EUROPEAN COMMISSION

European Research Area

A more research-intensive and integrated European Research Area

Science, Technology and Competitiveness key figures report 2008/2009

REPORT

Interested in European research?

*Research*eu* is our monthly magazine keeping you in touch with main developments (results, programmes, events, etc.). It is available in English, French, German and Spanish. A free sample copy or free subscription can be obtained from:

European Commission
Directorate-General for Research
Communication Unit
B-1049 Brussels
Fax (32-2) 29-58220
E-mail: research-eu@ec.europa.eu
Internet: http://ec.europa.eu/research/research-eu

EUROPEAN COMMISSION

Directorate-General for Research
Directorate C – European Research Area: Knowledge-based economy
Unit C.3 – Economic Analysis and Monitoring of National Research Policies and the Lisbon Strategy
Contact: Johan Stierna
Internet: http://ec.europa.eu/research/era

EUROPEAN COMMISSION

A more research-intensive and integrated European Research Area

Science, Technology and Competitiveness key figures report 2008/2009

Directorate-General for Research
2008 Directorate C – European Research Area: Knowledge-based economy EUR 23608 EN

EUROPE DIRECT is a service to help you find answers to your questions about the European Union

Freephone number (*):

00 800 6 7 8 9 10 11

(*) Certain mobile telephone operators do not allow access to 00 800 numbers or these calls may be billed

LEGAL NOTICE

A great deal of additional information on the European Union is available on the Internet. It can be accessed through the Europa server (http://europa.eu).

Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 2008

ISBN 978-92-79-10173-1
DOI 10.2777/27864

Printed in Belgium

PRINTED ON WHITE CHLORINE-FREE PAPER

Preface

Today's economic situation is particularly difficult. The financial crisis has reached historic proportions. It remains to be seen how severe the downturn will be and how long it will last. But one thing is clear – Europe's policy response must not only be strong but it must also be coordinated and pave the way for Europe's global competitiveness in the future.

In times of crisis, Europe should not decrease investment in research. On the contrary, Member States should focus on improving their attractiveness as locations for investment and prepare their economies and industries to make the most of the next economic upturn. This makes knowledge-related activities and structural reforms even more important than during phases of economic expansion. Among our competitors, countries such as the US, South Korea and Japan reaped the benefits of increasing their investment in knowledge during previous economic downturns. Measures to boost education, research and innovation should therefore be included in the wider mix of measures for supporting demand.

The global challenges like climate change, energy security and the ageing population have not gone away. We can address these challenges by pooling our resources and coordinating our investments in knowledge thereby contributing to a sustainable recovery. An opening up of our research systems and a free circulation of researchers and technologies, the so-called 'fifth freedom', is necessary to increase competition and promote excellence in research. This opening up will accelerate high quality cooperation within academia and industry, and lead to the solutions and innovations that our society and economy need. This is what the European Research Area is about. Realising a single European Research Area will make the European research system more efficient and more effective, and thus ensure a better return on investment. These advances will stimulate increased investment and attract both human and financial resources into Europe's research system. In order to increase the knowledge intensity of the EU economy, the European research system must pursue the commercial application of the results of scientific research. This requires better cooperation of academia and industry in a system of open innovation and the capacity to exploit research within high-tech innovative SMEs.

This year's Science, Technology and Competitiveness key figures report analyses the progress made towards answering these challenges since the launch of the Lisbon agenda in March 2000. It provides answers to a number of questions, such as: Is Europe investing more in research? Is Europe becoming a more attractive place to invest in research? Is Europe progressing towards a European Research Area and making its research system more competitive? Is Europe moving rapidly enough towards a more adaptable and knowledge-intensive economy?

I would like to underline the importance of some key findings. Between 2000 and 2006, R&D investment grew by 14.8 % in real terms in EU-27 compared to 10.1 % in the US. There has been a significant increase in the R&D intensities of more than half of the EU Member States. However, as a result of significant increases in EU-27 GDP and relatively small increases in R&D expenditure by the larger Member States, overall EU-27 R&D intensity has decreased from 1.86 % in 2000 to 1.84 % in 2006. At the same time, R&D intensity in Japan, South Korea and China has increased considerably. The main reasons for the decline in EU-27 R&D intensity are an insufficient growth in business R&D expenditure and the fact that EU companies have invested more outside of Europe, in particular in emerging research-intensive countries, than non-European companies have invested in Europe. Tackling these issues will be important as we continue to pursue the strategy for growth and jobs in the years ahead.

The way forward involves making the most of the mobilising role of the European Research Area with specific efforts to facilitate structural change and increasing the circulation of researchers and knowledge.

This report shows that since 2000, Europe has made clear progress towards a European Research Area. Universities in Europe are undergoing reforms and are linking up in transnational networks. Funding for coordinated research is increasing in absolute terms, and in 2006 half of the national research programmes in Europe allowed for the participation of non-resident researchers. There has been a growth in the mobility of science and technology professionals inside the EU, while European researchers are increasingly cooperating in the co-authorship of scientific articles and in applications for technological patents.

There are signs that the European Research Area is opening up to the world at large. Approximately 13 % of the doctoral candidates in the EU come from countries outside the European Research Area. Most of the scientific cooperation in the world takes place between researchers from Europe and the US while the highest growth in cooperation over the last six years has been with researchers from Asia. At the Community level, the research Framework Programme has progressively opened up to countries outside of Europe.

What lessons can be drawn from the report for future policy orientations?

The first lesson to be drawn is that policies and initiatives aimed at increasing investment in research, supporting innovation and improving the efficiency of the European research system through partnership with other ERA countries all reinforce each other and should be monitored in a consistent manner. This report is a first attempt to monitor the progress of these measures from a European perspective.

The second lesson, no less important, is that with increasing international competition in the years ahead, substantial progress must be made to achieve a more efficient European research system. In particular, a partnership between Member States, together with the Commission, is required for realising a more extensive flow of researchers within the ERA, for the development of links between research performers across Europe, for the common realisation of joint programmes, for a reduction of patent costs for high-tech SMEs, for a systematic removal of obstacles to the up-take of new technologies and for the development of markets for technology-based products and services, and for stronger cooperation between research, industry and education.

I hope this report and its future versions will become a regular monitoring tool to assess how well these challenges are being addressed and what progress Europe makes in transforming itself into a knowledge-driven society.

Janez Potočnik

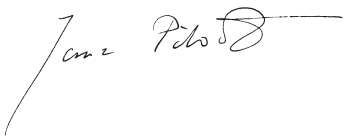


Table of contents

Executive summary 5

Part I Investments and performance in R&D in the European Research Area 17

Chapter 1. R&D investment in the European Research Area since 2000 18
1.1 Has there been progress towards increased investment in R&D? 18
1.2 Has the financing of R&D progressed towards the public and private funding targets of 1 % and 2 % of GDP? 28
1.3 How is public sector R&D distributed between government and higher education? 35
1.4 Why is business sector R&D intensity lower in the EU than in the US? 38

Chapter 2. Investing in human resources for R&D 47
2.1 Is the pool of human resources in S&T growing? Is the number of researchers increasing? 47
2.2 Is the EU training more researchers? 56

Chapter 3. The scientific and technological outputs of R&D activities and their high-tech outcomes 61
3.1 Has the EU increased its efficiency in producing scientific publications since 2000? 61
3.2 Has the EU's inventiveness, as measured by patent applications, improved since 2000? 67
3.3 Has the EU moved towards a more knowledge-intensive economy since 2000? 76

Chapter 4. Attractiveness of the ERA and the integration of private R&D 83
4.1 Is the EU attracting foreign funding of research? 83
4.2 Is the private sector moving towards increased integration across ERA countries? 86

Part II Integration of the European Research Area 91

Chapter 1. Strengthening universities 92
1.1 What is the situation for universities in Europe in terms of scientific output, funding and reforms? 93
1.2 What is the configuration of transnational links between universities in Europe? 98

Chapter 2. Optimising research programmes and priorities 102
2.1 Have European countries increased their funding of coordinated research initiatives? 102
2.2 Are research programmes at national level opening up to non-resident researchers? 107

Chapter 3. Research infrastructures 109
3.1 Has there been any progress in the creation of new large-scale research infrastructures at European level? 110
3.2 What is the scale of Structural Funds support for capital expenditure on research, development and innovation? 114
3.3 Are existing research infrastructures in Europe networked and accessible to research teams across Europe and the world? 115

Chapter 4. Mobility of researchers and human resources in S&T 119
4.1 Has the mobility of human resources in S&T increased in Europe since 2000? 119
4.2 Are countries in Europe attracting foreign researchers? 122

