trade. Everyone is very familiar with the retail trade.[299] Sometimes, we do our shopping alone, now and then together with friends. But each of us has frequently or even daily contact with this part of the economy. In fact, the retail trade acts as an intermediate between producers and consumers. The industry is responsible for a considerable part of output and employment of industrialised countries, including the Netherlands. In fact, the share of nominal value added and employment was approximately 4 and 7 percent respectively in 2000 for the Netherlands.

The retail trade is at the forefront of the discussion in an international perspective, since its productivity performance considerably accounts for the difference in productivity growth between EU and US at the aggregated level. The Conference Board states that "… over [a] half of the economy-wide productivity growth lead of the US over Europe after 1995 is accounted for by diverging performance in wholesale and retail trade" (McGuckin et al., 2005).

The Netherlands is not an exception within the EU. According to several sources the labour productivity level and productivity growth in the Dutch retail trade was not outstanding in international perspective in the 1990s (McKinsey 1997, OECD 2004). Although, the Dutch labour productivity per hour worked is above the EU-average, it is much lower than in the US as it could not keep track with the strong productivity growth of the US retail trade after 1995. Also in a longer perspective the Dutch productivity growth performance in this industry is less favourable than for the EU as a whole.

According to The Conference Board, slow adoption of new technologies and differences in legislation may explain the lag of the EU retail trade. This corresponds with earlier findings for the Dutch retail trade of McKinsey in 1997 (McKinsey, 1997) indicating that both aspects are characteristic for the meagre performance of this sector.

The productivity performance of the retail trade might be reason for policy concern. In the 1990s Dutch policy took various measures to enhance competitive forces in product and

299 We define the retail trade according to the SIC 52-code, this includes industries like supermarkets, department stores, electronic appliances, and so on. This does not include trade in motor vehicles, motorcycles and petrol.

labour markets. These considerations and developments give rise to the following research questions:

- Did competition in the Dutch retail trade change during the 1990s and early 2000s, and what are the main drivers of these changes?
- Did competition affect innovation intensity in this industry?
- Did competition and innovation affect labour productivity (growth) in this industry?

The issues are relevant for two respective reasons. First, recent literature points out that the relation between competition and innovation is ambiguous, as it may follow an inverted U-shape (see Aghion et al., 2002). Second, a positive impact of policy measures on competition may be counteracted by negative effects from other determinants, such as the strong economic growth in the 1990s (see Creusen et al., 2006a).

Using firm-level data for the Dutch retail trade covering the period 1993–2002, we analyse competition, innovation and productivity over time, and analyse their mutual relationship. To our knowledge current studies have only considered separate parts of this three-way relationship. Due to data availability at the time of research, the period at issue in this study is before the current price war in the supermarkets, which started in 2003. We therefore do not go into causes and implications of this recent development.

The structure of this study is as follows. In the next chapter we discuss the characteristics of the Dutch retail trade with a focus on productivity performance in an international and national perspective, and on regulatory reforms. The third chapter explores the available data and introduces several key variables. The fourth chapter provides several theoretical considerations and it presents empirical findings on the relations between competition, innovation and productivity. The final chapter ends with concluding remarks.

The Dutch retail trade

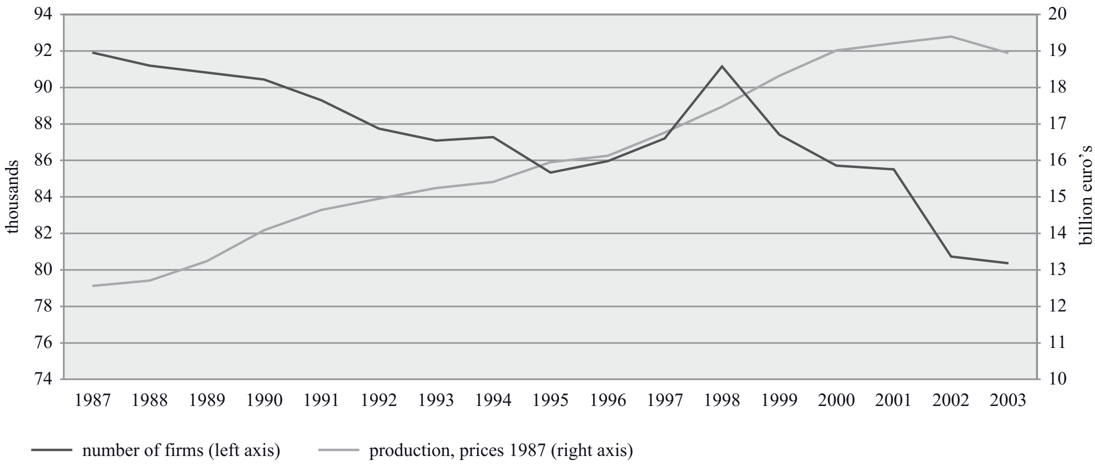
Characteristics of Dutch retail trade

The retail trade is an industry which is continuously transforming and in most countries it is still in the midst of a process of structural change. Beginning at the end of the 1950s with the appearance of the self-service shops and supermarkets, the retail trade has undergone a tremendous metamorphosis. Recent major trends that can be distinguished include larger outlets, consolidation into retail chains, spreading of hypermarkets and increased vertical integration.

Graph 21–1 summarises these developments in terms of the number of firms and output levels, pointing at larger firms. Despite the considerable pickup from 1996 to 1998 the number of firms decreased dramatically over time, whereas the output of the Dutch retail trade improved considerably.[300] Note that this temporary pickup partly matches with the

[300] Although the number of shops also declined over time, this reduction was smaller indicating that the shops per firm increased due to consolidation.

Lower number of firms and increased output in Dutch retail trade, 1987–2003 **G 21–1**



Sources: number of enterprises: Statistics Netherlands, Statline,
Historie economische demografie production in prices of 1987: Statistics Netherlands, National Accounts.

upturn in the business cycle at that time, but it also corresponds to the introduction of the longer opening hours in 1996. This pattern is less visible in the output of the industry.

Three major forces play an important role in this ongoing transformation of the (Dutch) retail trade; (1) consumers, (2) the government and (3) retailers themselves. First, the shopping behaviour of consumers is continuously changing. These changes are to a great extent determined by factors such as increases in income, higher participation rates of women on the labour market and greater mobility (including an increase in car-ownership).

The second important force in the transformation is the role of the government. As we will discuss more extensively, legislation has shaped the structure of the Dutch retail trade for decades. A number of regulatory reforms may have affected competition in the retail trade as well.

Finally, retailers are continuously transforming their business concepts. Partially, this is a response to changing consumer behaviour and legislation. For example, supermarkets introduced more ready-to-eat meals to accommodate consumers' shortage of time and large shopping centres appear at several designated locations at the periphery of towns. But firms in retail trade may take various actions to reduce cost and enhance their competitive advantage. On the one hand, economies of scale can be pursued via larger outlets and consolidation into retail chains. On the other hand, economies of scope can be pursued via horizontal integration. For example, stores specialised in household appliances now sell also DVD-players and computers. In addition, technological developments, especially in the area of ICT, have altered logistic operations in the retail trade. For example, stock control is continuously optimised with the use of scanner data.

These three transformations may have altered the type of competition in the Dutch retail trade. Price levels in combination with product quality remain the main instrument of competition as is demonstrated by the recent 'price-war' between supermarkets. However, also the store itself and the (differentiation in) assortment offered are instruments of competition. Moreover, this also incorporates increasing competition between initially different markets such as on the one hand supermarkets with their ready-to-eat meals or DVD-players and on the other hand (fast-food) restaurants and retail sale of electrical equipment respectively. To put it differently, a bundle of products have become closer substitutes over time.

Productivity performance of the Dutch retail trade

An international perspective

Reports of the OECD (2004) and McKinsey (1997) refer the under average performance of the Dutch retail trade. According to McKinsey, the Dutch retail trade is a sector characterised by lack of competition and lack of incentives to create and seek jobs, inflexible work and compensation legislation, limited opening hours (in spite of deregulation in 1996), restrictive zoning laws and slow innovation.

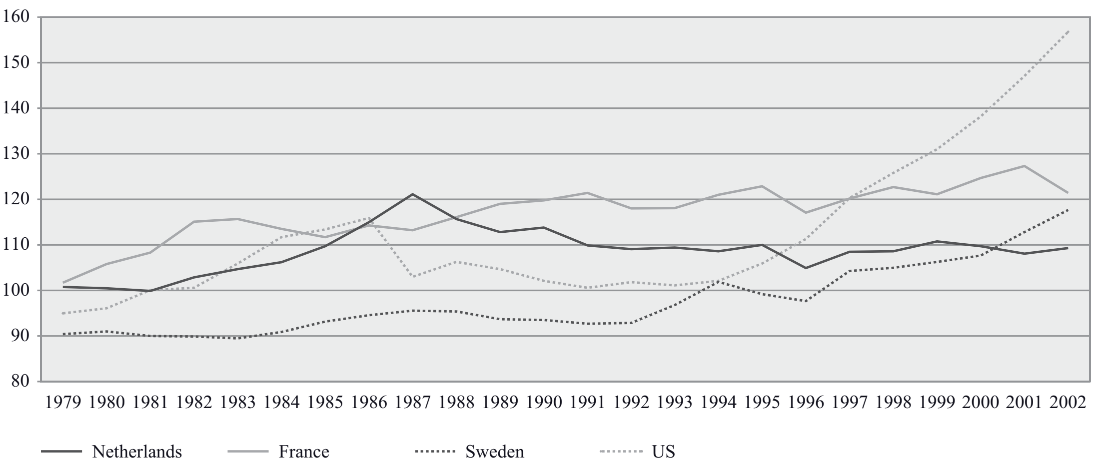
Graph 21–2 displays labour productivity per hours worked for several countries relative to the EU-average (EU=100).[301, 302] Since 1995 the US labour productivity growth accelerated compared to the EU, and the US productivity level quickly caught up and surpassed the Dutch and French retail trade. The labour productivity in Sweden was initially below the EU average, and could neither keep track with the strong US growth pattern. However, it did catch up with the Netherlands around 2000 and is heading towards France with a growth pattern in-line with the US. Still, the differences between the EU-countries and the US in 2002 demonstrate that the productivity gap has become substantial, and that EU-countries may have a considerable catch-up bonus to collect.

Focussing on the Netherlands, we see that until 1987 the Dutch retail trade demonstrated a stronger growth pattern than the EU. But after that the lead in productivity compared to the EU gradually declined and levelled off just above the EU-average. Further, between 1987 and 1995 the Dutch retail trade had a somewhat higher productivity level than the US retail trade. Like other EU-countries, the Dutch retail trade could not follow the steep productivity growth of the US since 1996.

301 Measurement issues often hamper a productivity analysis, especially in services sectors like the retail trade. Difficulties in measuring output, quality and labour input in terms of hours hinder to gauge the efficiency in these industries.

302 Productivity is a key indicator for the efficiency of a particular firm, industry or for the economy at large. Productivity can be expressed in terms of labour productivity or in terms of total factor productivity (TFP). Labour productivity is a partial productivity concept relating only output to labour. TFP is defined as labour productivity adjusted for (changes in) capital intensity and use of economies of scale within the same technology. TFP growth merely reflects the productivity changes due to reduced X-inefficiency or adaptation of new technologies, but this productivity concept is hard to measure.

Labour productivity (per hours worked) relative to EU-average. 1979–2002 **G 21–2**
base year=2000, EU-15=100.



Source: Groningen Growth and Development Centre, 60-Industry Database, February 2005, Rijksuniversiteit Groningen, http://www.ggdc.net

The Conference Board attributes the lag in productivity growth of EU-retailers to US retailers to five determinants (see McGuckin et al., 2005). These determinants are (1) the head-start US of retail trade in the adoption of new (ICT) technologies, (2) the regulatory obstacles within and between EU-countries, (3) the scale advantage of the US retail trade,[303] (4) the slower complementary changes in the EU,[304] and (5) culture and taste differences across Europe.

Gordon also emphasizes the impediments in some EU-countries to develop "big box" retail formats (see Gordon, 2004). Following Phelps (2003), Gordon also points to Europe's underdevelopment of capitalists' institutions like venture capital, the overdevelopment of corporatist institutions such as employee participation in management and business licensing, social cultural differences and different view on environmental planning.

With regard to the number of outlets per 10,000 inhabitants the Dutch retail trade has fewer outlets than the EU-average (see table 21–1). The Netherlands are however characterised by a high population density. This may enable retailers to obtain economies of scale via larger outlets as they can serve a large group of consumers from one location. The size of the enterprises in terms of employees is above the EU-average. The latter effect is mainly due to the high Dutch part-time factor. Recent Dutch figures from Statistics Netherlands show that in 2000 the average firm in the retail trade employs about 5.7 full-time equivalents.

303 The Conference Board indicates the reduced opportunity of cross-border scale in the EU as a factor for lower productivity levels compared to the US. Our study purely focuses on the Dutch market itself and it indicates that the retail trade is characterised by constant returns to scale for larger firms (see chapter 4).

304 I.e. regulatory changes in industries related (complementary) to the retail trade, for example, transportation.

T 21 – 1 Key figures on efficiency levels of the retail trade, 2000

	Labour productivity [a, b]	Outlet density [c]	Employees per enterprise
Netherlands	110	54	8.5
Belgium	106	80	3.5
Germany	105	35	9.0
France	125	64	4.2
United Kingdom	83	36	14.2
Sweden	108	65	4.3
European Union	100	71	6.3
United States	138	.	.

[a] Value added per hours worked, EU = 100.
[b] Source: RUG (2004), GGDC, 60-Industry database.
[c] Outlet density is defined as number of enterprises per 10,000 inhabitants.
Source: OECD (2004).

A national perspective

In addition to the international comparison we provide in table 21–2 figures on the performance of the Dutch retail trade compared to other industries in the Netherlands. In terms of value added (prices of 1995) the share of the retail trade remains quite stable at just over 4 per cent in the 1990s, whereas other Dutch services industries experienced a rise of their share in the Dutch economy.

T 21 – 2 Dutch retail trade in a national perspective, 1990-2002

	Share in economy			Labour productivity in hours	
	1990	2000	1991–2000	1991–1996	1997–2002
	% of total value in prices 1995			Annual growth rates in %	
Total economy	100.0	100.0	1.2	0.9	1.2
Market sector	69.0	73.0	1.5	1.0	1.8
Manufacturing	18.0	16.9	2.9	3.0	2.1
Services	46.7	53.2	1.1	0.4	1.7
Retail trade	4.1	4.1	1.2	0.4	1.7

Source: Statistics Netherlands, National Account data 2003.

The figures on the labour productivity growth reveal that the growth rates of the retail trade are lower than the growth rates of the market sector. However they are similar to the values for services as a whole. Moreover, linked to the upturn in the business cycle growth over the period 1997–2002 has improved for the Dutch retail trade.

The relatively meagre productivity growth in the retail trade, particularly between 1991 and 1996, may point to other factors besides the decline in economic growth. Studies of the

OECD (2002) and Van der Wiel (2001) indicate that the poor growth performance in this period might be caused by the relatively low use of ICT technology when compared to other countries.

Regulatory changes in Dutch retail trade

During the 1990s several regulations have changed the institutional setting of the Dutch retail trade. This might have had an effect on the intensity of competition. We will first briefly discuss some general changes followed by a discussion on several regulations specific for the Dutch retail trade.

Main regulatory changes

Most OECD-countries have shifted their attitude from tight government control to a confidence in market mechanisms and incentives to enhance welfare in the 1990s (see Gonenc et al., 2000). In this regard, the new Competition Act of 1998 in conjunction with the founding of the Dutch Competition Authority (NMa) is of importance as it may have affected the intensity of competition in the Dutch retail trade henceforth. Following practices in other European countries, the new Competition Act explicitly prohibits abuse of dominant positions and cartels, except for several exemptions such as franchising, purchasing combinations or cooperation in technical research.[305] In addition, the NMa monitors mergers and take-overs in markets.

Specific regulatory changes

A wide range of regulatory restrictions affects the scope of the Dutch retail trade, including regulations related to health and safety of employees, urban planning and other environmental issues. Besides overall regulatory reforms, the Dutch government deployed specific reforms as part of a larger operation called the MDW (Competition, Deregulation, Legislation quality).

Three specific regulatory changes within the MDW-operation are directly related to the retail trade: (1) the liberalisation of opening hours, (2) PDV/GDV policy (policy on peripheral and large-scale retail outlets), and (3) the business licensing requirements or establishment law.

The liberalisation of opening hours is the most important MDW-operation concerning the retail trade. Until June 1996, Dutch retailers were not allowed to be open on evenings and on Sundays. The new regulation allows retailers to be open from 6 AM to 10 PM. Moreover, shops may be open 12 times a year on Sundays and public holidays (these days are assigned by municipalities). Under some conditions, retailers are allowed to be open after 10 PM and on more than 12 Sundays a year (for example in tourist regions).

Concerning the PDV/GDV policy the Netherlands apply a specific zoning planning policy similar to other European countries. That is, the freedom of establishment is restricted by

305 The previous system was more permissive and allowed, for example, cartels unless they caused needless welfare costs.

local and urban planning laws, particularly for the retail trade. Since 1973, the Netherlands has pursued a specific policy regarding the establishment of large retailing formats. In essence, the aim of the policy is twofold, i.e. to maintain the function of shops in the inner city or centre of a town, and to strengthen competitive forces in this industry. As a result of this policy, it was hardly allowed to establish a retail enterprise on the outskirts of a town.[306] This limits market entry and protects shops in town centres. During the 1990s this zoning and planning policy (in Dutch GDV/PDV-policy) has slightly been changed by extending the allowance of establishments on thirteen municipal junctions. More precisely, any type of retail firm is allowed to establish in these locations. Further, the zoning policy for the retail trade is decentralised to municipal and provincial authorities.

Finally, up to 1996, the conditions for entrepreneurs to start a new enterprise are constitutionalised in the 'Vestigingswet Bedrijven 1954' (Act on Business licensing requirements). This act protected consumers against non-capable entrepreneurs in terms of reliability, creditability and competencies. The law also protected incumbents against new competitors by evoking entry barriers. In 1996, the Dutch Act has been liberalised. In general entrepreneurs in the Dutch retail trade only have to fulfil general conditions on entrepreneurs' requirements nowadays. Particularly, the regulations for new retailers became more favourable as the main aim of the deregulation was to enlarge market dynamics by simplifying entry.[307]

Data and descriptive statistics

Data

Three sources of information, all obtained from Statistics Netherlands, are used to provide a overview of the development of competition, innovation and productivity, and the interactions between these three variables. We use firm-level data from the production statistics (PS, in Dutch "Productiestatistieken"), the General Firm Register (ABR, in Dutch: "Algemeen BedrijfsRegister") as well as data from the Community Innovation Survey (CIS),

Production Statistics

The PS-data provide a complete coverage of firms with at least 20 employees. Firms with fewer than 20 employees are sampled. The accounting data in the PS include, among other variables, the following key variables: total sales[308], employment in full time equivalents and in persons, intermediate inputs[309], wages (including social security charges), and depreciation costs.

306 Only certain types of retail were allowed. These are retailing in dangerous or voluminous products (e.g., fuel, cars and caravans), large scaled furniture retail trade, and builder's merchant.

307 In fact, in 1993 the government already allowed firms to enter the market under these less restrictive rules.

308 I.e. the value added by trade activities, calculated as the gross sales of traded goods minus the purchasing costs of traded goods.

309 Excluding purchasing costs of traded goods.

The PS-data cover the period 1993–2002 and contain information on five per cent of the total population of firms in the Dutch retail trade. Table 21–3 presents some statistics based on these PS-data. Comparing the firms in the PS-dataset with the population, we see that the PS contain on average firms with more employees and slightly higher productivity levels than the average of the total population.[310]

General Firm Register

Information on the number of firms active in the retail trade is derived from the ABR data set. This set contains information for each firm on its SIC-code, its date of birth and its date of death (if relevant). From these figures we can determine the total number of firms in the retail sector, as well as the entry and exit rate.[311]

CIS

We further employ three consecutive waves of the CIS, i.e. the CIS 2, CIS 2.5 and CIS 3 survey. These surveys cover, respectively, the periods 1994–1996, 1996–1998 and 1998–2000. The CIS provides firm-level data and consists of a sample of firms, which is smaller than the sample of the PS. Furthermore, the sample covers only firms with 5 or more employees. Consequently, this censoring omits a substantial part of small-sized firms. In particular, a large fraction of just started new firms are not included, even though these firms may be very important sources of innovation.[312]

Statistics Netherlands collects the CIS-data every two years, but the survey spans a three year period. Several variables in this survey provide information on the total three year survey period. Due to this construction of the survey, variables cover information in overlapping years as the survey is conducted each two years. However, our variables of interest are only available for the last (third) year of each wave of the survey. This implies that the information on innovation is discontinuous and that this will hamper the analysis of taking account of dynamic effects.

Merging of datasets reduces coverage

To make assertions on the relationship between competition, innovation, and productivity we merge the PS-data and CIS-data into one data set. This merging, however, reduces the number of observations.[313] In total the merged data set covers yearly 0.5 per cent of the total

310 To obtain estimates of the inputs and sales at an aggregated level such as an industry, sampled firms are multiplied with a raising factor. This factor is a ratio of the number of sampled firms to the total of firms in the same stratum of the population. This raising factor is provided by Statistics Netherlands.