Chapter 5. Knowledge flows 126
5.1 Are the levels of scientific and technological cooperation and the sharing of knowledge increasing in Europe? 126
5.2 Is knowledge transfer between public research and society improving? 131
5.3 Are European scientists and firms exploiting knowledge produced in other parts of the world? 136

Chapter 6. Opening up the ERA to the world 142
6.1 Is the European Research Area opening up to the world? 142

Acknowledgments 152
Methodological Annex 153
Index of graphs, statistical tables and maps 165

The status of the European Research Area: Europe's progress towards a knowledge-based economy

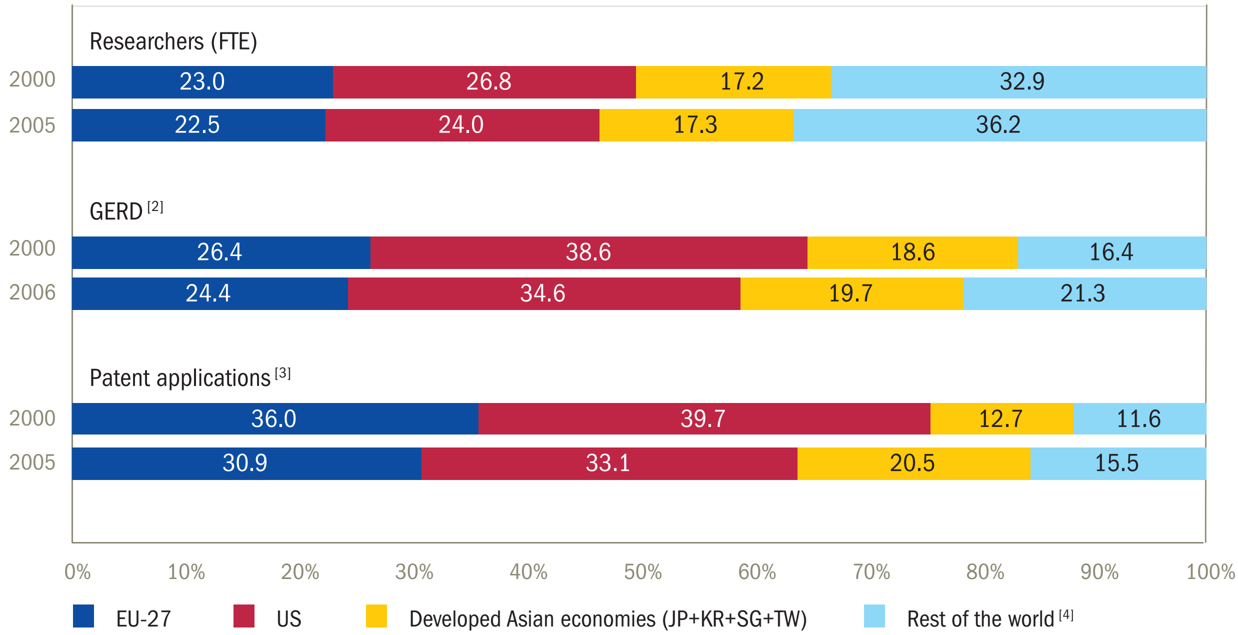
Executive summary

The place of Europe in a multi-polar world of science and technology

Research is a key competitive asset in the global world of science and technology

Since the 1990s major new players have emerged in science and technology – notably in Asia. The result is an increasingly multi-polar world where science, technology and patent applications are more widely distributed throughout the world. Figure 1 shows that almost 80 % of researchers work outside the EU, 75 % of gross domestic expenditure on R&D (GERD) is executed in other world regions, and 69 % of patent applications are made outside the EU. This is translated into a declining world share of GERD and patent applications, both for the US and for the European Union.

FIGURE 1 Participation in global R&D – % shares [1]



Source: DG Research STC key figures report 2008
Data: Eurostat, OECD, UNESCO
Notes: [1] Elements of estimation were involved in the compilation of the data
[2] GERD: Shares were calculated from values in current PPS€
[3] Patent applications under the PCT (Patent Cooperation Treaty), at international phase, designating the EPO by country of residence of the inventor(s)
[4] The coverage of the Rest of the World is not uniform for all indicators

A second noteworthy finding from Figure 1 is that while the EU's world share in GERD diminished by 7.6 % over 6 years, the EU's world share in patent applications declined by nearly twice as much (14.2 %). While the ratio of world share of patent applications/world share of GERD declined in the EU by 7 %, it increased in the Developed Asian Economies by more than 53 %. In other terms, Asian economies have increased their patents worldwide even more rapidly than their investments in research as compared with EU-27 [1]. The high costs of patents in Europe might possibly explain part of this striking result [2]. The initial costs of a patent application to the EPO covering 12 Member States and Switzerland are over 20 times higher than the corresponding costs for a patent application to the US and 13 times higher than in the Japanese patent office, while the costs of maintaining a patent protection in the 27 Member States are over 60 times higher in the EU than in the US [3].

[1] Of course, this indicator on patent applications under the PCT is a proxy. It gives an indication of patent activity and not of the development of research-based applications. However, it is widely counted as a relatively good proxy for the latter. The validity of this proxy depends on changes in the behaviour of economic actors in the countries applying for patent protection.

[2] Patent applications under the international Patent Cooperation Treaty have a different direct cost than patent applications to national patent offices. However, the decision to use the PCT procedure is linked to anticipation by economic actors of the potential future costs of their applications, which are determined by national patent application procedures.

[3] The European Commission has invited Member States to reduce by up to 75 % the fees for patent application and maintenance (see Communication of the European Commission 'A European Economic Recovery Plan', COM(2008) 800, 26.11.2008, page 13).

Public funding of R&D can be counter-cyclical [4]

Lower GDP growth rates and economic downturn affect the level of business funding of R&D [5]. Figure 2 shows that R&D expenditure financed by business enterprise decreased in the US after 2000-2001. The response of the US government, however, was not only to sustain but also to increase public funding of R&D. In the case of Japan in the early 1990s, a decreasing level of R&D financed by the business sector was countered with an increase in R&D financed by government. As in the case of the US, after a period of around three years, R&D expenditure financed by business enterprise regained a strong rate of growth [6].

FIGURE 2 Gross Domestic Expenditure on R&D (GERD) financed by business enterprise and by government, 1991-2006

Source: DG Research
Data: Eurostat, OECD
Notes: [1] US: Most or all capital expenditure is not included; There is a break in series between 1998 and the previous years
[2] Japan: There is a break in series between 1996 and the previous years; The values for GERD financed by government are OECD estimates

STC key figures report 2008

[4] The statistical evidence in Figure 2 provides some first elements for reflection. A fuller understanding of Figure 2 would involve a comprehensive economic analysis of the various factors influencing R&D financed by the public and the business sectors. Therefore, no definite conclusions can be drawn.

[5] One of the most salient conclusions of the seminar 'The Effects of the financial crisis on European research policy', organised by the European Commission in Brussels on 17 November 2008, was the sharp impact to be expected from the crisis on the R&D investment and financial independence of innovative start-ups.

[6] As there is a break in the data series for Japan between 1996 and the previous years, the finding on the impact on GERD financed by business enterprise is only indicative. Moreover, these first indications would need to be confirmed by a more in depth analysis of the specific policy measures taken by the US and Japanese governments in the field of R&D during the period of economic slowdown.

The EU pursues a policy to invest in more and better research…

In 2000, the EU Member States responded to the challenge of globalisation with the Lisbon Strategy for a competitive knowledge-based economy and, as part of this strategy, the 3 % objective for R&D intensity and the initiative to create a European Research Area (ERA). The objectives are clear: invest more in research and increase excellence and efficiency by joining forces in a European Research Area, including opening up to the world and stimulating international cooperation and knowledge spill-over.

This report analyses the status of and progress towards these objectives. The report consists of two main parts and a Methodological Annex. Part I of the report presents data on R&D investment and its impact, while Part II provides for the first time an overview of progress towards realising the European Research Area. While Part I is based on well known indicators, Part II is more experimental with indicators to be further developed in coming years. Additional statistical data can be found on the website of the European Commission (http://ec.europa.eu/research/era).

The report uses various groupings of countries. The analysis presents data, when available, for all the 'ERA countries' [7]. However, as comparable data at European level are mainly available for EU-27, many graphs and tables cover EU-27 only. Totals refer only to EU-27, as no totals are available for the ERA countries as a whole on a consistent basis.