311 I.e. the number of firms that entered and/or exited during some year as a percentage of the total number of firms at the beginning of that year.

312 Although the sample is continuously updated with young firms, those firms will pop up with a certain delay.

313 This loss of information arises due to sampling of firms. Only firms present in both sets can be used for our analysis.

T21 – 3 Characteristics of PS-data, PS-CIS-data compared to total population, 1996 and 2000 [(a)]

	Survey-PS	PS-CIS	Population
2000			
Average firms size in full time equivalents	48.4	300.9	5.5
		x 1000	
Number of firms	3.9	0.3	85.7
Labour productivity per full-time equivalent	32.5	34.6	30.4
1996			
Average firms size in full time equivalents	46.0	180.7	5.1
		x 1000	
Number of firms	4.0	0.4	86.0
Labour productivity per full-time equivalent	31.7	30.5	26.8

(a) Survey PS are data derived from the PS, PS-CIS are matched data from PS and CIS, Population data are derived form Statline Statistics Netherlands.

population. Yet, more than 1000 observations remain for the analysis. The low coverage of firms in the CIS-dataset could underestimate the importance of innovation in the retail trade. In table 21–3 we provide several statistics which reveal that, when compared to the population or the PS-data, this merged set consists of very large firms. However, their productivity levels are in line with those of the PS-data.

Seen from an international perspective the number of observable firms is still large. Additionally, an international comparison of innovation activities is unfortunately not possible for the retail trade, as this sector is frequently missing in CIS-data for other countries. Despite both shortcomings, CIS-data remain imperative for assessing the role of innovation and the interaction between competition, innovation and productivity.

Descriptive statistics competition, innovation and productivity

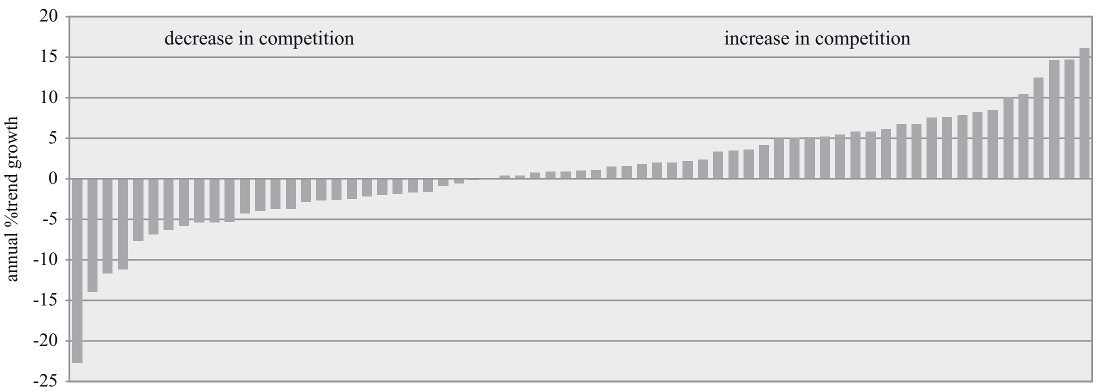
The (merged) datasets discussed above provide several indicators on the extent of competition and innovation in the Dutch retail trade. In this section we present two indicators, together with the average productivity growth of the Dutch retail trade derived from the Production Statistics. These indicators will be used to determine the relations between competition, innovation and productivity growth in the next chapter.

Competition 1993–2002

In this study, the developments in competition are mapped by the relative profits measure (RPM, see Boone, 2000). The RPM is a measure on the performance of firms, and rests on the assumption that firms in an industry mutually differ in their marginal costs. Fiercer competition can be observed by a steeper slope of the relation between firms' relative profits and relative levels of productivity. In fact, rising competition induces firms to exploit their efficiency advantage as much as possible. Then, efficient firms are more rewarded and attain relatively higher profits at the expense of less efficient firms. The RPM signals this as an increase in competition.[314]

We calculate the RPM for each industry in the Dutch retail trade at the SIC 5-digit level by using the PS-data. Graph 21–3 ranks all industries within the Dutch retail trade according to their trend growth. The figure reveals that the changes in competition are rather heterogeneous. About 40% of these industries demonstrate a decline in competition, and the other 60% an increase. In addition, changes in the intensity of competition are of a different magnitude. Note also that in graph 21–3 the industries have different sizes, and vary for example from small cheese stores to large supermarkets.

Changes in RPM across SIC 5-digit industries within the Dutch retail trade, 1993–2002 G 21–3

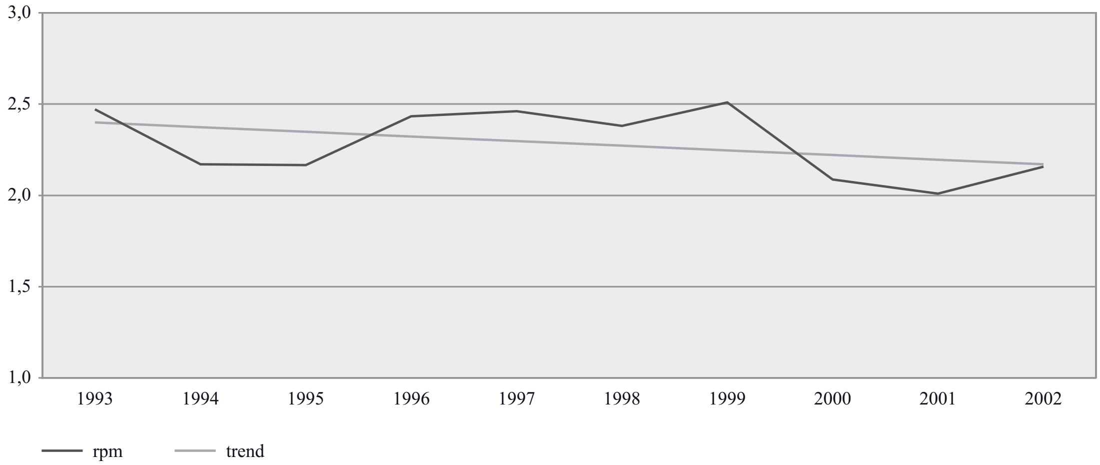


To obtain an indication of competition development for the *whole* retail trade, we aggregate the RPM of all industries, each weighed by its industry's market share in the total sales of the Dutch retail trade.

Graph 21–4 presents the average RPM and its trend for the period 1993–2002. As can be seen, competition is not constant over time. Overall, the trend of the average RPM suggests that competition in the retail trade demonstrated a small decline over the whole period. Moreover, the level of competition appears to be relatively low compared to other Dutch industries (see Creusen et al., 2006a)

314 Literature provides other competition indicators like the traditional price-cost margin (PCM). The PCM denotes firms' ability to set prices above marginal costs. In this study we focus on the RPM. Results using the PCM can be found in Creusen et al., 2006b. These are largely similar as the one in this study.

Competition development according to the RPM of Dutch retail trade, 1993–2002 **G 21–4**



Innovation 1994–2000

Table 21–4 presents some key statistics on innovation.[315] It points out that the number of firms with innovation expenditures is relatively low in the retail trade. Only a sixth to a third of the firms indicated to invest in innovations. The average innovation expenditure for *all firms* in the sample demonstrates an increase between CIS 2 and CIS 2.5, but remains stable between CIS 2.5 and CIS 3. In contrast, the average innovation expenditure for the *innovating firms* increased during the three consecutive periods.

T 21 – 4 Statistics on innovation CIS 2, 2.5 and 3

	CIS 2	CIS 2.5	CIS 3
Number of firms in sample	425	447	275
		%	
Share of innovating firms	24	31	15
		× 1000 euro	
Average innovation expenditures for all firms in sample	122	190	196
Average innovation expenditures for innovating firms	507	608	1350

Source: own calculations based on CIS data.

315 Note, these aggregated firm-level statistics may differ from the total population due to sampling of firms and the merging of the CIS and PS data, as discussed in Section before

Box 21-1 Innovations in retail trade mostly on processing

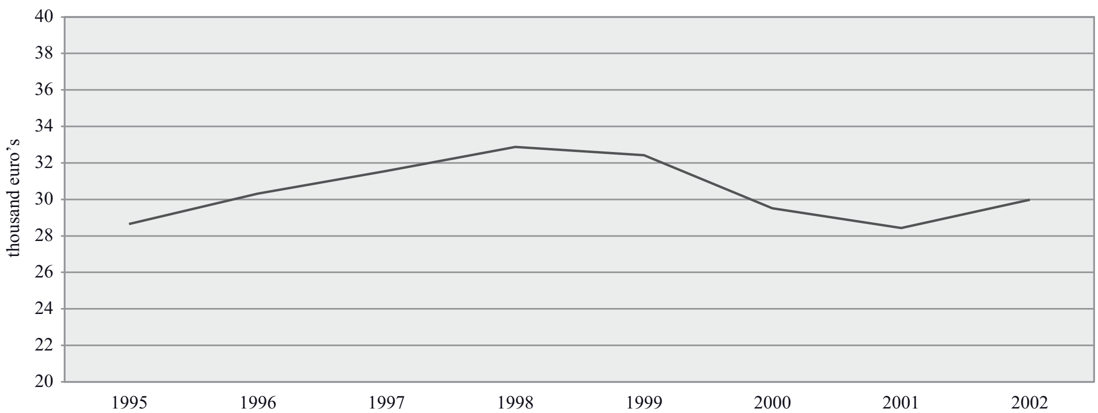
One may divide innovation into two types, process and product innovations. Concerning the retail trade product innovations affect the store concept, for example switching to self-service, or selling on the Internet. Process innovations, with the objective of increasing efficiency, include for instance a new cash-register system and an automated supply-management and stock system.

Unfortunately, the CIS-innovation survey among firms in services does not make a distinction between product and process innovations. Retailers however were asked to provide descriptions on their innovation activities. An analysis of these innovation examples revealed that innovations in the retail trade mostly consist of process innovations.

Productivity 1995–2002

Earlier we already discussed productivity levels of the Dutch retail trade for several periods in a national and international perspective. Graph 21–5 plots the average labour productivity levels per full-time equivalent for the retail trade between the years 1995 and 2002, based on the PS-data. In this period, labour productivity hardly improved. Until 1998 productivity significantly increased, thereafter productivity considerably declined. Productivity recovered again in 2002.

Average labour productivity per full-time equivalents for the whole Dutch retail trade, 1995–2002 **G 21–5**

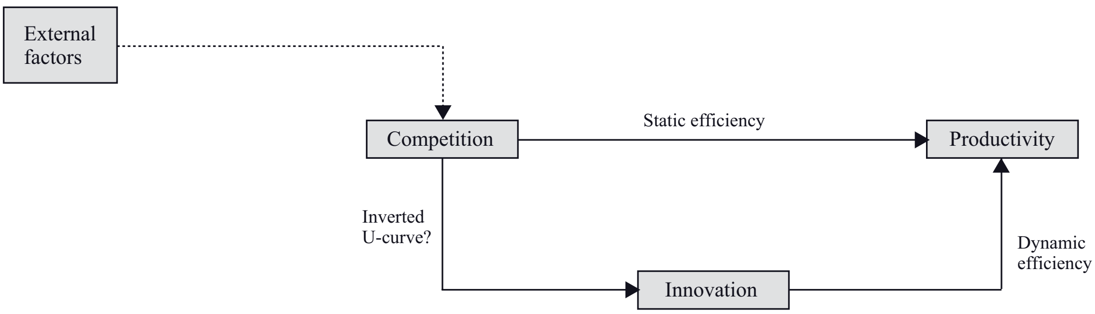


Source: own calculation based on PS-data.
Productivity levels deflated by price mutations derived from the input-output tables of the national accounts (1992=100).

Competition, Innovation and Productivity

Theoretically, both competition and innovation are important drivers of productivity (growth). Graph 21–6 presents our conceptual framework, which captures the mutual relation between competition, innovation and productivity. This framework includes the direct impact of competition and innovation on productivity as well as the impact of competition on innovation.

Relations between competition, innovation and productivity **G 21–6**



An increase in competition may force firms to achieve the highest level of efficiency in production and management, given available technologies. This is often referred to as *static efficiency*. That is, increasing competition may reduce X-inefficiencies and subsequently enhance the level of static efficiency in the market (see, e.g. Nickell, 1996). Weak competition makes managers and employees lax, or even seduces managers and employees to shirk. In addition, innovations may affect efficiency levels in the (near) future and stimulate the level of *dynamic efficiency* of the market (see, e.g. Baumol, 2003).

Competition and innovation are also interrelated. Aghion et al. (2001 and 2002) illustrate that this relationship include two counteracting effects and combining those effects may result in an inverted U-relationship. However, no consensus exists in the theoretical or empirical literature on the relationship between innovation and competition (see Canton et al., 2005). Therefore our analysis of this relationship is of an explorative type and assesses whether the Dutch retail trade is characterised by an inverted U-relationship or a linear relationship between competition and innovation.

Our conceptual model neglects two (feedback) mechanisms as we do not apply a simultaneous model explaining competition, innovation and productivity at once. First, we assume that innovation does not affect competition directly in the short term. If innovation affects competition, this will be in the long term via productivity increases or product differentiation. Second, we ignore a direct effect from productivity on competition. Our measure of competition, the RPM, is based on relative marginal costs. In a special case these relative marginal costs are the reverse ratio of labour productivity. This implies that changes in productivity are captured by our measure of competition.

Explanation competition development

Theoretical assertions on competition

Policy frequently considers more competition as a stimulus of economic growth. In that sense, policy has taken various measures to enhance competitive forces on the product markets, also in the Dutch retail trade.

However, we cannot directly identify effects of regulatory reforms on competition in the Dutch retail trade. Still, we may obtain indications for such effects by investigating possible shifts in the level of competition after a reform occurred. For example, such a shift may occur after the reforms on opening hours and business licensing in 1996 and after the introduction of the competition act in 1998.

In addition to regulatory reforms, other determinants may affect competition as well. Therefore, in line with Creusen et al. (2006a) we include five additional explanatory variables to explain competition development: entry, exit, market demand, strategic interaction and advertising.[316] More entry is expected to have a positive impact on competition and more exit a negative impact. The decision to enter or to exit the market is not exogenous but depends on other determinants.[317] An increase in market demand due to economic growth reduces competition (and vice versa).[318] Then all firms can set higher prices without being impeded by competitors' price cutting.

In contrast, competition may increase if strategic interaction intensifies, i.e. when firms react more aggressively to their opponents in using their competitive advantages. Finally, advertising has an ambiguous impact on competition. In fact, advertising can raise competition if it increases market transparency, but may also reduce competition if it lowers product substitutability and effectively raises an entry barrier.

To investigate the effects of the explanatory variables on competition, we apply the two stage model from Creusen et al. (2006a, see also the box above). Using PS-data, we estimate this model at the SIC 5-digit level.

Empirical findings on competition

Table 21–5 presents the regression results and shows that the signs of most coefficients of the explanatory variables fit well with the theoretical assertions. Increases in strategic interaction and advertising have a significant positive impact on competition in the Dutch retail trade. The positive impact of advertising suggests that advertising is used to inform consumers in order to enhance market transparency and hence to intensify competition. A larger market demand reduces competition, which was the case during the booming economy in the late 1990s. In addition, the significant and positive parameter of the lagged competition indicator suggests that effects of changes in determinants and entry/exit rates last for multiple periods.

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[316] We ignore the impact of import on competition because import by the retail trade is not present according to the National Accounts.

[317] I.e. including capital intensity as an indicator of the level of economies of scale. In fact, the contestability theory suggests that higher capital intensity and more economies of scale induce fewer firms on the market.

[318] We approximate changes in market demand by adjusting the total sales for supply-side effects, such as changes in productivity and the number of firms. These changes are computed at the SIC 2-digit level due to data limitations.

Box 21 – 2 Formal model for explaining competition

The competition model exists of two steps. The second step is the subject of this section: explanation of competition. The first step concerns the pre-determination of entry and exit. After taking logarithms of each variable, the regression equation for the relative profits measure (RPM) of industry j in period t reads as follows:

$$RPM_{tj} = \beta_0 + \beta_1\overline{Entry}_{tj} + \beta_2\overline{Exit}_{tj} + \beta_3 RPM_{t-1,j} + \beta_4 MD_{tj} + \beta_5 ADV_{tj} + \beta_6 SI_{tj} + \beta_7 Dob_{tj} + \beta_8 Dca_{tj} + \varepsilon_{tj}$$

With

$\overline{Entry}$	estimated number of entrants as percentage of total number of firms
$\overline{Exit}$	estimated number of exiting firms as percentage of the total number of firms
MD	market demand, i.e. total sales adjusted for supply-side effects
ADV	advertising rate, i.e. advertising costs as percentage of total sales
SI	dummy on strategic interaction [a]
Dob	dummy on the liberalization of shop opening hours and business licence requirements (1996 and later)
Dca	dummy on the new Competition Act (1998 and later)

The lagged RPM may capture the slack of incumbents' response to previous changes in the determinants. The fitted values of entry and exit ($\overline{Entry}$ and $\overline{Exit}$) capture the joint effects of all other determinants on competition that go through entry and exit. These predicted values are obtained from two other equations, which are used to solve for the issue of endogeneity. In fact, we also regressed the entry rate ($Entry$) and exit rate ($Exit$) on all the other lagged determinants. In these equations we used a one year lag, because it is likely that entry and exit only take place if the change in the determinant becomes more settled and definite. Stated formally, we estimated:

$$Entry_{tj} = \gamma_0 + \gamma_1 Entry_{t-1,j} + \gamma_2 DEP_{t-1,j} + \gamma_3 TS_{t-1,j} + \gamma_4 ADV_{t-1,j} + \gamma_5 Dob_{t-1,j} + \gamma_6 Dca_{t-1,j} + \gamma_7 RPM_{t-1,j} +$$
$$Exit_{tj} = \delta_0 + \delta_1 Exit_{t-1,j} + \delta_2 DEP_{t-1,j} + \delta_3 TS_{t-1,j} + \delta_4 ADV_{t-1,j} + \delta_5 Dob_{t-1,j} + \delta_6 Dca_{t-1,j} + \delta_7 RPM_{t-1,j} +$$

$$\gamma_8 Exit_{t-1,j} + \mu_{tj}$$
$$\delta_8 Entry_{t-1,j} + \nu_{tj}$$

With,

TS	(deflated) total sales of the Dutch market
DEP	capital intensity, measured by depreciation costs as percentage of total sales

The equations can be estimated in two sequential steps by the Ordinary Least Squares-technique. This procedure is known as the 2-Stage Least Squares-technique to correct for endogeneity problems (see for example Verbeek, 2004).[b]

[a] A positive and significant correlation between the RPM and the price-cost margin points to the existence of reallocation effects, i.e. when changes in competition also induce shifts in market shares

(see Creusen et al., 2006a). These reallocation effects, however, typically emerge if competition is altered by changes in strategic interaction. So, simultaneous increases (decreases) in the RPM and the price-cost margin point to an increase (decrease) in firm's strategic interaction.

[b] Note that serial correlation may occur in the cross-sections of the SIC 5-digit sectors. This could mainly bias the significance of the parameters.

T21–5 Estimation results for determinants of competition in the Dutch retail trade, 1993-2002

Dependent variable: RPM

Determinant	Expected sign[a]	Estimated parameter	t-value
Regulatory reforms			
Dummy 1996 on opening hours/ business licensing	+	0.12	2.66
Dummy 1998 on Competition Act	+	-0.01	-0.30
(Fitted) entry rate	+	0.06	1.54
(Fitted) exit rate	-	-0.05	-0.68
Market demand	-	-6.94	-3.72
Strategic interaction	+	0.05	3.90
Advertising rate	?	0.13	2.61
Lagged RPM	+	0.42	11.55
Intercept		0.40	2.46
R-squared		0.26	
Degrees of freedom		563	

[a] Positive sign indicates positive effect on competition, and visa versa.

In addition, our findings indicate that some regulatory reforms might have affected competition positively in the Dutch retail trade.[319] The dummy variable for the period following the reforms on opening hours and business licensing, demonstrates that a significant upward shift in the level of competition occurred. However, such a shift is not identified after the introduction of the competition act in 1998. Further research is required to identify the effect of both regulatory reforms on the level of competition in the Dutch retail trade.

[319] One can also combine the separate reforms in an overall indicator on regulatory reform (see Creusen et al., 2006b). Doing this, the results suggest that the regulatory reforms had a positive and significant impact on competition.

Relation innovation and competition

Theoretical assertions on innovation

Recent theory suggests that the incentive to innovate depends on the level of competition and the differences in efficiency level between competing firms (see Aghion et al., 2001 and 2002, Boone, 2001). It particularly shows that two countervailing effects determine the relation between competition and innovation.[320] On the one hand, an increase in competition enhances the innovative effort of leading firms, because in this way these firms can escape from fierce competition (escape competition effect). On the other hand, increases in competition forces lagging firms to refrain from innovation, because those innovations become non-profitable (Schumpeter effect). The escape competition effect therefore points to a positive relation between competition and innovation. However, the Schumpeter effect points to a negative relation.