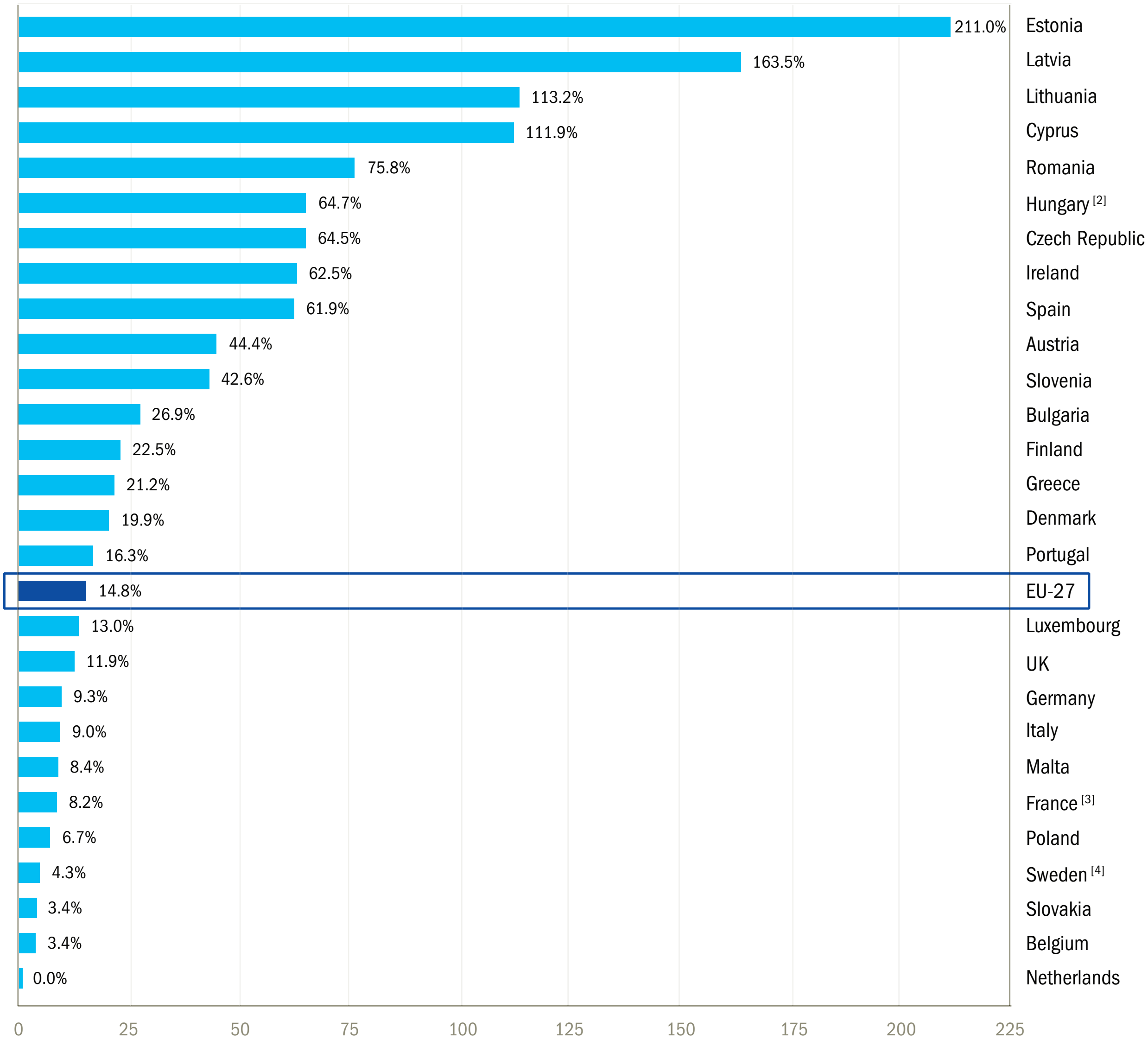
… and some Member States have made important progress on increasing investment in R&D in real terms, but overall EU R&D intensity has remained unchanged

Although there has been little evolution in R&D intensity at EU-27 level, there has been a considerable increase in R&D investment in real terms: between 2000 and 2006, R&D expenditure in EU-27 has grown in real terms by 14.8 %. Comparable figures for the US and Japan are 10.1 % and 21.9 %.

R&D expenditure grew in real terms in all 27 Member States between 2000 and 2006, although at strongly varying rates, ranging from 3.4 % in Belgium to 211 % in Estonia. The total real growth of R&D expenditure between 2000 and 2006 exceeds 100 % in the three Baltic States and in Cyprus. It is greater than 60 % in Hungary, Romania, the Czech Republic, Ireland and Spain.

[7] The 'ERA countries' include EU-27 Member States, the EFTA countries (Switzerland, Iceland, Liechtenstein and Norway), and Candidate Countries (Croatia, the Former Yugoslav Republic of Macedonia, and Turkey). Israel is also included in all relevant graphs and tables when comparable data are available.

FIGURE 3 Gross Domestic Expenditure on R&D (GERD) – real growth (%) between 2000 and 2006 [1]



Source: DG Research
Data: Eurostat
Notes: [1] IT: 2000-2005; EL, SE 2001-2006; MT 2004-2006
[2] HU: There is a break in series between 2004 and the previous years
[3] FR: There is a break in series between 2004 and the previous years
[4] SE: There is a break in series between 2005 and the previous years

R&D intensity increased substantially in these Member States, as well as in Austria. Cohesion Policy made a substantial contribution to these increases, in particular in the Baltic countries with an average estimated quarter of total national R&D investment stemming from the Structural Funds. As a result these countries have managed to move towards the national R&D investment targets they have set in the context of the revised Lisbon Strategy. However, because of their limited shares in total EU-27 GDP, the impact on overall EU R&D intensity is low.

R&D intensity decreased in 10 other Member States, including France and the United Kingdom and increased moderately in Germany and the remaining Member States. The three largest Member States account for 61 % of GERD and 51 % of GDP (2006), and there is a very high correlation between the development in their R&D intensity and the overall EU R&D intensity, which remained at 1.84 %.

The intensities of government and business funding of R&D have increased in a majority of Member States but remained almost unchanged at EU-27 level [8]

EU-27 is lagging behind the US, Japan and South Korea in terms of R&D intensity, mainly due to a lower level of R&D funded (and performed) by the business sector. The intensity of business funding of R&D has increased almost exclusively in Member States where this intensity was already low or very low. With the exception of Austria, EU Member States with medium and high levels of business funding have not been able to increase substantially their business R&D funding intensities. As a result, for EU-27, the intensity of business funding of R&D has declined slightly from 1.05 % of GDP in 2000 to 1.00 % of GDP in 2006. In the US, the decline was more marked, although from a much higher level.

In 20 Member States, the share of the government budget for R&D in total general government expenditure has increased between 2000 and 2007. This shows the commitment of these Member States to higher levels of R&D investment. As a result, the intensity of government funding of R&D has increased in a majority of Member States. However, at EU-27 level, it has remained stable at 0.63 % of GDP in 2006, due to its stagnation or decrease in those Member States accounting for high shares of EU-27 GDP.

A majority of manufacturing and services sectors in the EU have become more research-intensive

A positive evolution is to be highlighted. A large majority of EU manufacturing and services sectors have become more R&D-intensive between 1995 and 2003 [9]. Business enterprise expenditure on manufacturing R&D in the EU [10] has increased from 5.5 % of total manufacturing value added in 1997 to 6.5 % in 2003. At the same time business enterprise expenditure on services R&D has increased from 0.2 % of total services value added in 1997 to 0.3 % in 2003. This confirms the fact that the move to increase the knowledge content of large parts of the economy, such as manufacturing and services, tends to become a sustainable trend.

However, the result was only a relatively modest increase in total business R&D intensity in the EU from 1.13 % of GDP in 1995 to 1.19 % in 2003, subsequently followed by a slight decline to 1.17 % of GDP in 2006. The figures on R&D intensity in the EU indicate that structural change appears to be a key issue in relation to Europe's ability to increase its competitiveness.

[8] The 2008 Industrial Scoreboard shows increasing business R&D investment worldwide by EU-owned firms. The R&D investment of EU-owned companies grew by 5.3 % in 2005 and 7.4 % in 2006 in nominal terms, which is comparable with the growth in nominal terms of business expenditure on R&D (BERD) in EU-27 of 3.9 % in 2005 and 6.6 % in 2006. It should be noted, however, that the direct term by term comparison of the nominal increase in business funding of R&D in official R&D statistics and in the Scoreboard is not possible.

[9] Latest year available for computing an EU aggregate of R&D expenditure by economic activity.

[10] EU includes the following Member States in this calculation: BE, CZ, DK, DE, ES, FR, IE, IT, HU, NL, PL, FI, SE, UK.

The EU has a smaller share of high-tech industries than the US and the high-tech sector in the EU is less research-intensive

If one uses the US as a benchmark, it would seem that there is room for further increases in the research intensities of high-tech sectors in the EU, which are about 20 % less research-intensive than those in the US [11]. However, the structural change towards higher R&D intensity within sectors of the EU economy was not sufficient to raise substantially business R&D intensity in the EU. In particular, the general evolution towards a services economy in the EU implies a growing weight (in terms of GDP) for the less R&D-intensive services sectors. Also, the increase that took place in research intensity in low-tech and medium-low-tech manufacturing sectors, as well as in services sectors, had a limited impact on the overall business R&D intensity of the EU, the level of which is predominantly determined by the research intensity and size of the high-tech and medium-high-tech industries.

The lower level of business R&D intensity in the EU is also linked to the structural composition of its economy. High-tech industry occupies a larger part of the economy in the US than in the EU: the share of high-tech industry in total manufacturing value added is about 50 % higher in the US (18.3 %) than in the EU (12 %). Given the weight of high-tech sectors in the overall level of business R&D intensity, a change should include the sectoral composition of the business sector, a move towards a higher share of high-tech companies and research-driven clusters. Pursuing such a strategy would bring to the forefront policy issues such as the need to remove obstacles to the development of lead markets and to the generation and growth of new firms. The removal of these obstacles is necessary in order to facilitate change in the sectoral structure of the economy.

The EU attracts a growing share of private R&D investment from the US

Notwithstanding, the increasing importance of Asian countries in global R&D, 62.5 % of all R&D expenditure by US foreign affiliates takes place in the EU. However, the EU continues to invest more in R&D in the US than the US invests in R&D in the EU. Nevertheless, the gap between R&D investment by US companies in EU-15 and R&D investment by EU-15 companies in the US has decreased from 24 % of total EU-15 R&D investment in the US in 2003 to 11 % in 2005. This is mainly due to a 20 % increase in R&D investment by US companies' in EU-15 over the period 2003 to 2005. This is all the more significant given that over 75 % of world research is conducted outside the EU.

Private sector R&D in the ERA shows a relatively high degree of international integration

In all ERA countries for which the data are available, a significant part of business R&D (more than 20 %, except in Finland and up to 70 % in Ireland) is performed by affiliates of foreign parent companies. In some countries, foreign affiliates are even the main performers of business R&D. In the ERA countries for which data are available, more than 50 % (up to 93 % in Portugal and Austria) of R&D expenditure by foreign affiliates in the manufacturing sector is by affiliates of an EU or EFTA parent company. Only in Ireland is most R&D performed by foreign affiliates of US companies. This is an indication that investing in private sector R&D in EU Member States is an integral part of the R&D strategies of international firms.

[11] The difference of the research intensity in high-tech sectors in the US and the EU may partly be explained by the degree of outsourcing of R&D product suppliers.

The EU has a lower intensity of researchers in the business sector and absorbs fewer patents produced in other countries

Since 2000, the EU-27 share of researchers in the labour force has grown by 1.9 % per annum on average, which is twice as fast as in the US and at the same rate as Japan. However, on average the EU has proportionately significantly less researchers than the US and Japan. In 2006, the number of full-time equivalent researchers per thousand labour force was 5.6 in EU-27 compared to 10.7 in Japan and 9.3 in the US. This difference is mainly due to a far lower intensity of researchers in the business sector in the EU. On this measure, the only ERA countries are a comparable to Japan and the US are Finland, Iceland, Sweden, Luxembourg, Denmark and Norway.

An indicator for absorptive capacity is the share of foreign inventions in patents owned by domestic companies. These data show that EU-27 is behind the US in exploiting knowledge produced in other world regions. The US is more likely than the EU to acquire ownership of inventions made abroad. Foreign inventions account for a greater part of US-owned patents than of EU-27-owned patents. The leading European countries in absorbing inventions made abroad are Luxembourg, Switzerland and Ireland. The resulting time lag in the absorption of new knowledge produced elsewhere may constitute a competitive disadvantage, especially for smaller firms. This limits the speed of structural change towards more high-tech-based, fast-growing activities.

The EU shows less pronounced scientific and technological specialisation, while the US and Japan specialise in enabling technologies

The EU scientific specialisation pattern based on bibliometric data is less pronounced than that of the US and Japan in fast-growing scientific fields such as, for example, 'material sciences', 'environmental sciences' and 'health sciences'. In contrast, the US is specialised in 'health sciences' and under-specialised in 'materials sciences', the exact opposite of Japan's scientific specialisation. This entails not only a risk for the EU of lack of critical mass, but also a risk of fragmentation and duplication of effort.

Similarly, the EU technology specialisation pattern based on patent statistics is less pronounced than that of the US and Japan. The US and Japanese inventions are concentrated to a higher degree than the EU in enabling technologies (biotechnology, ICT and nanotechnology). The Asian countries for their part account for a rapidly growing share of ICT patents in the world.

The challenges, as identified above, that are involved in moving towards a more research-intensive and competitive European economy, call for a more efficient and effective European Research Area.

The need for an effective European Research Area in the global world of science and technology

Progress in implementing the European Research Area is essential for the adaptability of Europe to this changing paradigm

Progress towards a more effective European research system is indeed crucial both to stimulate investment in research and to facilitate structural change towards a more knowledge-based economy. An efficient and effective European research system would increase the returns from investment in research and make the most out of Europe's existing R&D intensity while at the same time stimulating new investment in research. In this context, the implementation of a true European Research Area would be instrumental in achieving this goal. The ERA Green Paper identifies six axes for making the ERA a reality:

- realising a single labour market for researchers;
- developing world class infrastructures;
- strengthening research institutions;
- sharing knowledge;
- optimising research programmes and priorities;
- opening to the world: international cooperation in S&T.

This report examines progress on the ERA by analysing available indicators within each of these six areas. In contrast to the well-established indicators on research investment, data and indicators on cross-national integration, cooperation and competition are still under development. Therefore, the analysis presented in this report represents a first but provisional step towards increased evidence-based understanding of progress towards a more efficient European research system. It looks first at research institutions, research programme funding and research infrastructures, and subsequently at mobility of researchers, transnational knowledge flows and internationalisation of R&D. The roles of funding instruments, and also of policy and institutional reforms, are instrumental in maintaining stable progress and in ensuring Europe's adaptability to the new global dynamics of science and technology.

Universities in Europe are undergoing reforms to improve performance while they increasingly link up to transnational networks

When compared to the US, Europe has fewer universities that act as major reference centres of large scientific size and impact. However in Europe the place of universities in public research is changing. European countries are directing a growing part of total public expenditure on R&D to the higher education sector, while at the same time reforming their higher education systems towards more autonomy for universities, a larger share of competition-based funding and more output-based core funding.

At the same time, universities in Europe have developed strong links between themselves. The links based on research collaboration co-funded by the EC research framework programme are centred in an area covering Western and Northern Europe. Universities in other European countries have more peripheral positions – although large countries such as France, Italy and Spain have more central positions when considering all research performing institutions. This spatial configuration of university links is by and large confirmed by an analysis based on web-based links between universities in EU-15. The most extensive links connect universities in a relatively limited number of regions in Western and Northern Europe.

Funding for coordinated research at European level is increasing in absolute terms and in parallel to an opening up of national research funding programmes

The overall proportion of European to national funding has remained unchanged at around 12-15 % in the period 1995-2006. However, in absolute terms, national funding of coordinated research at European level has increased steadily. This increase accelerated after 2005 with the implementation of new ERA-oriented instruments for coordinated research. In parallel, the funding for coordinated research and innovation in the Community budget (Research Framework Programme and Competitiveness and Innovation Programme) has more than doubled for the period 2007-2013 when compared to the funding for the period 2000-2006. In spite of the dominance of large EU Member States in absolute terms, smaller countries have a higher propensity to participate in the framework programme as well as in intergovernmental funding programmes at European level.

At national level, research programmes are increasingly open to non-resident researchers. Half of the programmes allow non-resident researchers to participate and 20 % allow these researchers to be funded. If the possibilities of subcontracting non-resident researchers, funding foreign researchers living in the country and funding national researchers for participation in transnational projects are also taken into account, even more national programmes can be considered as partly open.

Also noticeable is the progress made by Europe since 2003 towards large-scale pan-European research infrastructures

There has been progress in the creation of new large-scale research infrastructures at European level. 35 large-scale research infrastructures have been identified for development, out of which 32 have entered the preparatory phase. The substantial increase in the structural funds allocated for research infrastructures will give a major impetus to the development of research infrastructures not only at European level but also at national and regional level, in particular in the new Member States.