Aghion et al. suggest however, that combining these two effects in a dynamic model results in an inverted U-relationship between competition and innovation (see Aghion et al., 2001 and 2002). In fact, an initial rise in competition will first enhance total innovation efforts by the escape competition effect, but beyond some point it will reduce total innovative efforts as the Schumpeter effect becomes larger. To test whether an inverted U-relationship exists, we run two variants of the innovation expenditure equation (see the box below for more details).

When estimating the relationship between competition and innovation, one should be aware of the various steps firms have to go through in deciding to innovate. Recall that more than 70 percent of the retailers in our sample indicated that they had no innovation expenditures at all. Ignoring this group of non-innovative retailers and only focussing on the 30 percent of the retailers that *do* innovate may bias our empirical results on the relation between competition and innovation. So to capture all relevant innovation decision of all retailers, we employ the Tobit-I procedure and implicitly combine the decision to innovate in the first step with the decision on expenditures in the second step. As a result, the parameter estimates have now two interpretations. First they demonstrate an effect on the probability of innovation and second an effect on the relative innovation expenditures. Consequently, the impact of competition and market share on those expenditures, that is the marginal effects, are dependent on the probability of innovation.

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320 These effects denoted by Aghion et al. resemble the famous Schumpeter's mark I and mark II, in the sense that there are two countervailing effects of competition on innovation. Schumpeter's mark I argues that more competition stimulates (all) firms to innovate (see Schumpeter, 1934). Schumpeter's mark II, however, argues that too much competition may reduce innovation, because firms must have sufficient size and financial sources to benefit from innovation (see Schumpeter, 1942).

Box 21 – 3 Formal equation explaining innovation

To determine the dominant effect (escape competition or Schumpeter), the linear relation between competition and innovation for each firm i in industry j in period t reads as:

$$IS_{ijt} = \varphi_0 + \varphi_1 RPM_{jt} + \varphi_3 W_{ijt}$$

with

IS innovation rate, i.e. the firm's innovation expenditures as a percentage of its total sales

RPM relative profits measure of the industry

W market share, i.e. total sales of each firm as a percentage of the total sales of the industry

This equation includes the firm's market share as an explaining variable as firms may have exploit economies of scale from innovation. It is expected that larger firms have more opportunities to conduct research, such as financial funds or risk-sharing, or can better exploit economies of scale after implementing the innovation. Therefore, firms with a higher market share may also have more innovation expenditures in comparison to their sales.

Following Aghion et al. (2002) the relation between competition and innovative effort can be estimated by regressing the innovation rate of each firm on a quadratic function of the RPM of the respective industry.

The regression equation for the innovation rate becomes:

$$IS_{ijt} = \varphi_0 + \varphi_1 RPM_{jt} + \varphi_2 RPM_{jt}^2 + \varphi_3 W_{ijt}$$

Note that innovation outlays as an indicator of innovation are left censored, which means that these variables can only take values larger than or equal to zero. In estimating all the equations we have to take account of this censoring and therefore apply the so-called censored regression technique (Tobit-I model, see Verbeek, 2004).

Empirical findings on innovation

We use firm's innovation expenditures as a percentage of total sales as an indicator of innovation activities in the Dutch retail trade.[321] Although, for example, the decision to exit

321 Note that our approach differs with the one of Aghion et al. (2002) on two main elements. We use innovation expenditures as an indicator of innovation whereas they use patents. The latter is to our opinion a more limited indicator of innovation. The second main difference is that we apply a new indicator of competition,

the market is also a decision not to innovate, we will not analyse the impact of such effects separately. Furthermore, we assume that effects of legislation, strategic interaction, entry and exit are all captured by changes in the RPM as our indicator of competition.

The analysis of innovation partly consists of firm-level data (i.e. innovation expenditures and market share) as well as industry-level data (i.e. RPM). In addition, the RPM and are pre-determined on PS-data at the industry level (5-digit).

Table 21–6 presents the results of the estimated linear relation between innovations expenditures and competition. Remember that the coefficients of a Tobit-I model have two interpretations. So these estimations results indicate that higher competition induces a higher probability of innovation as well as a higher ratio of innovation expenditures relative to the sales levels of firm *i* (positive sign of competition).[322] Then in terms of the theory, these results suggest that the escape competition effect dominates in the Dutch retail trade, i.e. some (leading) firms innovate to escape fierce competition. Further, the empirical results also point out that firms with a higher market share spend relatively more on innovation than firms with a lower market share.[323]

T 21 – 6 Estimation results for Innovation (Tobit-I model)

Dependent variable: innovation rate (at firm level)

Determinant	Estimate	t-value
Intercept	-0.14	9.08
RPM	0.02	4.31
Market share	0.24	5.14
Scale parameter[a]		21.63
Number of observations		1147
Left-censored observations		864
Log-likelihood		-72.90

[a] Scale parameter in the distribution used to normalise the underlying variable.

Source: own calculations based on PS- and CIS-data.

Additionally, we test the existence of an inverted U-relationship. The results do not support the theoretical notions of this relationship. Table 21–7 presents the results of a regression of the innovation rate on a quadratic function of competition and the firm's market

the RPM that is probably more monotone with competition.

322 Parameters of the Tobit-I model cannot directly be interpreted as the marginal effect on innovation because the probability of having a positive outcome should also be taken into account. We therefore focus on the sign of the effect estimates and not on the magnitude.

323 Although it can be argued that there is a relationship between market shares and the relative profit measure, the correlation between both explanatory variables is low. Therefore, multicollinearity is not a serious issue in this respect.

share. These results suggest that that there is no inverted U-relationship between competition and innovation. The estimated coefficient of competition squared, i.e. φ_2, is positive and significant, and thus contrasts with the theory of Aghion et al. (2002).

T 21 – 7 Estimation of quadratic model (Tobit I-model)

Dependant variable: innovation rate (at firm level)

Determinant	Estimate	t-value
Intercept	-0.07	-1.76
RPM	-0.05	-1.50
RPM squared	0.02	2.22
Market share	0.24	4.59
Scale parameter[a]		21.65
Number of observations		1147
Left-censored observations		864
Log-likelihood		-70.46

[a] Scale parameter in the distribution used to normalise the underlying variable.
Source: own calculations based on PS- and CIS-data.

Some cautious remarks as the results for innovation are not without problems. First, although innovation data from CIS is imperative and indispensable for this kind of research, still innovation is a difficult concept in services. Second, innovation expenditures do not measure the success of an innovation. The latter is not available at the firm level. Finally, due to data availability, we had to use the same explanatory variables for both the decision to innovate and for innovation expenditures of innovating firms.

Impact competition and innovation on productivity

Theoretical assertions on productivity

In general firms' labour productivity depends amongst others on total factor productivity (TFP), capital intensity, use of economies of scale, and on cyclical fluctuations. In this study, the first determinant, TFP, is most crucial. In fact, we assume that firms may enhance their TFP-level by innovation, that is, by conducting research to develop new technologies and/or new products.

Furthermore, theory suggests that fierce competition forces firms to reduce X-inefficiency as much as possible, and consequently affects TFP-growth in the short term (see for instance Nickel, 1996, for an overview). Therefore, in our model we assume that TFP-growth in the short term is not only related to innovation, but to competition as well.

These relations described above are transformed in a formal model (see box), and can be estimated empirically. As labour productivity is highly correlated with the business cycle due to labour hoarding, we added two year dummies (i.e. for the year 1997 respectively 1999) to control for incidental effects, including business cyclical effects.

Empirical findings on productivity

Estimation of the productivity equation is based on the merged data set of PS and CIS-data at the firm level. The set of the RPM are pre-determined from the PS-data at the 5 digit industry level. Due to the restrictive availability of the innovation data and the assumed lagged effect of innovation, these merged data concern the years 1997, 1999 and 2001.

The positive and significant coefficients for competition and innovation reveal that they both enhance TFP-growth, as can be seen in table 21–8. The positive effect of competition on the productivity growth is in line with the findings of Nickell (1996), and indicates that the market attains higher static efficiency with increasing competition. The positive effect of innovation on productivity growth is supported as well (dynamic efficiency). The insignificance of the coefficient on labour indicates that the Dutch retail trade as a whole is characterised by constant returns to scale.

Finally, combining the positive impact of innovation on productivity with the positive impact of competition on innovation suggests that competition has a second *indirect* effect on productivity growth via innovation. As competition stimulates innovation, the initial effect of competition on productivity becomes even stronger in the long term.

T 21 – 8 Estimation results labour productivity growth, 1997-2001 [a]

Dependent variable: productivity growth (at firm level)

Determinant	Estimate	t-value
Intercept	-0.02	-0.61
Change RPM	0.07	1.91
Lagged innovation rate[b]	0.01	2.19
Capital intensity	0.22	12.95
Labour	0.00	-0.45
Dummy 1999	-0.04	-0.93
Dummy 2001	0.05	1.09
R-squared		0.17
Degrees of freedom		877

[a] Note that only the growth rates of the years 1997, 1999, and 2001 can be used due to the CIS-data.

[b] Relative to (lagged) value added.

Source: own calculations based on PS- and CIS-data. Productivity levels deflated by price indices derived from the input-output tables of the national accounts (1992=100).

Concluding remarks

This study analyses the relationship between competition, innovation and productivity. It focuses on the Dutch retail trade as this industry accounts for a large part of the negative gap in productivity growth compared with the US since the mid-1990s.

In general, shopping with friends give more fun compared to shopping alone. This is also the case with competition and innovation. We show that both competition and innovation may speed up productivity in the Dutch retail trade. But, competition also stimulates innovation, and therefore the initial effect of fiercer competition on productivity becomes even larger in the long term. However, we show that on average competition hardly increased in the Dutch retail trade in the period 1993–2002.

This study contains two renewing features in empirical research. First, it combines two effects of competition on productivity. Higher competitive pressure reduces X-inefficiencies in the short-term and it stimulates innovation in the long term. Second, using firm-level data, this study also contains an empirical test on the existence of an inverted U-relation between competition and innovation, as introduced by Aghion et al. 2001 and 2002. This test rejects the hypothesis of an inverted U-relationship for the Dutch retail trade. Still, these features are first steps towards an extensive empirical model that relates competition, innovation and productivity, and thus require further investigation.

The findings of our study are relevant for policy as we find indications that both the intensity of competition and innovation expenditures appear to be low in the Dutch retail trade. Policy measures aiming at stimulation competition such as longer openings hours in 1996 may already have had an effect. Following that track is, therefore, a policy option that needs further consideration.

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22. ECONOMIC GROWTH IN SWEDEN, NEW MEASUREMENTS

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Introduction

Almost 50 years ago Robert Solow[324] started up a new era in growth measurement by publishing his article on economic growth and technological development in the US economy. He used the technique of Growth Accounting to break down growth in US labour productivity into components. His results indicated that almost all growth in the US economy was due to technological developments and very little to capital deepening. This inspired Zwi Griliches and Dave W. Jorgensen[325] to try to improve the capital measurements. Another important contribution was made by Denison[326] who tried to incorporate a measurement of the improvement in labour quality. This period of rapid development of the neoclassical growth theory and use of the Growth Accounting technique lost momentum due to researchers' increasing interest in short term questions, a lack of adequate data and the fact that growth was treated as exogenous in the neoclassical word, so these theories could not explain growth in itself.

Solow did however later argue, for instance, that increased capital-intensive investment embodies new machinery and new ideas as well as increased learning for even further economic progress. But Kaldor[327] is the first theorist after the Second World War, who thought growth to be endogenous. Before the War it was of course Schumpeter who indeed saw growth as an exogenous process with creative destruction as one major concept. Kaldor regarded learning as a function of the rate of investments. Arrow went on and viewed learning as a function of cumulative investments. But this area stagnated nevertheless after the 1960s.

This changed drastically when Romer[328] published his breakthrough article 1986, where he finally incorporated endogenous growth in the model. This started up a new field of growth literature, which was called "new" or "endogenous" growth theory. But still the neoclassical growth theories have their supporters. Even if these theories cannot explain the driving forces

324 Solow, Robert M. (1957). "A Contribution to the Theory of Economic Growth", Quarterly Journal of Economics, 70, pp. 65–94.

325 Griliches Zwi and Dale W. Jorgensen. Sources of Measured Productivity Change: Capital Input,» *The American Economic Review*, Vol. 56, No. 2, May 1966, pp. 50–61.

326 Denison, Edward F. 1962. *The Sources of Economic Growth in the United States and the Alternatives Before Us.* New York: Committee on Economic Development.

327 N. Kaldor "A New Model of Economic Growth", with, 1962, RES

328 Romer, Paul, 1986, "Increasing Returns and Long Run Growth", Journal of Political Economy , vol. 94

behind different growth rates, they can still answer important questions, like if there is a tendency towards convergence (see among others Barro and Sala-i-Martin.[329]) The technique of decomposing economic growth by Growth Accounting has been widely used during the last decade with many important contributions, not least by Dave W. Jorgensen[330] , who is still very active in this field.

An important trigger has been the improved growth performance of the US economy. It ceased to lose ground to the European economies around 1995, as had been the case since the Second World War, and outperformed them thereafter. Now many articles have been published that have looked into the US economy in depth. The objective of these articles has been to get a better understanding of US transformation from the stagnating economy it was for many decades, into a growth economy. Some researchers have also compared US development to some European countries[331]. Important work has also been done in Canada during the last 10 years; at Statistic Canada led by Professor John Baldwin[332], both on the Canadian development and its comparisons with the US. Bart van Ark[333] at Groningen Growth and Development Centre the University of Groningen is another important researcher in this field. Another trigger of the increased use of the Growth Accounting technique was the interesting result Young[334] came up with when he decomposed the economic growth of the "Tiger Economies" in East Asia. He found their very imposing growth in labour productivity was almost entirely due to a drastic increase in capital intensity.

This development in the research field together with the increasing importance of the European growth problem has also led the EU Commission together with Eurostat to act. They have commissioned a development and analysis of a comprehensive long time series for most European countries. This is being carried out by a broad consortium lead by Bart von Ark. Statistics Sweden is also now linked up to this ongoing work.

329 Barro, Robert J. and Sala-i-Martin, Xavier,. Convergence», 1992, JPE

330 Jorgenson, Dale W., and Kevin J. Stiroh (2000), «Raising the Speed Limit: U.S. Economic Growth in the Information Age», Brookings Papers on Economic Activity, 1, pp. 125–211.

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Dale W. Jorgenson and Khuong Vu Information and the world economy Presented at the EU-KLEMS meeting in Helsinki 2005.

331 Susanto Basu, John G. Fernvald, Nicholas Oulton, and Syaja Srinivasan. The Case of Missing Productivity Growth, or Does Information Technology Explain Why Productivity Accelerated in the United States but Not in the United Kingdom?

332 Baldwin, John R., and Tarek M. Harchaoui (2003), productivity Growth in Canada – 2002, Ottawa: Statistics Canada.

333 Bart van Ark, Robert Inklaar and Robert H. McGuckin (2002), “”Changing Gear”: Productivity, ICT and Services: Europe and the United States”, Research Memorandum GD-60, Groningen Growth and Development Centre, December

Bart van Ark, Johanna Melka, Nanno Mulder, Marcel Timmer and Gerard Ypma (2002), “ICT Investments and Growth Accounts for the European Union 1980–2000”, Research Memorandum GD-56, Groningen Growth and Development Centre, September (revised version, March 2003)

334 Young Alwyn, «The Tyranny of Numbers», National Bureau of Economic Research, Inc in its series NBER Working Papers number 4680

The OECD has always had economic growth on its agenda, and has recently created a productivity section on their website on growth accounting, with both methodological papers and a database. This work as well as the analytical work in this field is led by Paul Schreyer at the Statistics Directorate and Dirk Pilat at the Directorate for Science, Technology and Industry. In the Nordic countries Statistics Denmark has led the way and published multifactor productivity growth figures on a very detailed sector level, already in 2004[335].

At Statistics Sweden this kind of work is still on an experimental level, but two studies made by external researchers have already been published in this field. The first one was the first time a separate series for ICT capital was constructed and used[336] in Sweden. The second study also used a quality adjusted labour input[337]. The former chief economist of Statistics Sweden has also led a Nordic Ministerial work group, GAG, that has compared economic growth in recent years in the Nordic countries. This study is presented in another chapter in this book.

All this work has inspired us to go on with our own experiments in the growth accounting field. This time we have tried to go beyond the value added and capital stock approach and try to use the KLEMS method. This means that growth of gross output is decomposed instead of growth in value added. In this attempt capital services will be used as measurement of capital input instead of capital stock. The capital service concept is an important improvement since a stock concept is changed into a more appropriate flow concept. An intuitive example of this is the difference between the rent of a building and the value of the building. It is of course more relevant to use the rent as a measurement of the input cost of building capital in explaining the production that has taken place in this building during a year since all other variables like worked hours, bought materials and services are flow concepts.

The variables that influence the cost of the capital service of a certain capital type are: the price of the investment goods, the alternative interest that can be earned, the depreciation rate due to the economical and physical reduction in its production capacity of using it a year, and finally the price development of the investment good during the same year. The price changes, which for most investments goods are positive, decrease the cost of the capital service. But since this is not the case with ICT goods we see a very marked difference in the importance of these goods when capital service is used instead of a capital stock as capital inputs. However, even more important is the difference in depreciation rate between ICT capital and other capital items. This means that the relative cost of ICT investments is markedly appreciated compared to other capital types, especially buildings, since the depreciation rate is much higher and its price developments are much lower. The other major difference is that we use the production, or gross output, as output measurement, which means that also intermediate input becomes an input variable. The intermediates are split into three categories; energy, other material input and service input. This makes it possible to study how outsourcing and energy conservation influences the production.

335 Statistics Denmark ”Produktivitetsudviklingen i Danmark 1966–2003”, 2005.

336 Lindström, Tomas (2002). “The Role of High-tech Capital Formation for Swedish Productivity Growth”, in Development and Improvement of Economic Statistics, SOU 2002:118.

337 Forsling, Gunnar and Lindström, Tomas (2004) in Background Facts on Economic Statistics 2004:07

The objective of this study is thus to improve the measurement of economic growth in the Swedish business sector by growth accounting experiments, where gross production is used as the output variable and capital service as capital input. However, the growth accounting methodology is just a technique to decompose the growth and it cannot answer the question of why the growth was high or low or what caused it. Nevertheless, it gives valuable data for further analysis of these important questions.

Theory and model outline

As mentioned above, we will take a KLEMS point of view in our productivity analysis. That is to say we will incorporate the effects of input of capital (K), labour (L) and intermediate input on production. The intermediate input is broken down into input of energy (E), materials (M) and services (S).

The production function expresses the relationship between the factor inputs and the output in the economy. Let gross output be a function of capital, labour and intermediate input. A is an index of the level of technology in the economy.

$$Y = AK^{\alpha} L^{\beta} M^{\gamma} \tag{1}$$

A is commonly referred to as total factor productivity, TFP, or multi factor productivity. Changes in A shift the production possibility curve making it possible to produce more without changing the factor inputs.

Growth accounting is a technique commonly used in productivity analysis. This method allows the growth in production and labour productivity to be decomposed into growth of the factor inputs and growth in total factor productivity, TFP. Studying the production function, estimates on growth in production and growth in factor inputs is normally not a problem to obtain. Using growth accounting, total factor productivity is that part of growth in output that cannot be explained by growth in the input factors. While having estimates on growth in output and input factors TFP is estimated residually.

While using the production function stated above we assume standard neo-classical growth assumptions, constant returns to scale, perfect competition and profit-maximizing firms. All of this meaning that factor inputs will be rewarded by the size of their marginal productivity. Also we assume the growth in TFP be Hicks-neutral. Assuming constant returns to scale yields the coefficients to sum to one; $\alpha + \beta + \gamma = 1$.

Being focused on growth we need to reformulate equation (5). By taking the logarithm and the first difference of the production function we express all variables in terms of rates of growth and get:

$$\Delta \ln Y = \alpha \Delta \ln K + \beta \Delta \ln L + \gamma \Delta \ln M + \Delta \ln A \tag{2}$$

Δ refers to the first difference, i.e. $\Delta x \equiv x_t - x_{t-1}$.

Studying the model one realizes that growth in gross output is possible only by raising the input of one of the input factors or by raising the level of technology in the economy, that

is, the total factor productivity, TFP. By expressing the production function in growth rates (log differences) the growth in Y is split up in the share weighted growth in capital, labour, intermediate consumption and TFP.
Using this model enables us to study the share weighted growth in GDP. In so doing we need estimates on the weights of the factor inputs. By taking the starting point in the firms profit maximization function, the quantities of capital services, labour and intermediate inputs are chosen so as to minimize total costs and maximize profits. Let Π denote the profit, Y is production, ωL is the total cost of labour, rK is the total cost of capital and pM is the total cost of intermediate inputs.

$$\Pi = Y - \omega L - rK - pM \tag{3}$$

While maximizing Π subject to $Y = AK^{\alpha} L^{\beta} M^{\gamma}$ it can be shown that

$$\alpha = \frac{rK}{Y}, \tag{4}$$

$$\beta = \frac{\omega L}{Y}, \tag{5}$$

$$\lambda = \frac{pM}{Y}. \tag{6}$$

We see that the weights of the factor inputs, α, β and γ, are represented by each factor's share in total production.