At the same time, research infrastructures in Europe are relatively accessible to foreign users, with one third of the research infrastructures having a majority of foreign users. Germany, Italy, the United Kingdom, France, Switzerland and Sweden are net providers [12] of research infrastructures that offer transnational access funded by FP6.

Some Member States have come further in opening up their research system to attract foreign researchers. However, mobility is more an international than a strictly intra-EU trend

There has been an increase in the mobility of S&T professionals both inside the EU and between the EU and the rest of the world since 2000. This parallel evolution is positive as it reflects the adaptation of the ERA to the overall globalisation of research. The growth of intra-EU mobility of S&T professionals however, lagging behind extra-EU mobility, shows that integration of the ERA still needs to be further pursued in order to increase efficiency. A complementary conclusion can be drawn when analysing the stock of doctoral cand dates. Non-EU doctoral candidates in the EU exceed the number of candidates coming from another ERA country. In 2005, 6.9 % of the doctoral students in EU-27 had the nationality of another country inside the European Research Area, while 13 % came from countries outside the ERA.

[12] Countries which are 'net providers of research infrastructures' in respect of the funding from FP6 are the countries that have higher shares of foreign users than participating institutions. (see Part II, section 3.3).

Some EU Member States have come further than others in opening up their research systems to attract foreign researchers. This is particularly the case for the United Kingdom, Austria, Belgium, Denmark and the Netherlands. In absolute numbers, the largest intra-EU flows of mobile researchers seem to be concentrated within the five largest EU Member States, with the United Kingdom being the main country of destination for mobile researchers. However, Canada, Australia, the US and Switzerland have a considerably higher share of foreign doctorate holders than some EU Member States.

Transnational knowledge flows are growing inside Europe and beyond

In the EU, knowledge is increasingly generated in transnational cooperation. Researchers in the EU are more involved in scientific and technological cooperation as measured by transnational co-publications and co-patents, which show an average annual growth of almost 9 %. At the same time, EU knowledge cooperation is opening up to non-EU countries. The greatest scientific cooperation takes place between authors from European and American countries, while the highest growth in cooperation over the last six years has been with researchers from Asia. European scientific cooperation with Asia is rather well distributed and 75 % of it takes place with countries other than China.

Transnational scientific collaboration for EU researchers usually involves a partner from a large research-intensive country (US, United Kingdom, Germany, France, Italy) or from a neighbouring country. With regard to transnational technological collaboration, larger Member States and the Nordic countries are more likely to co-patent with partners from countries outside the EU, while the other Member States predominantly co-patent with partners from other EU countries.

Although higher education institutions in Europe have increased their patenting activity and created new technology transfer offices, the links between publications and patents is still weaker in the EU than in the US. The impact of scientific publications is lower, and universities and public research institutes are not among the major cooperation partners for innovative firms in Europe.

The EC research framework programme has opened up to a broader range of countries outside Europe

The statistics on mobility of researchers, co-publications and co-patents all indicate an opening up of research in the European Research Area to countries outside Europe. At the Community level, the research framework programme has progressively opened up to countries outside Europe over the last 10 years. From an initial focus on developing countries, the framework programme has extended its scope to emerging and industrial countries as well.

Most participants from countries outside Europe come from the Russian Federation, the US and China. Although the larger research countries in Europe – Germany, France, the United Kingdom and Italy – have the largest numbers of collaborative links with researchers from countries outside Europe, several smaller Member States have benefited from the framework programme to substantially increase their collaborative links. There are no comparable statistics on the financial commitments made by individual countries in Europe to address global challenges by multilateral research initiatives. However, data from the EC research framework programme indicate an interest of countries outside Europe in collaborating with European researchers on projects concerning health, environment, ICT and food research.

Conclusion

Despite encouraging progress on increasing the amount of investment in R&D, the overall R&D intensity of EU-27 has remained unchanged. This highlights the challenges facing the EU – challenges such as increasing the research intensity in high-tech sectors, changing the balance of the industrial structure in favour of these research-intensive sectors and increasing the cost-effectiveness and attractiveness of the ERA. Underlying factors that might give further encouragement to such progress are higher returns for private investment in R&D, coming notably from a more efficient ERA and framework conditions that favour structural change, such as high-growth SMEs and higher demand and a single market for research-intensive products. ERA integration is a key competitive factor for increasing the effectiveness of the European research system.

A resulting change in industrial structure would have the potential to enhance EU-27 GDP growth in the long run. Progress on the 3% R&D intensity target would be a measure of success in achieving a change in the efficiency of the research system, as well as in the industrial structure. The big Member States are central to achieving progress, since they account for most of the investment in R&D. Moreover, a positive evolution in these Member States would likely generate a significant spillover effect for EU partner countries. The Member States have an important role in the promotion of structural internal reform, and also in the move towards greater ERA integration.

As regards steps towards making the ERA more efficient, constant progress in training new researchers has been particularly positive, also the fact that the EU maintained its position as the most attractive location for R&D investment by US private companies, even though this favourable position could be progressively undermined by the developments in recent years in the emerging economies. It is also noteworthy that foreign affiliates from other ERA countries typically account for a very high proportion of business R&D in a given ERA country. This is an indication that private R&D is quite well integrated into the networks of research capacities of international firms. The problem of fragmentation of European research appears, therefore, mostly to be an issue that concerns public research.

Progress on the six axes of the ERA Green Paper will be crucial for reducing the fragmentation of programmes and policies. Initiatives have been launched within five of the axes, and progress has been encouraging. This should not be a signal for complacency, since much still needs to be done, but rather an indication of the need for a common vision and a strategy to achieve this in partnership with all the players involved. The joint work of the French, Czech and Swedish presidencies in creating a consensus of European countries around such a vision is therefore particularly welcome.

Achieving progress in all six axes of the Green Paper at the same time is likely to have a higher impact than only achieving progress in some areas (e.g. cooperation will be facilitated by large-scale pan-European infrastructures, but also for example by facilitating mobility, joint IPR rules and joint programmes). A reinforced governance process based on the common ERA vision and strategy, could, therefore, be instrumental in supporting these initiatives. This report and future reports may constitute a systemic tool to inform and support such governance, by monitoring the progress of the ERA through appropriate indicators as well as by an analysis of the key factors explaining the performance. This would progressively provide a scoreboard of the progress being made in realising the ERA and in enhancing the attractiveness of Europe's science and technology base.

It is in this spirit that this report presents for the first time an overview of the evolution since 2000 of both R&D investment in Europe and of progress on the six axes of the ERA Green Paper. As was the case in previous years, it also presents the latest data on scientific outputs in Europe. The new analysis of the European Research Area is based on all currently available statistical and measurable qualitative data. Further data collection and indicators will in the future be developed to provide a more comprehensive understanding of the flows and inter-connectivity of the production and exploitation of knowledge in Europe and beyond. These activities, by providing a real 'state of the ERA', could therefore progressively become an efficient tool for economic and policy decision-makers.

Part I

Investments and performance in R&D in the European Research Area

Part I compares the scientific and technological performance of the EU with that of the other main world regions and also analyses the performances of individual countries within the European Research Area in relation to each other.

This part is divided into four chapters. Chapter 1 examines R&D investment in the European Research Area since 2000, and the progress or non-progress towards the 3 % target and its underlying causes. Chapter 2 analyses the investment in human resources for R&D: in particular, it looks at the stocks of human capital for research and their development. The issue of mobility is dealt with in Part II. Chapter 3 analyses the scientific and technological outputs of R&D activities and their high-tech outcomes on the basis of bibliometric and patent indicators. The purpose is to provide an assessment of the performance of the ERA compared with that of other large world regions in so far as this is possible. Finally, Chapter 4 uses data on funding and flows of funding to analyse the attractiveness of the ERA for R&D investment and to assess the integration of private R&D in the ERA.

Chapter 1. R&D investment in the European Research Area since 2000

Increasing investment in R&D is one of the key objectives of the Lisbon Strategy. A substantial increase in investment in R&D is important for the achievement of a European Research Area and for providing a significant boost to the industrial competitiveness of the European Union.

This chapter examines the performance and funding of R&D in the ERA. The chapter is structured around the following key questions: Has R&D investment increased? Has the financing of R&D progressed towards the public and private funding targets of 1 % and 2 % of GDP? How is public sector expenditure on R&D broken down between the government and the higher-education sectors? Why is business sector R&D intensity lower in the EU than in the US?