Assuming perfect competition, there are no profits other than the remuneration to labour, capital and intermediate input. Hence the value of output can be expressed as:

$$Y = \omega L - rK - pM \tag{7}$$

Then we see that the weights are represented by each factor inputs share in total cost.
In the empirical analysis below we are using different types of capital. Splitting capital into these subcategories yields:

$$\alpha \Delta \ln K = \sum_j \alpha_j \Delta \ln K_j \tag{8}$$

where α_j represents each capital's share in total capital costs:

$$\alpha_j = \alpha \frac{r_j K_j}{\sum_j r_j K_j} \tag{9}$$

Since we are interested in the effects of different types of labour the set of labour were divided into a number of categories. Assume in this case that A is the set of different labour types, and L_a the quantity of labour of type $a \in A$.

$$\beta\Delta \ln L = \sum_{a\in A} \beta_{ait} \Delta \ln l_{ait} \tag{10}$$

Here l_{ait} is the share of category a in total labour, and the β_{ait}-coefficients represent each types share in total labour cost:

$$\beta_{ait} = \beta_{it} \frac{\omega_{ait} L_{ait}}{\sum_a \omega_{ait} L_{ait}} \tag{11}$$

Labour Productivity

Economic growth is our focus thus the effects of changes in factor inputs on changes in labour productivity are of interest. Therefore we introduce total worked hours H_t. When dividing both sides of the production function above with total worked hours we get:

$$\frac{Y_t}{H_t} = A_t \frac{K_t^\alpha L_t^\beta M_t^\gamma}{H_t^\alpha H^\beta H_t^\gamma} ; \; \alpha + \beta + \gamma = 1 \tag{12}$$

Expressing the equation above in growth terms by taking the logarithmic first-difference we get:

$$\begin{aligned} \Delta Y_t - \Delta H_t = {} & \alpha(\Delta \ln K_t - \Delta \ln H_t) + \beta(\Delta \ln L_t - \Delta \ln H_t) + \\ & + \gamma(\Delta \ln M_t - \Delta \ln H_t) - \Delta \ln A \end{aligned} \tag{13}$$

In this case we identify four sources of the growth in labour productivity. First we have the change in capital per the change in hours worked, known as capital deepening. The second component is the improvement in labour quality which is defined as the difference between the growth rates of labour services and hours worked. The third part is the growth in intermediate consumption per hour worked. The fourth source is the growth in TFP.

Data

In the empirical analysis we will study the growth in TFP both on gross production and on value added. We use data from the national accounts on capital stocks, worked hours and intermediate input. The data on labour is derived from RAMS, register-based labour market statistics at Statistics Sweden and is presented in more detail below. We have data on all variables for the period 1994–2002. We also make an effort to estimate the TFP for the years 2003 and 2004. As so far as it has been possible we have used true values for the years 2003 and 2004. When that has not been possible (as in most cases besides preliminary data for value added and hours worked that we do have) we have extrapolated the following years with averages of the most recent preceding years. The section below will in more detail describe the data on the factor inputs.

Capital Services

As mentioned earlier we will in this empirical analysis use the flow of capital services streaming from capital rather than the value of the capital stock itself. By taking into account the heterogeneity of capital and that different types of capital have different marginal productivity, we get a more effective measure of the capital input in production.

The value of the flow of services from the stock is a better measure of the input in production than is the value of the stock itself. Over time there should be a substitution of capital towards capital with higher marginal productivity. For example as prices on ICT capital is falling industries tend to invest more in this cheaper and more productive capital.

For this study estimates of capital stocks were derived from national accounts, Statistics Sweden, to construct estimates of capital services. Official data on capital stocks is published by Statistics Sweden on *Machinery and equipment, Dwellings, Other buildings and construction* and *Other capital formations* which mostly consist of software. Using these stocks of capital, stocks of Machinery exclusive ICT, Transport equipment, Buildings and construction and ICT were estimated. The ICT stock was originally estimated for Lindström *(2002).* Following the recommendations of OECD an ICT stock was then estimated for the business-, goods-, manufacturing-, service- and ICT sector respectively for the period 1993 to 2000. For this study this time-series was prolonged to the year 2003 using data on investments for the same period and the perpetual-inventory method, PIM. While using these new stocks of capital, capital service measures for ICT capital and non-ICT capital were constructed.

Consider the capital stock K_t. The capital stock is estimated by using the traditional PIM-method.

$$K_t = K_{t-1}(1-\delta_{t-1}) + I_t \qquad (14)$$

Here δ is the value of depreciation in period t-1 and I is the value of investment in period t.
The value of the stock is estimated at the beginning of the year. Assuming that new investments becomes available for production in the middle of the year we express capital services as

$$C_t = a(0.5K_t + 0.5K_{t+1}) \qquad (15)$$

(footnote D. Jorgenson)

The capital service flow is assumed to be proportional to the average of the current and lagged capital stock where α denotes the proportionality constant[338]. The flow of capital services is then estimated by using asset specific user costs to weight the growth in each type of capital and to account for the substitution between them.

[338] Jorgenson, Dale W., Mun S. Ho and Kevin S. Stiroh. 2002. "Growth of U.S. Industries and Investments in Information Technology and Higher Education.

User Cost

The flow of capital services is weighted with the user cost of each type of capital. The user costs are, under certain assumptions, equal to the marginal productivity of capital. User cost can be seen as the cost of borrowing capital and investing in a capital good, renting it out, and collecting a rent.

The estimation of the user cost can be made more or less complex regarding tax regulations. In this study we are relaxing all effects of taxes.

The components of user cost are the rate of alternative investments, depreciation and the change in the price on investment goods. There are different options of choosing the rate of return. In this study we use the endogenous internal rate of return derived from the national accounts. By relating gross operating surplus to the capital stock, the rate of return was derived. This was done for each of the sector aggregates in the study. The rate of depreciation is estimated per sector and type of capital. Changes in prices on investment goods were derived from implicit price indices on investments in the national accounts.

In a very simple form the user costs were estimated as:

$$\mu_t = r_t + \delta_t - \Delta p_{t,t-1} \tag{16}$$

where μ is the user cost, r is the rate of return, δ is the rate of appreciation and Δ p is the rate of price change in new investment goods.

The estimated user costs are then used to calculate the weights by which the flows of services are aggregated. The weights are defined, for a capital good C_k as:

$$\upsilon_{k,j,t} = \frac{\mu_{k,j,t} C_{k,j,t}}{\sum_k \mu_{k,j,t} C_{k,j,t}} \tag{17}$$

T 22–1 Average user cost for the total business sector 1994–2002

Machinery excl. ICT	0.26
Transport equipment	0.25
ICT	0.49
Buildings and constructions	0.11

Labour Composition

The effect of the labour input on production is not only a question of quantity but also of quality, or more correctly on its composition. We have thus tried to calculate an indicator of the labour composition. The method which has been used is very much a market oriented one. The working population has been split in many subgroups according to four different characteristics. For each of the subgroups we calculated the average incomes from both the employed and the self-employed.

If the labour market functions well, the average income for each subgroup is the market's valuation of the different categories as labour inputs. This is in accordance with a long tradition represented by Jorgensen[339] and Bureau of Labour Statistics[340] both of which have somewhat different approaches for the US labour market. This has been further developed on US and Canadian data by Gu and Maynard[341]. The income means are then treated as the market valuation of different categories of labour in respective workplaces. In most workplaces there are of course only a small number of these categories represented. But with help of the average prices it is possible to calculate a synthetic labour cost or labour composition indicator for the whole workplace. It is necessary to go via the workplace level since this is the unit that has an industry definition, not the individuals. They get an industry connection by their workplace. The workplaces can then be aggregated to industries on different aggregation levels.

Instead of creating an average for the whole time period we want to take account of the changes that take place in the valuation of different types of labour over the years. To take account of the changes over the years in relative prices is rather uncommon in the literature, but has been used by the researchers mentioned earlier at Statistic Canada[342]. To be able to follow the changes in the labour market over the years in a meaningful way, it is necessary to deflate these mean incomes for different categories with the general wage increase; otherwise the labour composition indicator, which is based on the mean incomes, includes both inflation and real wage increases.

For this purpose the structure from one year, that is, the relative size of each category, is combined with the earnings for each category the following year. This is then aggregated to a fictive average earning of that year which is divided with the factual mean earnings of the last year. The increase in average earnings is then treated as a common price index that is used to deflate the incomes of each subgroup. The resulting changes of the deflated prices of a subgroup over the years is then only reflecting the market's relative appreciation, or its depreciation, of the value of this group as labour input compared with all other subgroups.

The characteristics that have been used are the traditional ones; age, education and ethnicity with one exception, i.e. gender is not included. The choice of the different categories for each variable is based on how they are valued on the market. The education variable is split into two dimensions: orientation, and levels. There are five different levels but only two

339 Jorgensen, Dale W., Frank M. Galup and Barbara M. Fraumeni. 1987. "Productivity and the U.S. Economic Growth," Cambridge, Harvard University Press.

340 Bureau of Labor Statistics. 1993. Labour composition and U.S. Productivity Growth, 1948–90, Bureau of Labor Statistics Bulletin 2426, Washington, D.C. , U.S. Department of Labour.

341 Gu, Wulong and J-P Maynard. 2001. "The Changing Quality of Canadian Work Force, 1961–95", in Jorgenson and Lee (eds) Industry-level Productivity and International Competitiveness between Canada and the United States, Industry Canada

342 Gu, Wulong, Mustaapha Kaci, Jean-Pierre Maynard and Mary-Anne Sillamaa in the chapter of "The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth" in the "Productivity Growth" edited by John R. Baldwin and Tarek M. Harchaoui. Statistics Canada 2002. Catalogue no. 15-204-XIE

fields: 1) the technical and natural science orientation and 2) all other orientations together. The levels starts with primary (level 1 and 2) and lower secondary, and end with post graduate education (level 6). Concerning age, the workforce is split in as many as six categories, but of these the first and the sixth are very infrequent on the Swedish labour market. These categories are namely those who are 16–20 years of age, and those who have reach the age of 67. The ethnicity variable is based on the countries where people are born. Those with an origin outside of Sweden are divided in four groups.

The reason why the gender variable is excluded is because most of the differences of yearly earnings between men and women are more of an indicator of the differences of working hours than of anything else. We do not have any data on worked hours for individuals, but we know that there are many more women than men who are working shorter hours. Since the quantitative labour input is measured in hours, the sector difference is already incorporated in that variable, and if the gender is included it is measured twice. The rest of the differences between the two sexes are considered to be a reflection of discrimination and not a difference in labour quality. All these variables and their different categories give us in theory as many as 600 cells in total, but some of them are of course empty. And in a small or medium sized workplace only a handful is represented.

Regional differences in wage levels also exist on the Swedish labour market, but these differences are not mainly due to differences in competence but rather to the size and character of the local labour market. The same is true for industries. In general there could be a tendency for an expanding sector to pay more for the same skill since it needs to attract more people. Sector differences can also be a reflection of regional differences. This is not only due to chance, but also to conscious choices. Industries that are maturing are driven out from growth areas due to high wages and high rents. These factors are the reason for not including regions and sectors among our variables.

We have also limited the calculation to the private business sector since we are just studying this sector. It is also known that the public sector is paying less for the same competence. We have chosen broad education categories for the education orientations, since if they are narrower they tend to become more sector-specific.

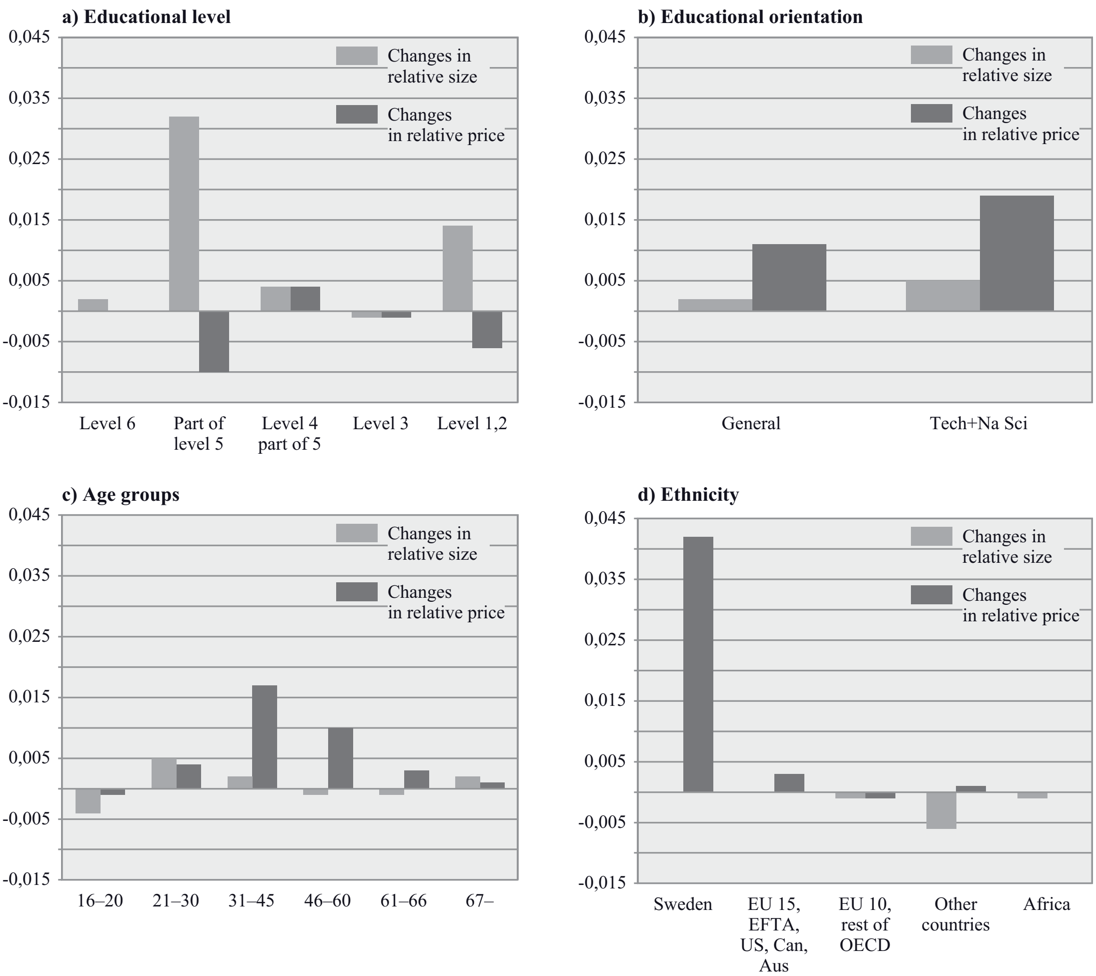
The development of the quality measurement has been decomposed into 1) the change in the relative importance of each category and 2) the change of its quality or price. The effects of the weights are of course positive if a high quality group increases its importance as well as if a low quality group decreases it. The total effect for each group is the sum of the price and the relative size effects. All the effects are the total effect and not the partial effect. This means that the sum of all bars in the four figures in graph 22–1 all equal 0.38.

The relative income of those who are on the education level 6, postgraduates is twice the average income and there relative size has almost doubled during the period 1993–2002. But there are still not very many at this level, and their relative salaries have deteriorated somewhat. Much more important for the increase in total quality of the workforce is therefore the increase of the relative share of graduates, most of those on level 5, even if they too have undergone a decrease of there relative incomes. The decrease of those without a high school exam (or completion of upper secondary school), levels 1 and 2, from 31 to 21 per cent of the workforce is also of substantial importance. The decrease of all but one educational group is probably partly due to the change of the relative size of the different age groups, and to a much smaller extent the increase of immigrants from outside of the western hemisphere. But the substantial increase of graduates and postgraduates have made those groups a less scarce resource and thus lowered their marginal productivity, since they are now used in areas other than where their education is most important. The change of educational orientation has also improved the quality of the labour force since those who are favoured by the market, i.e. those with an educational orientation towards natural science and technical fields have increased their share of the workforce somewhat from 30 to 33 per cent. However, the high bars in graph 22–1 b for the relative incomes are mainly due to the increase in educational levels in both groups.

Total contribution to the increase in labour quality by: educational level, educational orientation, age and ethnicity.

The impact is separated into the effects due to the change in the relative size of different groups and their relative quality or wage levels. The total effect is the sum of these two effects, positive or negative.

G 22–1



The same is true for figure c and d. The only two age groups which are above the average incomes are those aged 31–45 and those aged 45–60. This means that both the two most important changes in relative size are due to the movement in opposite directions of the two low income groups with younger people.

The negative effect is due to that the group with the youngest ones has increased in relative size and the positive ones to that the group with those who are a little older; 21–30 years of age, has decreased. The dominant effect in the last part of the figure, d), is due to the effects of higher educational standards and a more growth-oriented direction among those who were born in Western Europe or in other Anglo-Saxon nations. But there is also a small negative effect of an increase in the proportion of the labour force that comes from other countries with on average a lower educational level.

With the method we have used where the change in relative prices are into taken account instead of using a mean for all the years, the increase in the labour quality is reduced. The two methods give similar estimates for most years, (see graph 22–2) but it reduces the effect for the whole period from 0.5 to 0.35 per cent per year. This is due to the fact that the relative price has decreased for those groups with longer educations.

The increase in labour quality with constant and variable weights **G 22–2**

Intermediate Input

The intermediate input is divided into three categories, energy, materials and services. Input of energy consists of products in ISIC 10–12, 23 and 40. Material input consists of products in ISIC 01–05, 13–14, 15–37 exclusive 23, 41 and 45. Services are the total input of products in ISIC 50–95.

The growth in input per category is calculated as the percentage change in volume consumed. The relative effect of each category on the growth in total input is estimated as the weighted growth of the three parts. The weight's is calculated as the relative value of the three categories to the value of the total input in current prices. Consider $Z_{i,j,t}$ as the value of input of each category. Then the weight for each type of intermediate input is estimated as

$$\upsilon_{i,j,t} = \frac{Z_{i,j,t}}{\sum_i Z_{i,j,t}}, \qquad i \; i = \text{energy, material, services} \tag{18}$$

The average growth in intermediate input during the period 1994 – 2002 is higher in the goods sector than in the service sector. Except for energy input the growth is even higher in the manufacturing sector. But the overall strongest figures is derived in the ICT sector with growth rates three times as high as in the total business sector.

T22–2 Growth in intermediate input

		1994	1995	1996	1997	1998	1999	2000	2001	2002	94–02
Total business	Material	10.17	7.21	0.17	4.31	4.11	4.12	8.37	-0.53	-0.74	4.13
	Enery	0.04	0.61	8.80	-1.56	3.52	-1.34	0.35	0.59	-1.16	1.10
	Services	6.07	3.39	2.19	7.18	7.70	7.28	7.70	3.33	-2.53	4.70
Goods	Material	11.54	8.61	-0.06	5.14	4.44	4.44	8.94	-0.66	-0.66	4.64
	Enery	-0.19	1.04	11.76	-1.49	2.10	-1.95	1.08	0.26	-2.01	1.18
	Services	7.80	7.28	4.61	7.84	8.91	7.54	6.80	3.28	-4.41	5.52
Manufacturing	Material	14.00	10.48	0.08	6.24	4.34	4.78	9.86	-1.27	-0.49	5.34
	Enery	-1.34	1.46	5.91	3.31	-0.09	-1.00	5.14	-1.69	-4.24	0.83
	Services	9.89	9.84	5.05	8.12	10.22	8.30	7.53	3.41	-5.48	6.32
Services	Material	5.97	2.55	1.01	1.47	2.95	2.96	6.37	-0.07	-1.06	2.46
	Enery	0.55	-0.26	2.28	-1.73	6.65	-0.15	-1.16	1.36	0.75	0.92
	Services	5.22	1.42	0.90	6.82	7.03	7.14	8.21	3.35	-1.48	4.29
ICT	Material	23.34	28.80	21.43	11.89	10.95	20.15	25.78	5.39	-21.93	13.98
	Enery	-3.18	4.92	3.03	-5.77	14.01	7.41	7.09	5.73	-14.57	2.07
	Services	17.63	12.87	13.18	19.23	14.41	25.23	16.66	1.31	-12.51	12.00

Results

Intermediaries are as could be expected very important for the growth in gross production. The intermediaries can be split into three main components: energy, other materials and services. Together they account for a little more than half of the growth. Of these components, other materials are a little more important than services while energy is almost negligible. This means that the service society is not here yet. ICT capital services and non-ICT capital services are of almost equal importance, but the ICT capital service has a small edge. The

ICT capital service is thus during this time period more important than the input of all other capital service but together. This is a dramatic difference compared with the capital stock concept. The input of labour services is almost half as important as the capital service. Even if the quality has increased somewhat the quantity has not increased very much. And together they still cannot really match the total factor productivity, even if they are of the same magnitude. The intermediaries have as a whole developed quite parallel with gross output and consequently also with the value added. The service input has increased by a few per cent and the energy component has dropped substantially, or by around 20 per cent. But since the material input has had higher weights, especially in the beginning, its impact has been a little bigger.