1.1 Has there been progress towards increased investment in R&D?

MAIN FINDINGS

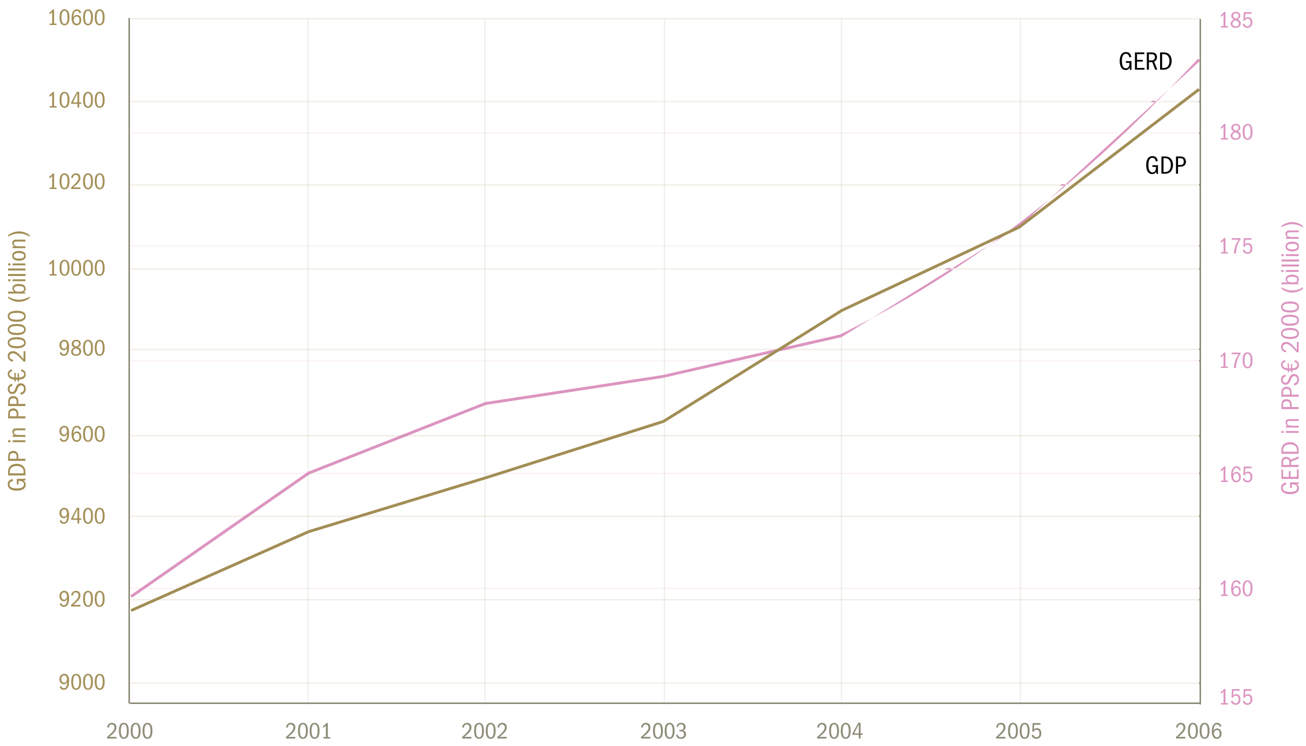
Gross Domestic Expenditure on R&D (GERD) in EU-27 grew by 14.8 % in real terms between 2000 and 2006. GDP experienced a similar rate of growth over the same period. As a result, EU-27 R&D intensity (GERD as a % of GDP) has not fundamentally changed over this period and stood at 1.84 % in 2006. In comparison R&D expenditure in the US grew by 10.1 % in real terms over the same period and US R&D intensity decreased by 4.6 %. This decrease was exclusively due to a lower intensity of business funding of R&D (section 1.2).

The stability of R&D intensity at EU-27 level hides a more dynamic and contrasting picture at Member State level. R&D intensity increased between 2000 and 2006 in 17 Member States and in particular in the less R&D-intensive Member States, where only Poland, Bulgaria, Slovakia and Greece have fallen further behind. Although substantial increases in R&D intensity would be easier to achieve starting from low values, as is the case for most of the new Member States and for Ireland and Spain, nevertheless the data for these countries show that increases in R&D intensity can also be achieved even with strong GDP growth. It is also clear that, in the EU, progress towards higher levels of R&D intensity has so far mostly been a catching-up process. However, Austria and Switzerland demonstrate that increases in R&D intensity can be achieved even when starting from high levels. R&D intensity has not increased at EU-27 level because the countries with increasing R&D intensities do not have very high shares of EU-27 GDP. In particular, R&D intensity has not increased in the United Kingdom, France and Italy, and has increased only slightly in Germany. These are the four countries with the highest GDP in EU-27.

Although R&D expenditure in EU-27 has grown substantially in real terms over 2000-2006, R&D intensity has remained unchanged

In 2006, Gross Domestic Expenditure on R&D (GERD) in EU-27 amounted to € 213 billion [13]. This represented an increase of 4 % in real terms since 2005. Between 2000 and 2006, GERD in EU-27 has increased by 14.8 % in real terms (Figure I.1.1).

FIGURE I.1.1 EU-27 — Evolution of GERD and GDP in real terms [1], 2000-2006



Source: DG Research
Data: Eurostat
Note: [1] PPS€ at constant 2000 prices and exchange rates

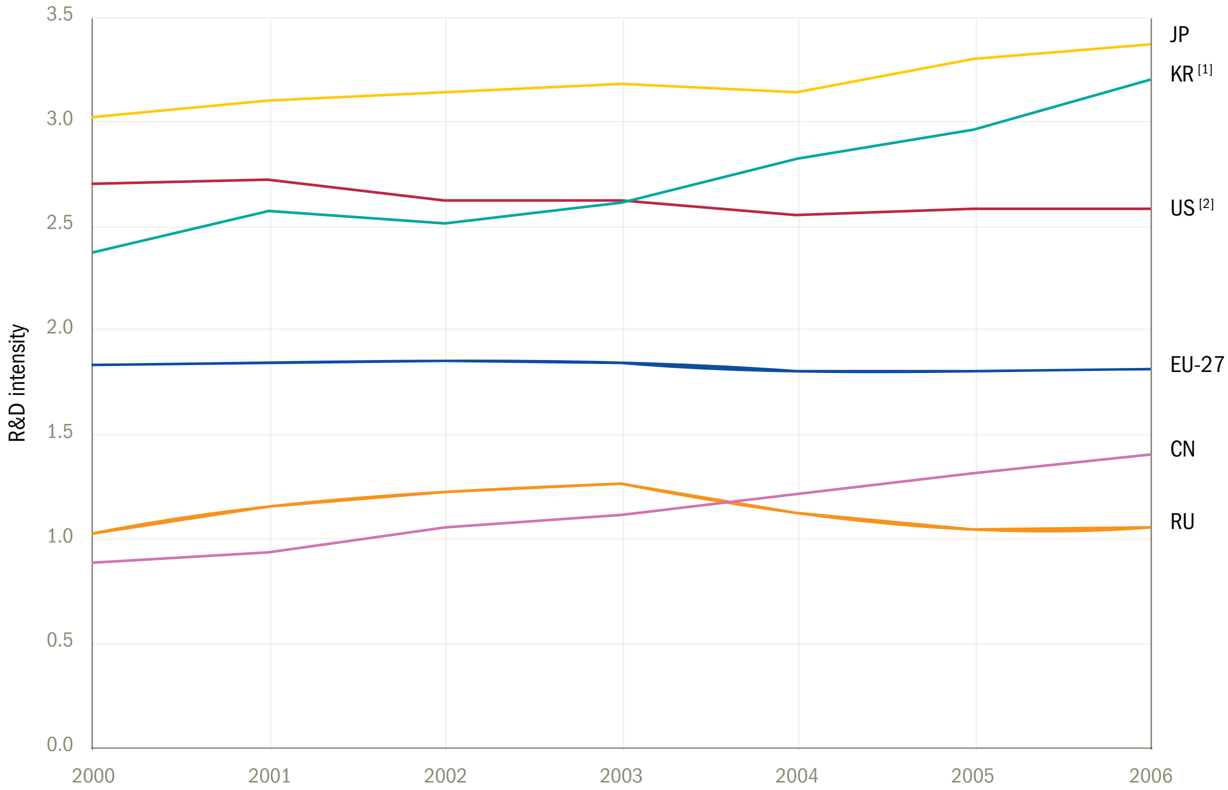
STC key figures report 2008

Over the same period, GDP in EU-27 has grown at almost the same rate as R&D expenditure, 13.7 % in real terms between 2000 and 2006. The result is a slight decline in EU-27 R&D intensity [14] in 2006 to 1.84 %, indicating that there has been no structural change leading to a greater weight of R&D in the EU economy over the period. In comparison, R&D intensity was 2.61 % in the US, 3.23 % in South Korea and 3.39 % in Japan in 2006 (Figure I.1.2).

[13] 183 billion PPS2000 (Figure I.1.1).