T22–3 The growth in production and value added 1993-2004 decomposed

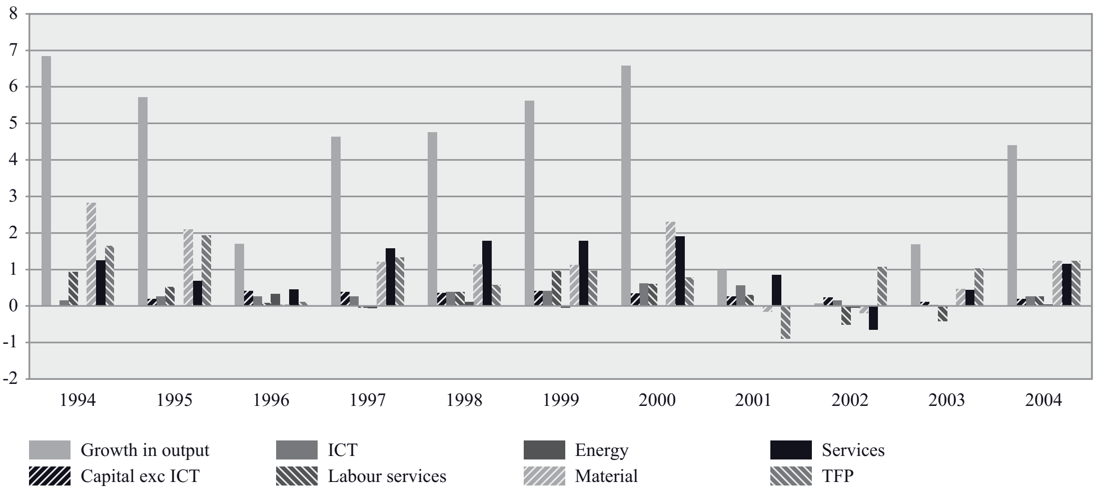
Production	1993-2004	Value added	1993-2004
	Per cent per year		Per cent per year
Growth in output	3.91	Growth in output	3.88
ICT capital service	0.31	ICT capital service	0.67
Non ICT capital service	0.26	Non ICT capital service	0.58
Labour services	0.28	Labour services	0.6
Intermediate consumption	2.16	TFP	2.03
Energy input	0.04		
Material input	1.1		
Service input	1.02		
TFP	0.89		

A decomposition of the growth of the value added gives us a total factor productivity which grows by a full 2 percentage points per year. This factor therefore accounts for a little more than half of the growth. This means that a little less than half of the growth can be explained by the increase in the inputs of the labour services, the ICT-capital services and the non-ICT capital services. Their relative importance is of course the same as above, but in absolute terms much higher.

In this calculation the capital input is measured as capital services which, as shown above, have increased twice as fast as the capital stock. This will of course increase the importance of the capital as an input factor and thus in parallel diminish the unexplained part of the growth, the total factor productivity. One of the short cuts we have taken in this, our first attempt to calculate the capital service input, has been to not take into account the tax effects. This will of course bias our estimate downwards. That means that if this will be included in our next effort, the measurement of the capital input will thus be increased.

In our measurement of labour quality we have lifted the common restriction on the weights so that they are not constant during our estimation period. That choice has led to a less rapid development of the labour quality measurement. This is due to the decrease of the relative price of some of the more attractive subgroups.

The growth of gross production decomposed 1993–2004
Per cent per year **G 22–3**



The growth pattern over the years is for most variables influenced by cyclical as well as trend components. The cyclical pattern is very distinct for inputs of materials as well as for services, as could be expected. The cycle is defined here as the development of the gross production of the business sector. This is however not true for input of energy. Perhaps this is due to the fact that most of the energy input is used in just a handful of industries and that the developments of these industries are not synced with the general production fluctuations.

In this rather short time period there is also quite a distinctive trend in the total input of intermediates, caused by services. The relative weight of material inputs in total production has no trend, and the same is true for the energy input. This is true at least up to 2002, which is our last observation; now this can have changed. In contrast the importance of services has increased 20 to 25 per cent relative to the production. This is almost entirely due to the increase in their relative price, even if there also has been a slight increase in volume terms. If this was true it could be interpreted as an indication that the service society is not approaching very fast. It is just a question of increased relative price due to slow growth in productivity. However, a reservation for the lack of good price measurement for the majority of the service industries during most of this period, and for some for the whole period, must be made. So probably the volume development of services is underestimated and the price increase overestimated.

The constancy of the weight of energy input is a result of the strong trends with higher prices and lower volumes. This means that it has been possible for the enterprises to diminish their energy intensity as a response to increasing relative prices. This has not been possible for the services, so this can be seen as a clear sign of the increasing importance of services.

The input of labour services has, like the intermediate input, a strong cyclical pattern, but no trend. As in the energy case, these are two balancing factors with distinctive trends that are hidden behind. The labour quality has a strong positive trend but quantitatively the trend is biased downwards.

The development of capital input has however a quite different pattern. There is an expansion of capital input from 1993 up to 2000 and then a contraction to 2003, our last observation. This is mainly caused by the ICT investment which has accounted for more than half of the capital service input during the whole period, but the proportion between non-ICT and ICT inputs has varied a lot. The increase in the ICT service input was much higher 2000–2001 and clearly lower 2002–2003, the years after the ICT crisis. This crisis has apparently not meant a decrease in the ICT capital input but a very distinctive slow down in the expansion rate. The expansion of the non-ICT capital service has been very stable but there was an acceleration during the first couple of years and a deceleration during the very last years.

There is still around one per cent of the yearly growth in production and two per cent in value added that is not accounted for, the total factor productivity. This is thought to be due to increased knowledge of different kinds together with new combinations and use of older knowledge. There should be a clear cyclical pattern in total factor productivity due to difference in capital utilisation and labour hoarding in different phases in the business cycle. This can also be found in our data, but the most interesting part is of course the other part, the level and the trend. The level is quite high internationally and probably distinctively much better than it could have been during the two previous decades, if it was measured. There is no trend even if the level that was achieved during the first two years after the big economic crisis 1991–93 has not been reached since.

The Sector Differences

When looking into the different sectors we see the largest contribution on average to growth in output from intermediate input in all sectors. Intermediate input is the factor with the highest weight in the model. Every percentage point of growth in intermediate input contributes with at least half a percentage point in output growth in all sectors.

The sector where the largest contribution to growth in output stems from capital input is the service sector. The contribution from non-ICT capital is larger than the contribution from ICT capital in the goods and the manufacturing sector. In the service sector and in the ICT sector the contribution from ICT capital is larger. The difference between non-ICT capital and ICT capital is in general small except in the ICT sector. In the ICT sector the effect of ICT capital is twice the effect of non-ICT capital.

Relative to the growth in output, the largest impact of labour services is seen in the service sector. However, the contribution from labour services is in general small. In both the goods and the service sector, the contribution of labour services is less than half of the capital services.

In all four sectors, half, or almost half, of the growth in production is explained by intermediate input. All sectors except the service sectors show a larger contribution from materials than from services. The contribution from material input to the growth in the goods sector is more than double the contribution from service input. Contrary to this is the service sector, where the contribution of service input is four times the input of materials.

When comparing the input of energy, both the service sector and the manufacturing sector display lower figures than the goods sector. This is explained by the fact that industries included in goods but excluded in manufacturing have had higher weights for the energy input. These sectors include, above all, the electricity, gas and water works sector but also the construction industry, mining and quarrying and agriculture, forestry and fishing sectors. Overall, the contributions from energy input are very low on average and in many cases close to zero.

Total factor productivity plays an important role for the growth in gross production in all sectors except the service sector. In the business sector the contribution from TFP is, as mentioned earlier, 0.89 percentage points on average. This should be compared with the goods sector where the contribution from TFP is 1.38 percentage points on average and the manufacturing industry is at 1.74 percentage points. In the service sector the contribution from TFP is only one tenth of the growth in production. The largest contribution of TFP is seen in the ICT sector where TFP explains more than a third of the growth in production. On average the size of the ICT sector is about ten per cent of the total business sector. According to this, more than half of the growth in TFP in the total business sector at 0.89 per cent, stems from the ICT sector.

T 22 – 4 Contribution to the growth in gross production by different factors
Goods sector

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	94-02	94-04
Growth in output	9.09	8.16	1.87	5.09	5.19	5.57	7.32	0.12	0.09	1.78	7.14	4.72	4.68
Capitalinput	-0.04	0.31	0.50	0.51	0.51	0.47	0.43	0.34	0.13	0.00	0.18	0.35	0.30
Non ICT	-0.14	0.13	0.34	0.36	0.31	0.25	0.19	0.14	0.09	0.02	0.09	0.19	0.16
ICT	0.10	0.17	0.16	0.15	0.21	0.22	0.23	0.20	0.04	-0.02	0.09	0.16	0.14
Labour services	0.41	0.95	-0.19	-0.39	0.31	0.36	0.27	0.25	-0.48	-0.48	0.33	0.17	0.12
Intermediate consumption	5.97	4.78	1.25	3.30	3.44	3.11	5.06	0.34	-1.19	1.09	4.38	2.90	2.87
E	-0.01	0.04	0.60	-0.07	0.09	-0.08	0.06	0.01	-0.10	0.02	0.09	0.06	0.06
M	4.92	3.77	-0.03	2.17	1.88	1.87	3.80	-0.28	-0.28	0.75	2.99	1.98	1.96
S	1.06	0.97	0.67	1.20	1.47	1.32	1.20	0.61	-0.81	0.32	1.29	0.86	0.85
TFP	2.76	2.13	0.32	1.67	0.93	1.62	1.56	-0.80	1.62	1.17	2.26	1.31	1.38

T 22 – 5 Contribution to the growth in gross production by different factors
Manufacturing Industry

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	94-02	94-04
Growth in output	12.54	10.44	2.23	6.79	6.30	6.50	8.81	-0.76	0.18	2.57	8.98	5.89	5.87
Capitalinput	0.01	0.47	0.68	0.63	0.57	0.50	0.39	0.29	0.10	-0.03	0.15	0.40	0.34
Non ICT	-0.11	0.26	0.49	0.46	0.34	0.26	0.15	0.09	0.06	-0.00	0.06	0.22	0.19
ICT	0.13	0.21	0.19	0.17	0.23	0.25	0.24	0.20	0.04	-0.02	0.09	0.18	0.16
Labour services	0.87	1.28	0.14	-0.19	0.37	0.02	0.42	0.25	-0.61	-0.50	0.23	0.28	0.21
Intermediate consumption	8.02	6.55	1.11	4.39	3.85	3.73	6.19	0.03	-1.52	1.57	5.48	3.59	3.58
E	-0.06	0.05	0.26	0.14	-0.00	-0.04	0.25	-0.08	-0.20	0.02	0.06	0.04	0.04
M	6.60	5.06	0.04	2.89	2.00	2.17	4.49	-0.58	-0.22	1.09	3.80	2.49	2.48
S	1.47	1.44	0.81	1.35	1.85	1.60	1.45	0.70	-1.10	0.46	1.62	1.06	1.06
TFP	3.63	2.14	0.31	1.96	1.51	2.25	1.81	-1.33	2.22	1.53	3.12	1.61	1.74

T 22 – 6 Contribution to the growth in gross production by different factors
Services sector

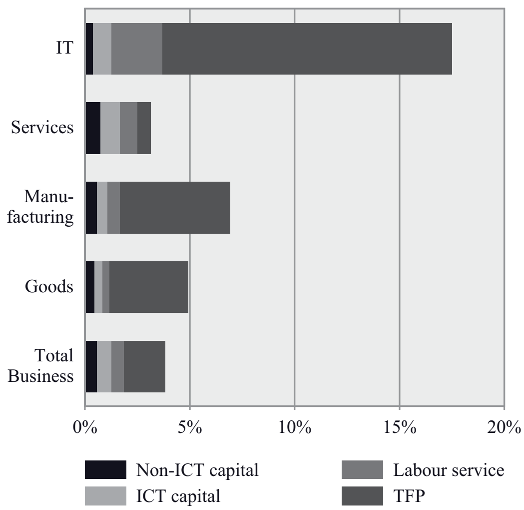
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	94–02	94–04
Growth in output	4.67	3.20	1.52	4.18	4.30	5.67	5.82	1.82	0.07	2.18	2.18	3.47	3.24
Capitalinput	0.31	0.61	0.82	0.77	1.01	1.22	1.57	1.38	0.92	0.51	0.86	0.96	0.91
Non ICT	0.12	0.24	0.46	0.40	0.42	0.58	0.48	0.36	0.62	0.42	0.38	0.41	0.41
ICT	0.19	0.37	0.36	0.38	0.59	0.64	1.09	1.02	0.30	0.09	0.48	0.55	0.50
Labour services	1.38	0.20	0.29	0.15	0.59	1.58	0.98	0.35	-0.42	-0.31	0.27	0.57	0.46
Intermediate consumption	2.24	0.72	0.43	2.13	2.65	2.60	3.39	1.13	-0.59	1.02	1.02	1.63	1.52
E	0.01	-0.01	0.05	-0.04	0.15	-0.00	-0.03	0.03	0.02	0.01	0.01	0.02	0.02
M	0.78	0.34	0.13	0.19	0.37	0.37	0.77	-0.01	-0.12	0.20	0.20	0.31	0.29
S	1.44	0.39	0.25	1.98	2.13	2.24	2.65	1.10	-0.48	0.81	0.81	1.30	1.21
TFP	0.74	1.67	-0.02	1.12	0.05	0.26	-0.12	-1.03	0.17	0.95	0.02	0.32	0.35

T 22 – 7 Contribution to the growth in gross production by different factors
ICT sector

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	94–02	94–04
Growth in output	21.31	23.39	19.62	18.60	15.70	21.32	19.74	2.44	-9.73	6.02	24.22	14.71	14.78
Capitalinput	-0.04	0.49	0.65	0.40	0.54	0.60	0.68	0.69	0.31	0.02	0.36	0.48	0.43
Non ICT	0.29	0.26	0.28	0.15	0.18	0.16	0.04	0.08	0.03	-0.00	0.04	0.17	0.14
ICT	-0.34	0.23	0.37	0.25	0.36	0.44	0.63	0.61	0.28	0.02	0.32	0.31	0.29
Labour services	1.36	1.98	1.74	0.96	1.38	2.31	2.82	1.68	-3.37	-1.63	-0.06	1.21	0.83
Intermediate consumption	12.12	13.55	10.76	9.86	8.20	15.46	14.81	2.27	-10.95	3.46	13.92	8.45	8.50
E	-0.02	0.02	0.01	-0.02	0.05	0.03	0.02	0.02	-0.05	0.00	0.01	0.01	0.01
M	7.18	9.95	7.04	3.85	3.46	6.38	8.69	1.79	-6.36	1.91	7.68	4.67	4.69
S	4.95	3.58	3.71	6.03	4.68	9.05	6.10	0.46	-4.54	1.55	6.22	3.78	3.80
TFP	7.88	7.37	6.47	7.37	5.58	2.94	1.43	-2.20	4.28	4.17	10.00	4.57	5.03

Turning to the growth in value added the average contributions of factor inputs to the growth are displayed in graph 22–5. The weight of the intermediate input relative to capital and labour differs between the service industry and the other industries, with manufacturing having the largest share of 69 per cent, followed by the ICT sector and the goods sector at 66 and 64 per cent respectively. The service sector has a substantially smaller share of intermediate inputs, only 44 per cent. This gives the total business sector a share of intermediate input of 55 per cent. Eliminating the effects of growth in intermediates by decomposing the value added instead of the gross production results in a similar picture as described earlier. However, all the factor inputs increase proportionally as does TFP. The magnitude of this difference is proportionate to the share of the intermediate input in each sector. The higher estimate of TFP for value added relative to TFP for gross production is thus largest in the manufacturing industry. However, the overall largest contribution of TFP, by far, is recorded in the ICT sector where the growth rises from 5.03 to 13.8 percentage points. The growth in TFP in the ICT sector is more than double the growth in the second ranked sector.

Average contribution by factors to the growth in value added 1994–2004 G 22–4



Effects on Labour Productivity

Table 22–8 shows the growth rates in gross production and the growth rates in average labour productivity, ALP, in the total business sector. The growth rate in ALP is calculated by subtracting the growth rate of hours worked from the growth rate of output. Further, the growth rate of ALP is decomposed in the table by the contributions from capital deepening, labour quality, intermediate input per hour worked and TFP.

This decomposition shows that intermediate input per hour worked is the largest contributor to the growth in labour productivity by 1.72 per cent. The contribution from capital deepening by 0.38 percentage points is almost a tenth of the growth in total output. The main part of that stems from ICT capital which contributes almost three times that of non-ICT capital. Substitution towards labour with higher marginal productivity has contributed by 0.09 per cent per year. Average TFP growth rate is 0.89 per cent. The highest TFP rates appear in the beginning of the period, 1994 and 1995. Also in the last part of the period, 2002 to 2004, the TFP growth is higher than average. This period recognising firms reducing their working staff and trimming their organizations.

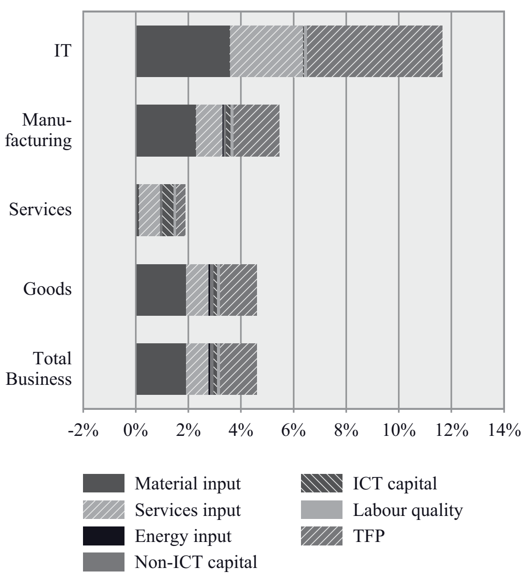
Graph 22–5 presents an overview of the decomposition of average labour productivity, ALP, for all the sectors. Overall, contributions from TFP and intermediate input of materials and services explain the main part, on average, of the growth in ALP for just about all sectors. The contribution from capital deepening is larger than the contribution from labour quality

T 22 – 8 Contribution to the growth in labour productivity by the Business sector by different factors

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	94–02	94–04
Growth in output	6.84	5.71	1.70	4.64	4.75	5.62	6.57	0.98	0.08	1.69	4.40	4.10	3.91
Hours worked	2.75	2.82	-0.15	-1.01	1.75	3.50	2.04	0.73	-2.13	-1.94	0.72	1.14	0.83
Growth in ALP	4.09	2.90	1.85	5.65	3.01	2.12	4.53	0.24	2.21	3.63	3.68	2.96	3.08
Capital deepening	-0.49	-0.22	0.70	0.87	0.38	0.11	0.57	0.69	0.79	0.48	0.33	0.38	0.38
Non ICT	-0.57	-0.41	0.44	0.58	0.06	-0.18	0.06	0.17	0.53	0.36	0.10	0.07	0.10
ICT	0.08	0.19	0.27	0.29	0.32	0.30	0.52	0.52	0.26	0.13	0.23	0.31	0.28
Labour quality	0.27	-0.13	0.13	0.19	-0.05	0.11	0.09	0.12	0.05	0.09	0.09	0.09	0.09
Intermediate input	2.66	1.32	0.91	3.26	2.10	0.94	3.08	0.31	0.30	2.02	2.03	1.65	1.72
E	-0.09	-0.07	0.33	-0.02	0.06	-0.15	-0.06	-0.01	0.04	0.09	0.02	0.00	0.01
M	2.07	1.27	0.09	1.48	0.66	0.17	1.74	-0.34	0.37	1.00	1.05	0.83	0.87
S	0.68	0.12	0.49	1.80	1.38	0.92	1.41	0.66	-0.10	0.93	0.97	0.82	0.84
TFP	1.65	1.93	0.11	1.33	0.57	0.96	0.78	-0.89	1.07	1.03	1.24	0.83	0.89

in all sectors except in the ICT sector. In the services sector we see the largest effect on ALP is from capital deepening. The smallest effect from capital deepening is seen in the ICT sector. The effect of labour quality does not diverge much from the business sector in any of the sectors. TFP, relative to labour productivity, is largest in the ICT sector and smallest in the service sector. In the goods and manufacturing sectors the effect of TFP on labour productivity is about the same as in the total business sector.

Average contribution by factors to the growth in labour productivity 1994–2002 **G 22–5**



Conclusions

As has already been underlined, the objective of this study is to improve the measurement of economic growth in the Swedish business sector by growth accounting experiments. But it is important to remember that the growth accounting methodology is just a technique to decompose the growth and that it cannot answer the question of why the growth was high or low or what caused it. Nevertheless, it gives valuable data for further analysis of these important questions.

In this experiment we have focused on three methodological concepts. We have decomposed the gross output of the business sector instead of the value added, used capital service instead of capital stock as capital input and allowed for variable weights for different categories of the labour service input.

The analyses of input of intermediates give us the insight that they are very important for the growth in gross production, and their importance has grown over the years. This is caused by the service input that has increased slightly in volume but more strongly in price terms. The increase in relative price for the intermediate input of energy has in contrast been balanced by a very substantial decrease in its relative volume. This is true for the service sector as well as for the goods sector, and that sector's dominant part, the manufacturing industry. This means that the material input into the manufacturing sector has neither increased during the period 1993–2002 in value terms, nor in volume terms.