[14] R&D intensity is calculated as the ratio between GERD and GDP in current euro. Growth in R&D intensity is therefore not equal to the difference between the real growth rates of GERD (14.8 %) and GDP (13.7 %).

FIGURE I.1.2 Evolution of R&D intensity, 2000-2006



Source: DG Research
Data: Eurostat, OECD
Notes: [1] KR: GERD does not include R&D in the social sciences and humanities
[2] US: GERD does not include most or all capital expenditure

STC key figures report 2008

While EU R&D intensity did not change significantly over the period 2000-2006, the increase in R&D expenditure in real terms has been higher in EU-27 than in the US (14.8 % compared to 10.1 %), so that in 2006 total GERD in EU-27 was equal to 71.4 % of total GERD in the US, an increase of 3 percentage points from 68.5 % in 2000 [15].

The decline of R&D intensity in EU-27 (-1.1 %) was less significant than in the US (-4.6 %) over the period 2000-2006. Japan has outperformed both EU-27 and the US, increasing R&D expenditure by 21.9 % in real terms and R&D intensity by 11.5 % in the same period. Starting at a level of 2.4 % in 2000, the R&D intensity of South Korea had reached 3.23 % in 2006, almost the same level as Japan.

The R&D intensity of China has grown by more than 50 % since 2000, driven by the business enterprise sector, which financed R&D at a level of almost 1 % of GDP in 2006 (the same level as EU-27) compared to a level of only 0.52 % in 2000. By contrast, R&D financed by government in China increased only from 0.30 % to 0.35 % of GDP (about half of the EU-27 value) over the period 2000-2006 [16]. Therefore, we can conclude that in 2006 EU-27 R&D intensity was only higher than that of China because of higher public funding of R&D.

A large range of R&D intensities in the ERA

Total GERD by country (in million euro and as % of EU-27 total) is shown in Table I.1.1 for 2006. Germany, France and the United Kingdom accounted for 61 % of GERD in EU-27 (74 % if Italy and Spain are included). By contrast, the share of the 12 new Member States in EU-27 GERD was only about 2.8 %.

[15] These ratios were calculated from values expressed in PPS2000.
[16] See Part I, Chapter 1.2, Figure I.1.7.

TABLE I.1.1 Gross Domestic Expenditure on R&D (GERD)
(Countries are ranked in terms of total GERD)

	GERD million euro 2006 [1]	GERD EU-27 shares (%) 2006 [2]
US [3]	*273772*	-
EU-27	*213805*	100.0
Japan	118295	-
Germany	*58848*	*27.5*
France	*37844*	*17.7*
UK	34037	15.9
China	30002	-
Italy	15599	7.7
Spain	*11815*	*5.5*
Sweden	11691	5.5
Netherlands	*8910*	*4.2*
Switzerland	8486	-
Austria	*6946*	*3.0*
Finland	*6016*	*2.7*
Belgium	*5798*	*2.7*
Denmark	*5349*	*2.5*
Israel [4]	*5263*	-
Norway	4071	-
Ireland	*2500*	*1.1*
Turkey	2432	-
Czech Republic	1761	0.8
Poland	1513	0.7
Portugal	*1294*	*0.6*
Greece	*1223*	*0.6*
Hungary	900	0.4
Luxembourg	*497*	*0.2*
Slovenia	484	0.2
Romania	444	0.2
Iceland	364	-
Croatia	297	-
Slovakia	*252*	0.1
Lithuania	191	0.1
Estonia	*151*	*0.1*
Bulgaria	121	0.1
Latvia	112	0.1
Cyprus	*62*	*0.03*
Malta	*28*	*0.01*

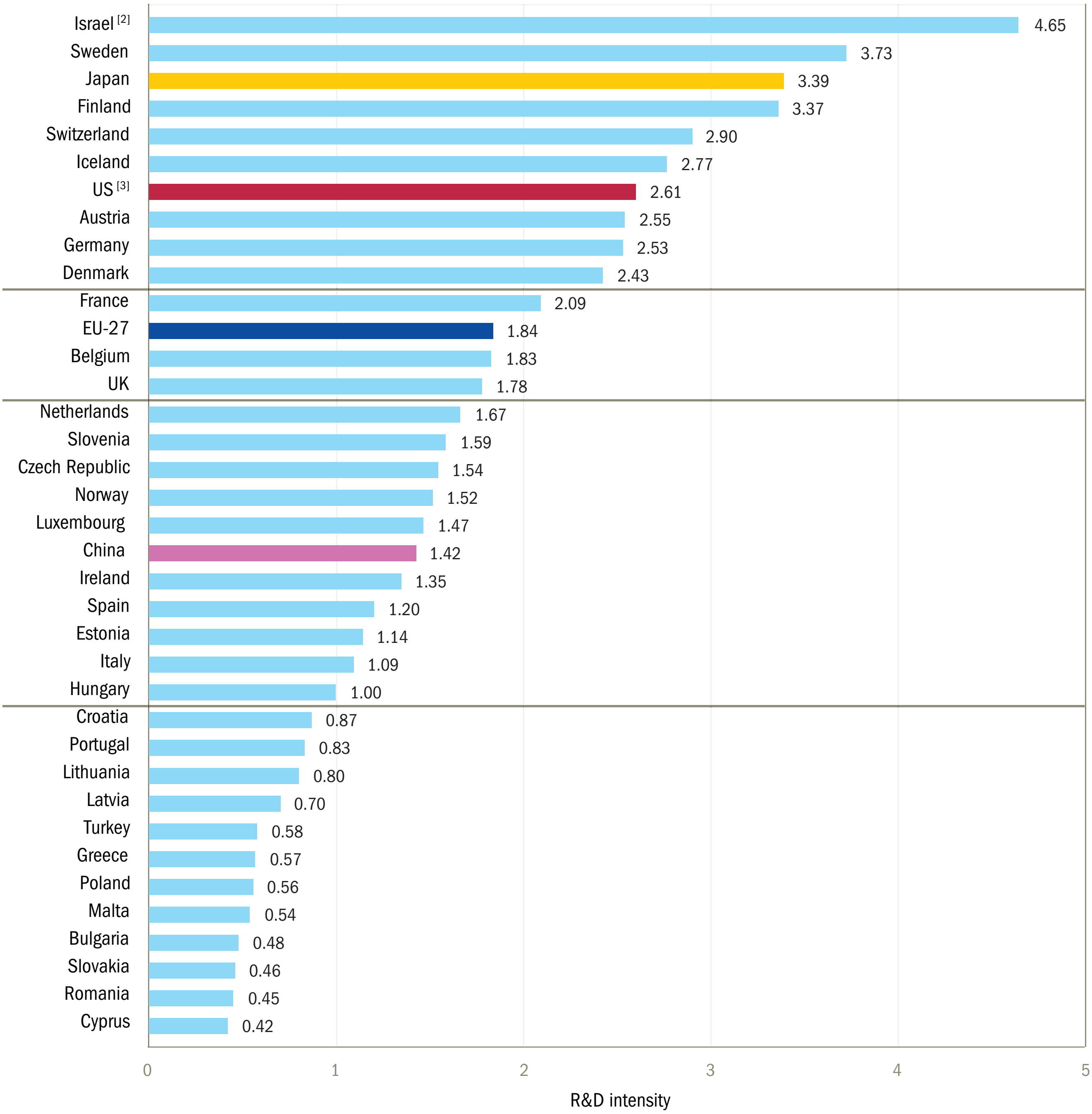
Source: DG Research
Data: Eurostat, OECD
Notes: [1] CH: 2004; IT, IS: 2005; IE, AT, SK, FI: 2007
[2] IT: 2005
[3] US: GERD does not include most or all capital expenditure
[4] IL: GERD does not include defence
[5] Values in italics are provisional

STC key figures report 2008

The stability of EU-27 R&D intensity at EU-27 level disguises quite different situations and developments across Member States. In Figure I.1.3 the EU-27 Member States and the Associated States are divided into four groups according to the level of R&D intensity:

- a group of Member States with *high R&D-intensities*: Finland, Sweden, Denmark, Austria and Germany. Of the Associated States, Switzerland, Iceland and Israel have similar or higher R&D intensities;
- a group of three Member States with *medium-high R&D intensities* close to the EU-27 average: France, Belgium and the United Kingdom;
- a group of countries with *medium-low R&D intensities* (1 % to 1.7 %) composed of nine Member States and Norway;
- a group of countries with *low R&D intensities* (less than 1 % of GDP) composed of twelve Member States, Turkey and Croatia.