The change of measuring the input of capital from capital stock to capital services has increased the importance of capital inputs, since capital services have increased twice as fast as the capital stock. This is primarily due to the ICT investments that have increased dramatically in importance during this period, accounting for just over half of the capital services for the whole period. Both high depreciation rates and low or negative price increases lie behind the high cost of ICT capital services. But also the capital service input of the non-ICT machinery has increased quite substantially. And it is of course the capital services of buildings and interiors that has balanced this by almost dramatically decreased importance. All these developments have also lead to an almost continuous capital deepening during our studied time period.

Instead of using constant value weight for the different categories of labour and allowing for changing weights over time, the growth of the input of labour services has been lower. This is due to that most categories of qualified labour have decreased their relative prices, caused by a considerable increase in their supply.

The OECD is publishing TFP measurement of many of the OECD-countries on their website. These TFP measurements are in value added terms for the whole economy including the public sector. A very rough translation of our results into value added for the whole economy, that is GDP, give on average very similar results to the OECD data. But the time profile differs somewhat since the OECD-figures have a marked higher growth rate the last years and lower the first years. In the OECD material the Swedish TFP performance is above average, but not in any way extreme.

23. ESTIMATES OF LABOR AND TOTAL FACTOR PRODUCTIVITY BY 72 INDUSTRIES IN KOREA (1970–2003)

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Pukyong National University respectively.

Introduction

In recent years, especially since the 1997 economic crisis in the East Asian countries including Korea, considerable changes have taken place in the Korean economy, such as investment stagnation (see e.g. Pyo (2006) Pyo and Ha (2005)), changes in production input patterns, and so on. One of the most important changes is the demand for high productivity, which would compensate the recent slowdowns of growth rates in capital and labor inputs. As Krugman (1994), Young (1994), and Lau and Kim (1994) showed, the East Asian economic miracle may be summarized as `input-led' growth. Korea was no exception in this respect of growth pattern.

However, both the stagnation in investment and the decrease in average working hours require a productivity surge for long-term growth in Korea. In addition, a sharp decrease in the fertility rate in Korea necessitates productivity increase in order to improve the present income level and facilitate the support of the large elderly population by the small numbers of working age adults. For these reasons, `productivity-driven' growth is indispensable for Korea. According to Lewis (2004), the fast economic growth in Korea is the result of both large labor input and capital accumulation. He argues that the average working hours is 40% higher than that of the U.S., and almost a third of GDP has been allocated to investment, while GDP per capita in Korea is about half of the U.S. GDP per capita. The focus is changing from how much inputs are put into production to how well those are organized.

The purpose of this paper is to explain the data structure of Korea for the estimation of productivities by industry in KLEMS model and present preliminary estimates of labor productivity and total factor productivity (TFP) at reasonably detailed industry level. We have used 72-sector industrial classification following the guidelines of EU KLEMS project for the future comparability with EU member countries, the United States, and Japan. Therefore, an analysis based on detailed industrial classification gives us better views on productivity and growth, which is difficult to grasp in broader industrial classifications. Industries in an economy

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have shown different productivity trends and growth patterns according to their characteristics of production, competition policies, and other economic and non-economic circumstances.

KLEMS model is a kind of gross output growth accounting in which output is measured by gross output and inputs are decomposed by capital (K), labor (L), energy (E), material (M), and service (S). Since this methodology is basically based on gross output, it has the advantage of eliminating effects of intermediate inputs from other industries on productivity, therefore allowing productivities by industry to be more accurate. Moreover, the assumption on real value-added production function (separability assumption) is not usually guaranteed[344], which also gives legitimacy to gross output growth accounting. However, gross output growth accounting requires more information on intermediate inputs than value-added growth accounting. Therefore, the data structure for estimating productivity has to be consistent with not only national income accounts but also input-output tables, Use and Make Matrix etc. and the estimation methodology for unavailable data should be examined more carefully.

We have found that Korea's catch-up process with industrial nations in its late industrialization has been predominantly input-led and manufacturing based. We have also found that TFP growth has been positively affected by the growth of labor productivity and output growth. However, since its financial crisis in December 1997, the sources of growth seem to have switched to TFP-growth based and IT-intensive Service based. But lower productivity in service industries due to regulations and lack of competition seems to work against finding renewed sustainable growth path.

This paper is organized as follows. Section 2 examines data structure including the methodology of measuring gross output by industry from Input-Output Tables and National Accounts published by the Bank of Korea and input measurements. Section 3 presents the estimates of labor productivity and TFP by 72-industry and examines the relations between labor productivity and TFP and between output growth and TFP growth by periods. Section 4 concludes the paper.

Data Structure

Gross Output Data

National Accounts by the Bank of Korea (1999, 2004) report annual series (1970–2002) of nominal gross outputs at basic prices, both nominal and real value-added at basic prices, nominal compensation of employees, and operating surplus at current prices of 21 industries including 9 manufacturing industries. Those data can be extended to the year 2005 from ECOS (Economic Statistics System) in the Bank of Korea website[345]. National Accounts (1987, 1994, 1999, 2004) also reports annual series (1985–2002) of both nominal and real Make Tables (V-Tables) and real Use Tables (U-Tables).

[344] See Berndt and Christensen (1973,1974), Berndt and Wood (1975), Denny and Fuss (1977), and Yuhn (1991) for the U.S., and Pyo and Ha (2005) for Korea

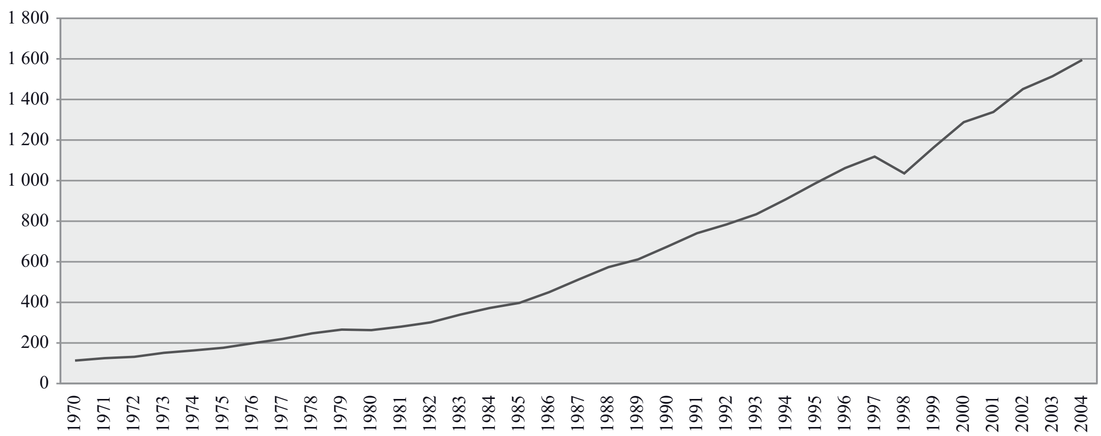
[345] http://www.bok.or.kr

In addition to nominal gross output and both nominal and real value-added, real gross output at basic prices and real intermediate inputs at purchase prices can be obtained from Use Tables. However, since Make Tables and Use Tables for the years 1970–1984 and 2003–2004 are unavailable, we have generated them through RAS method using annual data from National Accounts and Input-Output Tables, and benchmark tables of 1985 and 2000, respectively. As the published Use Tables of National Accounts in Korea present the Domestic and Import Use Tables combined, we have not been able to isolate them into two separate tables. In the case of Use Tables before 1995, all the intermediate commodity inputs by industry are measured at purchase prices. Since 1995, those inputs have been measured at incomplete basic prices in the sense that those inputs include trade and transportation margins but isolate net production tax to the last row of intermediate input matrix. Because we have no information for transformation of the Use Tables from purchase prices to basic prices before 1995 and the Use Tables after 1995 have been measured at incomplete basic prices, we have changed the Use Tables at basic price after 1995 into Use Tables at purchase price allocating net production tax to each commodity proportional to each volume.

The trend of gross output has been shown in graph 23–1. There was no real break in gross output growth in Korea's economy-wide economic performance except in the year 1998 after the financial crisis in December 1997. Even during the years of first oil crisis of 1974–1975 and the second oil crisis of 1980–1981, the Korean economy's real gross output continued to grow without major setbacks. After the economic crisis of December 1997, Korean economy had to go through IMF-mandated adjustment and restructuring program as documented in Pyo (2004). We observe that even though economy-wide labor productivity continues to grow, the disparity between labor productivity in Manufacturing and that in Service has been widening. As the IMF-mandated restructuring in Manufacturing sector has improved on labor productivity gain through cut-back of unnecessary manpower, the restructuring in most of Service sectors except a few IT-related finance and communication sectors has been lagging behind.

Trend of Real Gross Output
(2000 prices)

G 23–1



Measurement of Capital Input

The success of late industrialization by newly industrializing economies could not have been made possible if both the rapid accumulation of capital and its changing distribution among sectors were not realized in their development process. However, it is difficult to identify these factors empirically because the time series data of capital stocks in fast-developing economies by both types of assets and by industries are not readily available. The lack of investment data for a sufficiently long period of time to apply the perpetual inventory estimation method was the main cause of the problem. However, the National Statistical Office of the Republic of Korea has conducted nation-wide national wealth survey four times since 1968. Korea is one of a few countries which have conducted economy-wide national wealth surveys at a regular interval. Since the first National Wealth Survey (NWS) was conducted in 1968, the subsequent surveys were made in every ten years in 1977, 1987, and 1997, respectively. Since such regular surveys with nation-wide coverage are very rare in both developed and developing countries, an analysis on the dynamic profile of national wealth seems warranted to examine how national wealth in a fast growing economy is accumulated and distributed among different sectors.

The estimation of national wealth by types of assets and by industries was made by Pyo (2003) by modified perpetual inventory method and polynomial benchmark year estimation method using four benchmark-year estimates. We have extended his estimates to the year 2004, and changed the base year from 1995 to 2000. Since the database of Pyo (2003) covers 10 broad categories of industrial sector together with 28 sub-sectors of Manufacturing, it has been reclassified and reconciled with 72 industry classification using other sources such as Mining & Manufacturing Census and Surveys, Wholesale and Retail Surveys, and so on. We have classified assets into five categories; residential building, non-residential building, other construction, transportation vehicles, and machinery, while excluding large animals & plants, household durables, and inventory stocks. We have used estimated depreciation rates in Pyo as shown in table 23–1.

T 23 – 1 Estimated Depreciation Rates of Assets (%)

	1968–1977	1977–1987	1987–1997
Total	5.1	5.7	4.6
Residential Building	5.5	1.2	3.3
Non-residential Building	-6.7	-1.3	3.0
Other Construction	9.7	8.4	1.0
Transportation Vehicles	49.3	28.7	16.9
Machinery	1.1	11.4	9.2

Source: Pyo(2003)

In order to derive capital service inputs from capital stocks, we have followed the method of Jorgenson, Ho, and Stiroh (2005) except the adjustment for a rapid IT asset price decline. The capital service flows for each asset have been estimated from the capital stocks, and have been aggregated over all the assets assuming that the flow of capital service is proportional to the average of current and one-year lagged capital stocks, which means that currently installed capital stock is available in the midpoint of the installed period. We have estimated the price of capital service through the user cost of capital formula. This methodology derives the cost of capital by the equality between two alternative investments: earning a nominal rate of return and investing in asset earning a rental fee and selling the depreciated asset. We have used yields of corporate bonds for nominal rates of return and Pyo's (2003) results for depreciation rates as shown in table 23–1. We did not consider tax effects in estimating cost of capital for the unavailability of data.

Measurement of Labor Input

In order to measure labor input for KLEMS model, we have to obtain both quantity data of labor input such as employment by industries and hours worked and quality factors such as sex, education and age. Both availability and reliability of labor statistics in Korea have improved since 1980. But the measurement of labor input by industries cannot be readily made because the statistics of employment by industries are not detailed enough to cover 72 sectors. Therefore, we have used other sources for breaking down the labor data. More detailed classifications of employment will have to rely on Employment Table, which is published as a supporting table to Input-Output Table. But it is available only every five year when main Input-Output Tables are published. Mining and Manufacturing Census and Survey by National Statistical Office also report employment statistics but it is limited to mining and manufacturing only.

Economically Active Population Yearbook by National Statistical Office reports the number of employment, unemployment, not-economically-active population and economically active population. Report on Monthly Labor Survey by Ministry of Labor publishes monthly earnings and working days of regular employees. Survey Report on Wage Structure by the same ministry reports wages. Nominal wages are also available from this survey. For the present study, we have obtained the raw data file of Survey Report on Wage Structure from the Ministry of Labor and Economically Active Population Survey from National Statistical Office for the period of 1980–2003. The data are classified by two types of gender (Male and Female), three types of age (below 30, 30–49, and 50 above), and four types of education (middle school and under, high school, college, and university above) and, therefore, there is a total of 24 categories of labor as shown table 23–2.

Since the raw-data file of the Survey Report on Wage Structure contains more detailed industrial classification than that of the Economically Active Population Survey, we have calculated the quantity of labor from the Economically Active Population Survey and the quality of labor from the Survey Report on Wage Structure. This enables us to include self-employed labor as well as to use more detailed data. However, since the Survey Report on Wage Structure does not include Agriculture and Government sectors, we had to use the average value of the entire economy for the quality measure of these two sectors. In order to make quality adjustments to the employment data, we have taken the method of Jorgenson, Gollop, and Fraumeni (1987).

T 23 – 2 Classification of Labor Input

Categories	
Gender	(1) male (2) female
Age	(1) below 30 (2) 30–49 (3) above 50
Education	(1) middle school and under
	(2) high school
	(3) college
	(4) university or above

Energy, Material, and Service and Input Shares

In order to decompose intermediate inputs into energy (E), material (M), and service (S) inputs, we have identified coal and lignite, crude petroleum and natural gas, uranium and thorium ores, metal ores, coke, refined petroleum products and nuclear fuel, gas, water, and electricity commodities as energy inputs, both primary commodities and remaining manufacturing commodities as material inputs, and remaining service inputs as service inputs.

Regarding shares of inputs, we have used compensation of employees as shares of labor inputs and remaining value-added as shares of capital inputs. This method may underestimate the shares of labor input by allocating the compensation of self-employed to the shares of capital input, and this gap would be especially large in primary industry. There are some adjustment processes to correct underestimation of labor share as attempted by, for example Harberger (1987), but we have not applied it in order to avoid arbitrary adjustments. This can be improved in future studies. As for energy, material, and service inputs, we have used nominal inputs for their own shares.

Estimates of Labor Productivity and TFP by 72-industry

Trend of Labor Productivity Level and Growth Rates by Sector

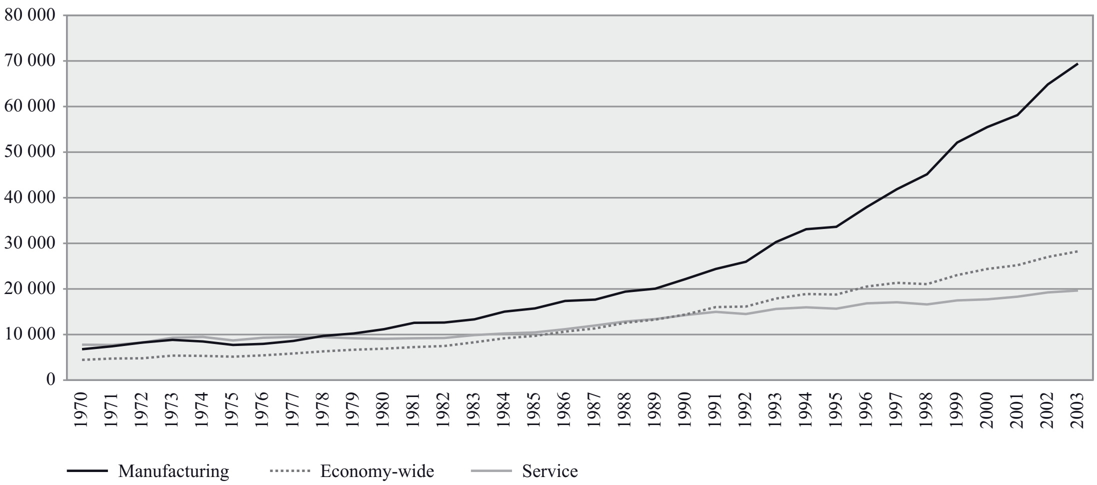
(1) The Level and Trend of Labor Productivity

As shown in graph 23–2, the general trend of labor productivity reveals a rising trend but with a remarkable difference between Manufacturing and Service. While the labor productivity level in Manufacturing measured as the ratio of real price output to working hours increased sharply, the level in Service increased very slowly. The role of productivity gain in Manufacturing in the catch-up process of Korea has been well-documented by Timmer (1999) and Pyo (2001). As observed in Pyo and Ha (2005), the labor productivity level was not reduced during the years (1997–1998) of the Asian Financial Crisis because of IMF-mandated industrial restructuring: the reduced output was matched by reduced employment leaving labor productivity level unaffected.

The relatively sluggish productivity gain in Service sector has been pointed out by IMF in their recent consultation with the Korean authorities as a bottleneck of sustainable growth for Korea. Inklaar, Timmer and van Ark (2006) also pointed out the slower productivity gain of service industries in Europe relative to those in the United States. A more detailed decomposition of labor productivity by sector and by sub-period is presented in Table 4. According to Kim(2006), while the share of Service sector in Korean economy has increased sharply reaching 56 percent level of GDP and 65 percent of total employment in 2005, the Service productivity is not only low in level terms compared to industrial nations' levels but also lags behind in terms of growth rate. She also points out that Korea's inter-industry linkage effect between Manufacturing and Service is also only about half the size of industrial nations.

Trend of Labor Productivity Level
<gross output per hour (won)>

G 23–2



(2) The growth rates of labor productivity by Sector

The growth rates of labor productivity as summarized in table 23–3 confirm the remarkable difference between Manufacturing and Service sector. Throughout the entire period of 1972–2003, the economy-wide labor productivity has grown at the average rate of 5.59 percent but with the sectoral difference between Manufacturing (6.99 %) and Service (2.91 %). The difference did not shrink but rather has expanded as the process of industrialization continued. For example, the difference in the 1990's (9.55 % vs. 2.64 %) has been more than doubled since 1970's (4.01 % vs. 2.15 %).

The observed difference in both levels and growth rates of labor productivity between Manufacturing and Service can signal the difference in the degree of foreign competition, the proportion of tradable and non-tradable and the degree of domestic competition due to historically different regulatory environments. For example, the proportion of public enterprises and their subsidiaries in total output of many service industries such as utilities (electricity, water and gas), transportation and communication is a lot greater than their proportion in Manufacturing so that their productivity improvement could have been sluggish over time. In addition, many non-tradable sectors of service industries such as retail trade, real estate and financial services, hotels and restaurants etc. have been subject to all kinds of regulations such as zoning, sanitary standards and segregated financial market services etc.

T 23 – 3 Growth Rtaes of Labor Productivity by Sector (%)

Period	Economy-wide	Manufacturing	Service
72–'79	4.32	4.01	2.15
80–'89	6.87	6.75	3.77
90–'99	5.54	9.55	2.64
90–'98	5.14	9.01	2.40
99–'03	5.87	8.61	3.33
72–'03	5.59	6.99	2.91

Gross Output Growth Accounting and TFP Growth

The growth rate of economy-wide TFP has been estimated as -0.59 percent. The growth rates of TFP in Manufacturing and Service are estimated as 0.48 percent and -0.92 percent respectively throughout the entire period of 1972–2003 as shown in table 23–4. Also the economy-wide TFP growth rate during the pre-crisis period (1990–1998) has been estimated as -0.84 percent**.** And the growth rate during the post-crisis period (1999–2003) has been estimated as 0.86 percent.

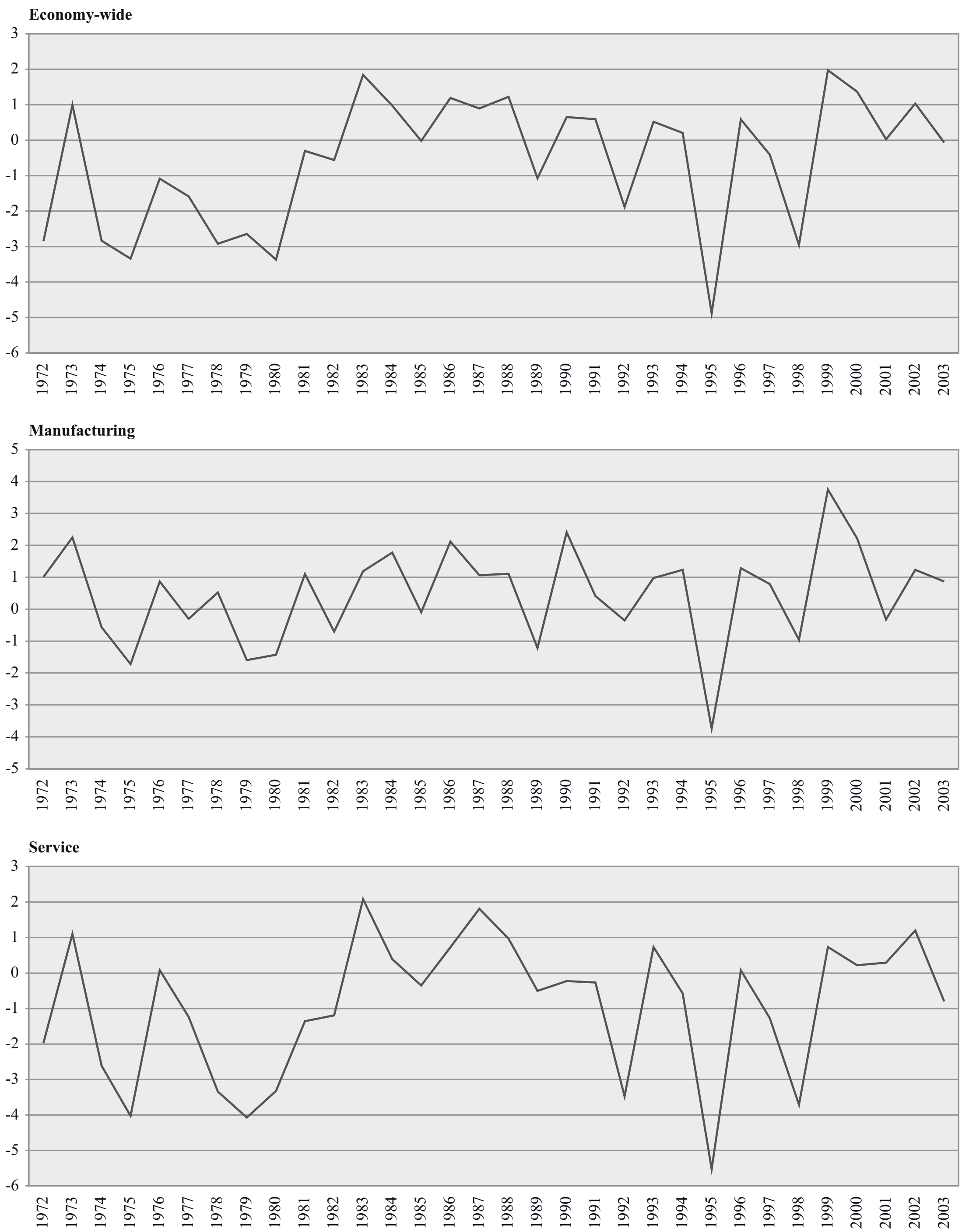
(1) The Level of TFP Growth and its Trend by Sector

The growth rates of TFP by sector are shown in graph 23–3. Throughout the entire period 1972–2003, Korean economy experienced about 2 break-points: mid-1970s which was the first oil shock and in 1997 which was the financial crisis. The difference between two break points can be summarized as follows. During the second half of 1970's, the growth rate of gross output was not low, but the growth rates of inputs such as capital(4.56%), labor(1.79%), energy(0.69%), intermediate goods(3.34%) especially, were relatively higher. Therefore, the growth rates of TFP have been estimated as negative. In case of late 1990's the negative growth of TFP has been resulted from the shrink of gross output rooted from economic crisis.

In addition we observe that the estimated TFP growth rates in Manufacturing are in general greater than in Service. It maybe due to the fact that innovation processes such as product innovation or process innovation are more sensitive and stronger in manufacturing than in service. Also the R&D investment for innovation is in general more intensive in manufacturing than in service. So the growth rates of TFP in Manufacturing seem to be greater than in Service.

After the economic crisis in 1997–1998, the economy-wide growth rate of gross output has been recovered, at the same time the growth rates of input factors such as capital, labor and service have also been reduced from those during the pre-crisis period. Accordingly, the growth rate of TFP during the post-crisis period has been relatively higher than that during the pre-crisis period. Secondly the contributions of TFP to economy-wide gross output growth during the entire period of 1972–2003 are -7.5 percent, and 4.7 percent in Manufacturing, and -12.8 percent in Service. Then we can examine the relative contribution ratio of the input factors to the output growth. The relative contribution ratios to output growth during the entire period are in order of intermediate goods (52.3 %), capital (15.6 %), energy (11.3 %), service (10.2 %), labor (5.8 %) in Manufacturing. So the innovation or the role of intermediate goods for enhancing productivity is more important in Manufacturing than in Service. And the contribution ratio of TFP to Manufacturing output growth (4.7 %) is of rather insignificant magnitude. On the other hand, in Service the contribution are in order of capital (48.7 %), service (23.9 %), labor(20.1 %), intermediate goods(15.8 %), energy (4.2 %). Hence we can see the input's role for enhancing productivity is different between Manufacturing and Service.

The Growth Rates of TFP (%) — G 23–3



Thirdly the total factor productivity growth in gross output growth accounting is lower than that without quality adjustment in input data. The quality of labor has affected the growth of output about 2.4 % in Manufacturing and 3.9 % in Service during the entire period, Also the quantity of labor has affected the growth of output by about 3.4 % in Manufacturing and about 16.3 % in Service during the entire period, Thus the labor input in Service has influenced output growth both in quantity and quality of labor than that in Manufacturing. The quantity of labor input in Manufacturing has been reduced during the pre-crisis period. It reflects a drastic structural adjustment in Korea's labor market after the crisis of 1997–1998. As a consequence, the contribution rate of labor to output growth has become negative in Manufacturing after the crisis. In Service, Post and telecommunication which is related strongly with IT technology has recorded a relatively higher growth rate (4.93 %) of TFP among service sectors.

On the one hand the sectors which were based on IT technology such as i) Office, accounting and computing machinery (1.91 %), ii) Other electrical machinery (2.45 %), iii) Electronic valves and tubes(2.87 %), iv) Telecommunication equipment (2.13 %) in Manufacturing, have shown higher growth rate of TFP during the entire period (1972–2003). But the labor intensive sectors such as i) Leather and foot-wear (-1.25 %), ii) Food products and beverages (-0.73 %), iii) Wearing apparel, dressing and dying of fur (-0.69 %), iv) Printing and reproduction (-0.61 %) have shown negative growth rates of total factor productivity as shown Table A1 in Appendix.

In Service, Post and telecommunication which is related strongly with IT technology has recorded a relatively higher growth rate (4.93 %) of TFP among service sectors. But the social and private sectors such as i) Public administration and defense (-10.36 %), ii) Private households with employed persons (-8.95 %), iii) Other service activities (-8.74 %) have shown negative growth rates of TFP such as i) Public administration and defense (-10.36 %), ii) Private households with employed persons (-8.95 %), iii) Other service activities (-8.74 %) have shown negative growth rates of TFP as shown Table A1 in Appendix. Therefore, we can see that the leading sectors for enhancing productivity growth are related with IT sectors. Korean economy has heavily invested in IT sectors on a full scale since 1995 as shown in Table 5 and recently analyzed in Ha and Pyo (2004).

T23–4 Gross Output Growth Accounting and TFP Growth

Period	Gross output	Capital input	Economy-wide			Energy input	<log growth rates(%)>		
			Labor input				Inter-mediate input	Service input	TFP
			Total Labor	Quantity Labor	Quality Labor				
72–79	9.48	4.56	1.79	1.03	0.76	0.69	3.34	1.13	-2.03
80–'89	8.36	3.05	0.62	0.28	0.34	0.45	3.18	0.98	0.08
90–'99	6.43	2.40	0.49	0.19	0.31	0.70	1.64	1.76	-0.56
90–'98	5.84	2.54	0.49	0.15	0.34	0.63	1.30	1.71	-0.84
99–'03	7.61	1.11	0.48	0.33	0.14	0.75	2.78	1.62	0.86
72–'03	7.81	2.98	0.85	0.44	0.41	0.61	2.63	1.32	-0.59

contribution to output growth									
72–79	100.0	48.1	18.9	10.9	8.1	7.3	35.3	11.9	-21.5
80–'89	100.0	36.5	7.4	3.4	4.0	5.3	38.0	11.8	0.9
90–'99	100.0	37.3	7.7	2.9	4.8	10.9	25.6	27.3	-8.7
90–'98	100.0	43.5	8.4	2.5	5.8	10.8	22.4	29.4	-14.4
99–'03	100.0	14.6	6.3	4.4	1.9	9.9	36.6	21.3	11.4
72–'03	100.0	38.2	10.9	5.6	5.3	7.8	33.7	17.0	-7.5

Period	Gross output	Capital input	**Manufacturing**			Energy input	Inter-mediate input	Service input	TFP
			Labor input						
			Total Labor	Quantity Labor	Quality Labor				
72–79	15.30	2.41	1.72	1.28	0.43	1.66	8.29	1.17	0.06
80–'89	10.27	1.68	0.59	0.40	0.19	0.88	5.83	0.80	0.49
90–'99	6.94	1.20	-0.14	-0.34	0.20	1.19	2.94	1.17	0.58
90–'98	5.56	1.26	-0.22	-0.44	0.22	1.08	2.17	1.04	0.23
99–'03	10.11	0.70	0.26	0.16	0.09	1.02	5.26	1.32	1.55
72–'03	10.18	1.59	0.59	0.35	0.24	1.15	5.33	1.04	0.48
contribution to output growth									
72–79	100.0	15.8	11.2	8.4	2.8	10.8	54.2	7.6	0.4
80–'89	100.0	16.3	5.7	3.9	1.8	8.6	56.8	7.8	4.8
90–'99	100.0	17.3	-2.0	-4.9	2.8	17.2	42.3	16.9	8.4
90–'98	100.0	22.6	-3.9	-7.9	4.0	19.5	39.0	18.7	4.1
99–'03	100.0	6.9	2.5	1.6	0.9	10.1	52.1	13.0	15.3
72–'03	100.0	15.6	5.8	3.4	2.4	11.3	52.3	10.2	4.7

Period	Gross output	Capital input	**Service**			Energy input	Inter-mediate input	Service input	TFP
			Labor input						
			Total Labor	Quantity Labor	Quality Labor				
72–79	7.86	4.77	2.05	1.52	0.54	0.26	1.43	1.36	-2.01
80–'89	7.92	3.70	1.33	1.11	0.22	0.18	1.52	1.27	-0.08
90–'99	6.54	3.17	1.28	1.12	0.16	0.37	0.69	2.37	-1.35
90–'98	6.61	3.37	1.39	1.22	0.17	0.34	0.69	2.40	-1.58
99–'03	5.87	1.39	0.86	0.68	0.18	0.54	0.73	2.02	0.33
72–'03	7.22	3.51	1.45	1.17	0.28	0.30	1.14	1.73	-0.92
contribution to output growth									
72–79	100.0	60.7	26.1	19.3	6.8	3.3	18.1	17.3	-25.6
80–'89	100.0	46.6	16.8	14.0	2.8	2.3	19.2	16.0	-0.9
90–'99	100.0	48.5	19.6	17.2	2.5	5.7	10.6	36.3	-20.7
90–'98	100.0	51.1	21.0	18.4	2.6	5.1	10.5	36.4	-24.0
99–'03	100.0	23.6	14.7	11.6	3.1	9.3	12.4	34.4	5.6
72–'03	100.0	48.7	20.1	16.3	3.9	4.2	15.8	23.9	-12.8

T23–5 The Investment in IT Sector
(2000 prices, %)

Year	IT Investment (billion won)	Growth(%)
1995	15,125.7	–
1996	17,916.0	16.9
1997	19,122.0	6.5
1998	17,099.2	-11.2
1999	23,716.0	32.7
2000	32,190.9	30.6
2001	31,502.0	-2.2
2002	33,143.8	5.1
2003	31,551.8	-4.9
2004	31,391.9	-0.5

*Source: Bank of Korea(http://ecos.bok.or.kr)

Cumulative Contribution of Sectors to TFP growth

Following Fukao et. al,(2006), we can examine the sectoral contribution of TFP growth and identify what are the core sectors for enhancing productivity. As shown in graph 23–4, the weight of gross output of the sectors with positive Economy-wide TFP growth is about 52 % while the weight with negative TFP growth is about 48 % during the entire period of 1972–2003.

We can identify sectors that have contributed to the growth of economy-wide TFP positively. Leading sectors in this group include Financial Intermediation and Post and Telecommunications in Service and Basic Metals and Electronic Valves and Tubes in Manufacturing among others. We also identify sectors with negative contribution to Economy-wide TFP growth such as Agriculture, Hotels and Restaurants, Imputation of owner-occupied housing and Media activities etc.

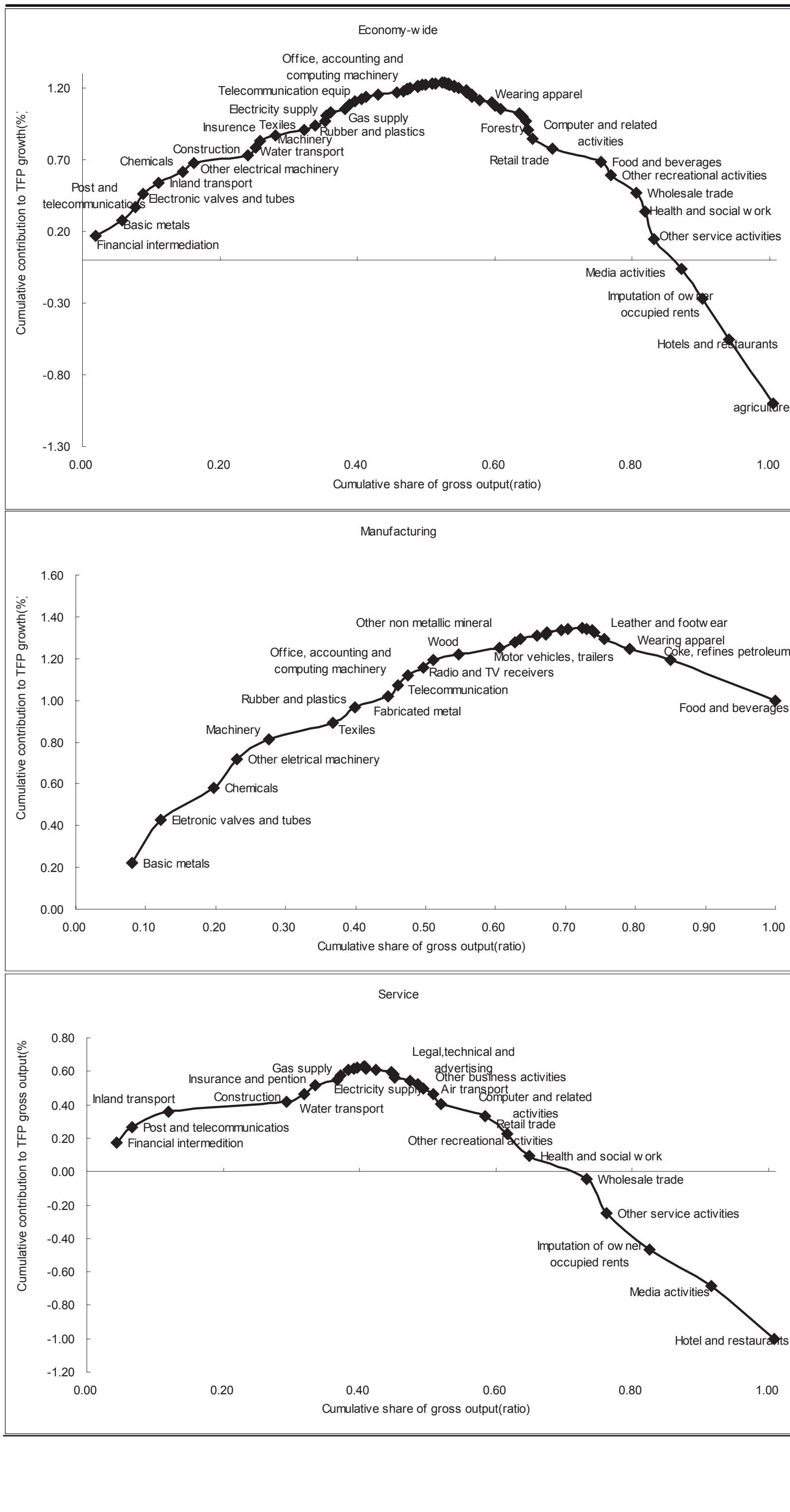
As shown in graph 23–4, the weight of gross output of the sectors with positive TFP growth in Manufacturing is 72.4% while the weight with negative TFP growth is 27.6% during the period of 1972–2003. The sub-sectors with positive TFP growth are basic metals, chemicals, machinery, textiles, rubber and plastic, fabricated metal, wood, other non metallic mineral, motor vehicles and trailers as non IT sectors, and electronic valves and tubes, office, accounting and computing machinery, telecommunications, radio and TV receivers as IT sectors. The sub-sectors with negative TFP growth are leather and footwear, wearing and apparel, coke and refined petroleum etc.

On the other hand, we can look at Service industry separately. As shown in graph 23–4, the weight of gross output of the sectors with positive TFP growth in Service is only about 40 % while the weight with negative TFP growth is 60 % during the period of 1972–2003. The group of service industries with positive TFP growth includes Financial intermediation, Post and communication, Inland Transport, Water Transport, Construction etc. The group with negative TFP growth includes Hotels and Restaurants, Imputation of owner-occupied housing, Media activities and Wholesale trade etc.

Relations of TFP growth with Labor Productivity and Output Growth

In order to identify the relation between labor productivity growth and TFP growth, we can divide sectors into 4 groups by the average growth rates in Manufacturing and Service. The relations of TFP with labor productivity and output growth can be further examined by looking at the scatter diagrams such as Figure 5 and 6. A visual inspection tells us that TFP growth is positively correlated with both labor productivity growth and output growth and TFP-LP relation is stronger than TFP – Output relation.

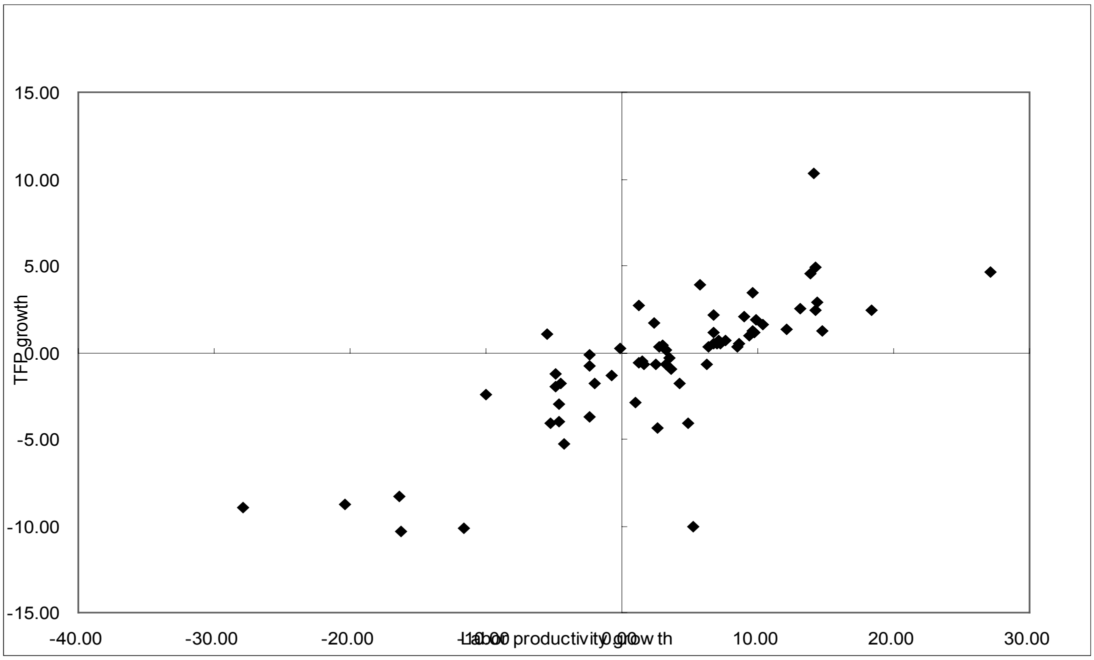
Cumulative Contribution of Sectors to TFP Growth (1972–2003) G 23-4



In table 23–6, we have summarized two simple regression results where TFP Growth rate is regressed upon LP and output growth rate. We are adopting implicit hypotheses that higher LP and output growth induces TFP growth through enhanced human capital and economies of scale. In both regressions, the coefficients of LP growth and Output Growth are significant. The TFP-LP regression seems more significant than TFP-Output regression.

Plotting between TFP Growth and Sectoral Labor Productivity Growth (1972–2003)
in percent

G 23-5



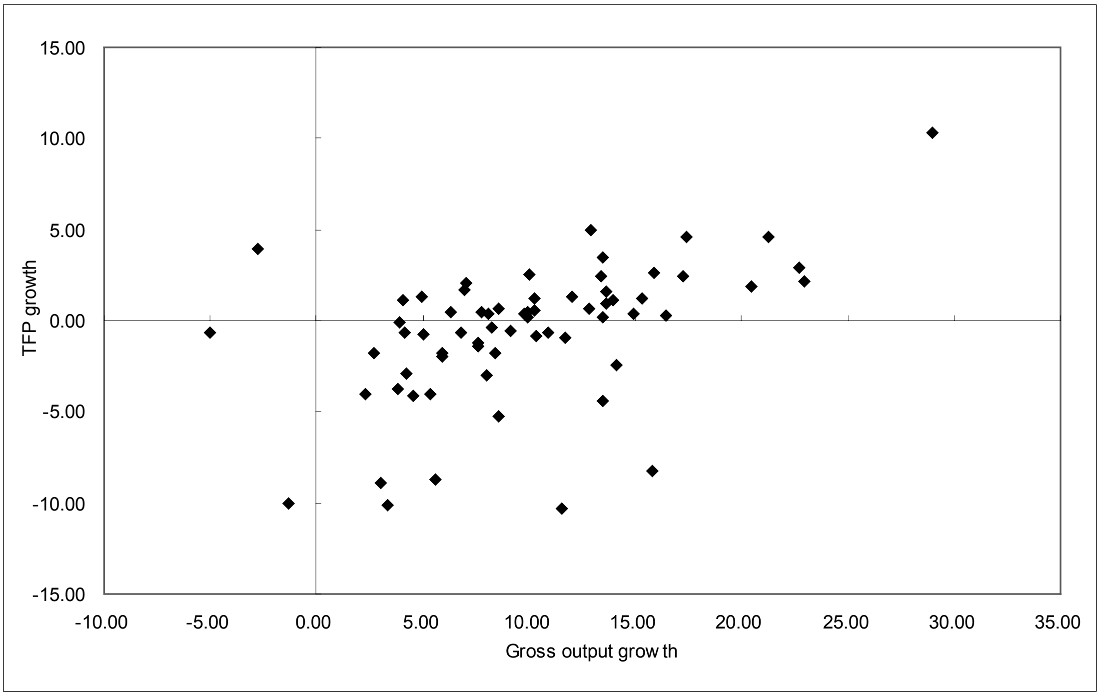
A Linear Rank Test of Independence

In addition to regression analysis, we have used a type of distribution-free linear rank statistic, a generalization of the Mann-Whitney-Wilcoxon statistic for two Independent samples following Baily, Hulten and Campbell (1992) and Hogg and Craig (1978) and Choi (2003) and Neter et al.(1996).

Let $(X_1, Y_1), (X_2, Y_2), ..., (X_n, Y_n)$ be a random sample from a bivariate distribution of the continuous type. Let R_i be the rank of X_i among $X_1, X_2, ..., X_n$ and Q_i be the rank of Y_i among $Y_1, Y_2, ..., Y_n$. If X and Y have a large positive correlation coefficient, we would anticipate that R_i and Q_i would tend to be large or small together. In particular, the correlation coefficient of $(R_1, Q_1), (R_2, Q_2), ..., (R_n, Q_n)$, namely the Spearman rank correlation coefficient :

Plotting between TFP Growth and Sectoral Gross output Growth (1972–2003)
in percent

G 23-6



$$r_s = \frac{\sum_{i=1}^{n}(R_i - \bar{R})(Q_i - \bar{Q})}{\sqrt{\sum_{i=1}^{n}(R_i - \bar{R})^2 \sum_{i=1}^{n}(Q_i - \bar{Q})^2}} \tag{1}$$

would tend to be large. Since $R_1, R_2, ..., R_n$ and $Q_1, Q_2, ..., Q_n$ are permutations of 1,2,…,n, this correlation coefficient can be shown to equal :

$$r_s = 1 - \frac{6\sum_{i=1}^{n}(R_i - Q_i)^2}{n(n^2 - 1)} \tag{2}$$

The mean and the variance of r_s under H_0 is derived as:

$$\mu_s = 0, \qquad \sigma_s^{\,2} = \frac{1}{\sqrt{n-1}} \tag{3}$$

As shown in table 23–7, the computed linear rank statistics reject the null hypotheses that TFP growth is stochastically independent of LP growth and that TFP growth is stochastically independent of output growth at the 1 % significance level.

T 23 – 6 Regression Results

(2000 prices, %)

1. Relation between Labor Productivity Growth and TFP Growth

Model: log(TFPt/TFPt-1)=α+βlog(LPt/LPt-1)+γ

log(TFPt/TFPt-1)=Sectoral avergae TFP growth rate during 1972–2003

log(LPt/LPt-1)=Sectoral avergae labor productivity growth rate during 1972-2003

Number of sectors: 66 sectors(except #5, #6, #33, #39, #66, #72 for data insufficiency)

Dependent var.	β	S.E.	DW	adjR^2
TFP Growth rate	0.322***	0.031	1.967	0.613

***: Pr>t is 1%, **:Pr>t is 5%, *:Pr>t is 10%

1) Data for sector 36 is available only during 1977–2003, and data for sectors of #44, #55, #59 are available only during 1989–2003

2. Relation between Gross Output Growth and TFP Growth

Model: log(TFPt/TFPt-1)=α+βlog(GOt/GOt-1)+γ

log(TFPt/TFPt-1)=Sectoral avergae TFP growth rate during 1972–2003

log(GOt/GOt-1)=Sectoral avergae Gross output growth rate during 1972–2003

Number of sectors: 66 sectors(except #5, #6, #33, #39, #66, #72 for data insufficiency)

Dependent var.	β	S.E.	DW	adjR^2
TFP Growth rate	0.306***	0.066	1.479	0.235

***: Pr>t is 1%, **:Pr>t is 5%, *:Pr>t is 10%

1) Data for sector 36 is available only during 1977–2003, and data for sectors of #44, #55, #59 are available only during 1989–2003

Conclusion

The purpose of this paper is to explain how the database of Korea has been constructed for estimating productivities by industry in KLEMS model and how we have estimated 72-industry level labor productivity and TFP. We have also conducted a gross output growth accounting. Throughout the entire period of 1970–2003, the economy-wide labor productivity has grown at the average rate of 5.59 percent but with the sectoral difference between Manufacturing (6.99 %) and Service (2.91 %). The difference did not shrink but rather has expanded as the process of industrialization of the Korean economy continued. For example, the difference in the 1990's (9.55 % vs. 2.64 %) has been more than doubled since 1970's (4.01 % vs. 2.15 %). The observed difference in both levels and growth rates of labor productivity between Manufacturing and Service can signal the difference in the degree of foreign competition, the proportion of tradable goods and non-tradable goods and services and the degree of domestic competition due to historically different regulatory environments.

The growth rate of economy-wide TFP has been estimated as -0.59 percent. The growth rates of TFP in Manufacturing and Service are estimated as 0.48 percent and -0.92 percent respectively throughout the entire period of 1972–2003. Korean economy experienced two major break-points: in 1974 which was the first oil shock and in 1997 which was the financial crisis. The difference between two break points can be summarized as follows. During the second half of 1970's, the growth rate of gross output was not low, but the growth rates of inputs such as capital(4.56%), labor(1.79%), energy(0.69%), intermediate goods(3.34%) especially, were relatively higher. Therefore, the growth rates of TFP have been estimated as negative. In case of late 1990's the negative growth of TFP has been resulted from the shrinkage of gross output rooted from economic crisis.

In addition we observe that the estimated TFP growth rates in Manufacturing are in general greater than in Service. It maybe due to the fact that an innovation process such as product innovation or process innovation is more sensitive and stronger in Manufacturing than in Service. Also the R&D investment for innovation is in general more intensive in Manufacturing than in Service. So the growth rates of TFP in Manufacturing seem to be greater than in Service.

We can identify sectors that have contributed to the growth of economy-wide TFP positively by decomposing relative contribution of each sector to total TFP growth (Y-axis) with each sector's relative weight of output (X-axis). Leading sectors in this group include Financial Intermediation and Post and Telecommunications in Service and Basic Metals and Electronic Valves and Tubes in Manufacturing among others. We also identify sectors with negative contribution to Economy-wide TFP growth such as Agriculture, Hotels and Restaurants, Imputation of owner-occupied housing and Media activities etc.

The relations of TFP with labor productivity and output growth can be examined by looking at the scatter diagrams and a regression analysis. A visual inspection tells us that TFP growth is positively correlated with both labor productivity growth and output growth and TFP-LP relation is stronger than TFP –Output relation. We have adopted an implicit hypothesis that higher LP and output growth induces TFP growth through enhanced human capital and economies of scale. In both regressions, the coefficients of LP growth and Output Growth are significant. The TFP-LP regression seems more significant than TFP-Output regression.

Productivities in an economy are not identical across industries, and productivity differences are also observed when compared with other economies. For example, most industries in Japan exhibit higher productivity in Manufacturing such as Electrical machinery, Motor and other transport vehicles, and Instruments industries resulting in higher productivity in the entire economy. However, total factor productivities of Korea in Construction, Petroleum products, Fabricated machinery, and Finance industries are higher than those of Japan. International comparison of productivity among industries will demonstrate a relative productivity of each industry, illustrating whether the way goods and services are produced is relatively efficient or not and referring to the appropriate policies for improvement such as competition, restriction, R&D policies, and so on. Establishment of dataset with the same standards for productivity measurement will facilitate these inter-industry and international comparisons, and contribute to better understanding of economic growth.

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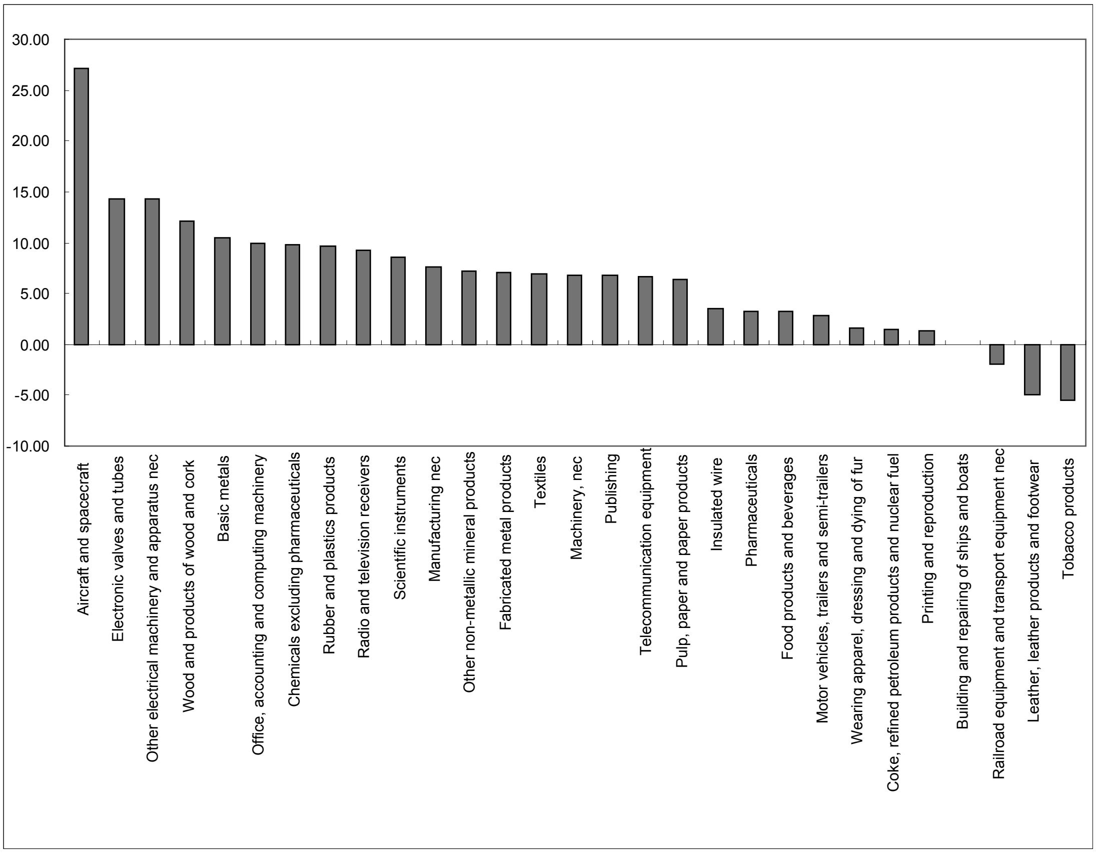
Appendix

Graph 23-A1 Growth Rates of Labor Productivity in Manufacturing (1972-03/%)

Growth Rates of Labor Productivity in Manufacturing (1972–03)
in percent

G 23-A1



Graph 23-A2 Growth Rates of Labor Productivity in Service (1972-03/ %)

Growth Rates of Labor Productivity in Service (1972–03)
in percent

G 23-A2

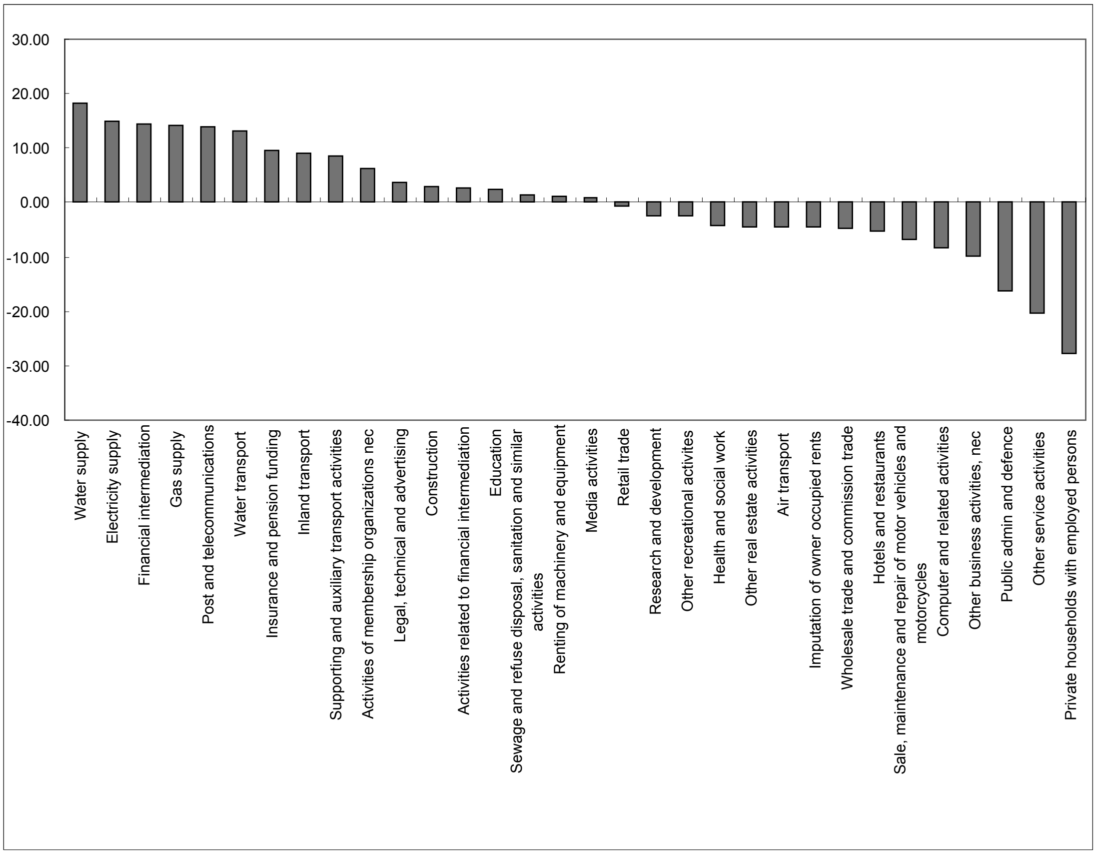


Table 23-A1 Sectoral TFP growth in manufacturing (%)

T 23 – A1 Sectoral TFP Growth in Manufacturing (%)

Code	Industry	72–'79	80–'89	90–'99	Before crisis 90–'98	After crisis 99–'03	72–'03
9	Food products and beverages	-1.52	-0.65	-0.61	-0.59	0.12	-0.73
10	Tobacco products	-2.14	1.65	3.13	3.44	0.88	1.09
11	Textiles	0.97	0.38	0.33	0.05	0.73	0.49
12	Wearing Apparel, Dressing And Dying Of Fur	-1.36	-0.04	-1.60	-2.23	1.85	-0.69
13	Leather, leather products and footwear	-5.91	-1.55	2.16	2.33	0.39	-1.25
14	Wood and products of wood and cork	3.26	0.87	0.39	0.57	0.57	1.34
15	Pulp, paper and paper products	-0.61	0.90	0.74	0.70	0.08	0.34
16	Publishing	-0.60	2.80	-0.19	-1.60	1.33	0.48
17	Printing and reproduction	6.20	-3.66	-2.05	-1.45	-3.90	-0.61
18	Coke, refined petroleum products and nuclear fuel	-0.84	-0.27	-0.84	-1.01	0.19	-0.55
19	Pharmaceuticals	-3.21	0.92	-1.32	-1.53	7.01	0.15
20	Chemicals excluding pharmaceuticals	1.48	1.29	1.23	0.98	0.57	1.14
21	Rubber and plastics products	2.13	1.97	0.32	-0.29	1.38	1.28
22	Other non-metallic mineral products	-0.17	0.29	0.59	0.24	2.38	0.49
23	Basic metals	3.24	1.49	0.87	0.93	0.21	1.57
24	Fabricated metal products	1.57	0.63	-0.16	-0.36	1.10	0.66
25	Machinery, nec	1.46	1.01	0.78	0.26	2.76	1.18
26	Office, accounting and computing machinery	3.13	-0.78	3.37	2.32	4.62	1.91
27	Insulated wire	-4.09	-0.87	2.22	1.54	3.15	-0.37
28	Other electrical machinery and apparatus nec	5.33	0.75	1.40	1.14	3.58	2.45
29	Electronic valves and tubes	5.36	2.91	1.08	0.45	3.15	2.87
30	Telecommunication equipment	-0.05	2.12	5.02	3.99	2.32	2.13
31	Radio and television receivers	2.22	0.29	0.95	-1.36	4.61	0.98
32	Scientific instruments	0.51	0.81	-0.04	-0.42	0.62	0.36
33	Other instruments	–	–	–	–	–	–
34	Motor vehicles, trailers and semi-trailers	0.00	0.74	-0.37	-1.43	2.98	0.29
35	Building and repairing of ships and boats	1.22	1.33	-2.81	-3.99	3.92	0.21
36	Aircraft and spacecraft	6.76	5.14	4.22	5.60	0.52	4.62
37	Railroad equipment and transport equipment nec	-2.96	-2.00	1.22	1.32	-5.06	-1.78
38	Manufacturing nec	-0.24	2.18	0.04	-0.08	0.30	0.65
39	Recycling	–	–	–	–	–	–

Table 23-A2 Sectoral TFP Growth in Service (%)

T 23 – A2 Sectoral TFP Growth in Service (%)

Code	Industry	72–'79	80–'89	90–'99	Before crisis 90–'98	After crisis 99–'03	72–'03
40	Electricity supply	2.20	0.76	1.10	1.18	0.77	1.24
41	Gas supply	15.03	14.00	7.31	7.10	2.29	10.34
42	Water supply	8.67	3.38	-2.19	-2.51	-0.39	2.46
43	Construction	-0.13	2.31	-0.91	-0.36	-1.27	0.39
44	Sale, maintenance and repair of motor vehicles and motorcycles	–	–	-12.91	-14.71	2.09	-8.71
45	Wholesale trade and commission trade	-3.04	-2.46	-1.28	-2.21	1.26	-1.95
46	Retail trade	-0.77	-3.31	-0.73	-0.71	0.41	-1.36
47	Hotels and restaurants	-4.75	-4.69	-4.59	-6.20	1.80	-4.11
48	Inland transport	4.14	3.06	-0.42	-0.72	1.90	2.09
49	Water transport	4.72	2.21	1.31	1.92	0.71	2.52
50	Air transport	-10.49	-0.79	-2.20	-1.85	2.70	-2.97
51	Supporting and auxiliary transport activities; activities of travel agencies	5.71	0.76	-4.52	-4.83	1.50	0.54
52	Post and telecommunications	6.51	2.24	5.36	5.08	5.18	4.56
53	Financial intermediation, except insurance and pension funding	7.45	5.61	3.20	3.05	2.89	4.93
54	Insurance and pension funding, except compulsory social security	1.46	5.81	0.99	4.76	-0.28	3.47
55	Activities related to financial intermediation	–	–	-2.77	-9.28	7.03	-3.46
56	Imputation of owner occupied rents	-8.68	-7.03	5.12	7.66	-11.66	-4.03
57	Other real estate activities	-6.44	-3.41	-2.86	-3.70	12.35	-1.79
58	Renting of machinery and equipment	-1.69	3.45	4.14	9.44	-4.13	2.66
59	Computer and related activities	-	-	-7.89	-10.08	0.07	-6.45
60	Research and development	-0.73	-1.19	-2.51	-2.91	3.54	-0.82
61	Legal, technical and advertising	-2.67	-0.04	-1.22	-1.24	0.38	-0.97
62	Other business activities, nec	-11.74	3.97	-2.54	-4.20	2.69	-2.46
63	Public admin and defence	-29.94	4.94	-18.73	-22.09	11.51	-10.36
64	Education	16.39	2.01	-2.35	-3.77	-12.68	1.68
65	Health and social work	-32.93	9.88	1.43	1.88	-4.19	-5.27
66	Sewage and refuse disposal, sanitation and similar activities	–	–	–	–	–	–
67	Activities of membership organizations nec	-3.54	-0.31	1.36	2.52	-2.73	-0.70
68	Media activities	-16.43	-0.25	-9.24	-11.98	29.66	-2.92
69	Other recreational activites	-4.15	2.90	-17.29	-20.27	13.60	-3.71
70	Other service activities	-30.77	6.08	-18.93	-19.42	16.12	-8.74
71	Private households with employed persons	-32.53	3.78	5.72	5.77	-23.15	-8.95
72	Extra-territorial organizations and bodies	–	–	–	–	–	–

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