FIGURE I.1.3 R&D intensity (GERD as % of GDP), 2006 [1]



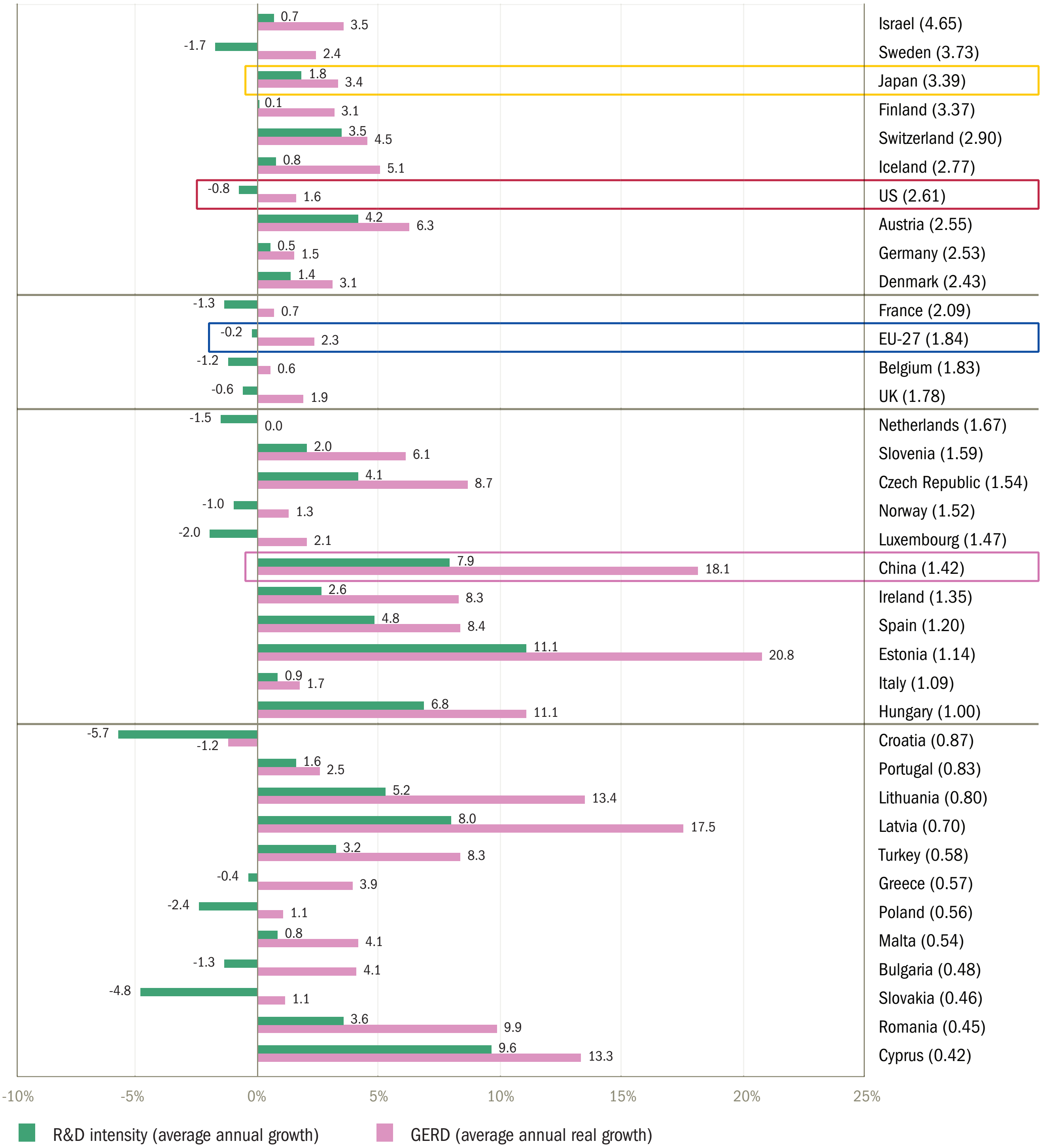
Source: DG Research
Data: Eurostat, OECD
Notes: [1] CH: 2004; IT, IS: 2005; IE, AT, SK, FI: 2007
[2] IL: GERD does not include defence
[3] US: GERD does not include most or all capital expenditure

STC key figures report 2008

R&D expenditure grew in real terms in all Member States between 2000 and 2006, but the evolution of R&D intensity has varied across Member States

Over the period 2000-2006 R&D expenditure (GERD) has grown in real terms in all 27 Member States, and in some cases the growth has been considerable. Real growth of R&D expenditure over the period 2000-2006 ranges from 3.3 % (0.6 % per year on average) in Belgium to 210 % (20.8 % per year on average) in Estonia (Figure I.1.4, pink bars; as in Figure I.1.3, countries are ranked by level of R&D intensity in 2006). The total real growth of R&D expenditure between 2000 and 2006 exceeds 100 % in the three Baltic States and in Cyprus; it is greater than 60 % in Hungary, Romania, the Czech Republic, Ireland and Spain. In fact, within the ERA, R&D expenditure decreased in real terms only in Croatia.

FIGURE I.1.4 Growth of R&D intensity and GERD, 2000-2006 [1]; in brackets: R&D intensity, 2006 [2]



Source: DG Research
Data: Eurostat, OECD
Notes: [1] CH: 2000-2004; IT, IS: 2000-2005; IE, AT, SK, FI: 2000-2007; EL, NO: 2001-2006; FR, HU, MT: 2004-2006; SE: 2005-2006
[2] CH: 2004; IT, IS: 2005; IE, AT, SK, FI: 2007

R&D intensity has increased in 17 Member States over the period 2000-2006

- Three of the new Member States (Estonia, Cyprus and Latvia, representing about 0.4 % of EU-27 GDP [17]) have managed to *increase their R&D intensities by more than 50 %*.
- Nine Member States (Lithuania, Spain, Austria, Hungary, Romania, Ireland, Czech Republic, Slovenia and Portugal, representing about 16.5 % of EU-27 GDP) have had *R&D intensity increases of between 10 % and 50 %*. With the exception of Austria, the growth for all of these Member States is from a low or relatively low level of R&D intensity. Austria is the only intermediate R&D-intensive Member State that managed to increase its R&D intensity substantially to reach the level of the Member States with high R&D intensities. Of the Associated States, Turkey and Switzerland have experienced comparable increases in R&D intensity.
- Five Member States (Denmark, Italy, Malta, Germany and Finland), representing about 36 % of EU-27 GDP) have *increased their R&D intensities by up to 10 %*. Of the Associated States, Israel and Iceland have increased their R&D intensities to a similar extent.

Cohesion Policy has made a substantial contribution to the increases in R&D investment particularly in the new Member States. The EU Structural Funds contributed an average annual total of € 157.4 million to research investment in the 10 new Member States over the period 2004-2006, an investment which triggered an average annual total of € 69.6 million in national R&D investment. This represented some 8 % of the total national public R&D investment and was estimated for instance in Latvia, Estonia and Lithuania to amount to between 25 and 30 % of total GBAORD. In the period 2007-2013, such investments in the 12 new Member States are expected to increase to an average annual total of € 2.9 billion [18].

By contrast, ten Member States (representing about 47.1 % of EU-27 GDP) have seen their R&D intensities decrease over the period 2000-2006. These include Sweden, Luxembourg and countries from the two intermediate groups (France, Belgium, the United Kingdom and the Netherlands) as well as four countries with very low R&D intensities (Poland, Slovakia, Bulgaria and Greece) which, therefore, have fallen further behind. Among the Associated States, R&D intensity also decreased in Norway and Croatia.

In conclusion, R&D expenditure has grown in real terms in all EU Member States over 2000-2006, but with the exception of Austria, substantial increases in R&D intensity have almost exclusively taken place in the two groups of countries with lower R&D intensities. Therefore, for EU-27, progress towards higher levels of R&D intensity has mostly been the result of countries with low R&D intensities 'catching-up' in the period 2000-2006 (see Figure I.1.4 for the average annual growth in R&D intensity by country).

The dynamics of R&D intensity evolution over the periods 2000-2004 and 2004-2006 differ across Member States

Table I.1.2 provides a comparison of the average annual growth of GDP and R&D expenditure in nominal terms [19] for each Member State over the two periods 2000-2004 and 2004-2006. For countries with values in violet, R&D expenditure had a lower rate of growth than GDP, resulting in a negative growth of R&D intensity (9 Member States over 2000-2004 and 11 Member States over 2004-2006), while countries with values in green experienced the opposite development. While some Member States show a clear acceleration in the growth of R&D expenditure over the period 2004-2006 (Czech Republic, Estonia, Latvia and Slovenia), other Member States by contrast experienced a modest acceleration or a slowdown of this growth (France, Ireland, Italy, Denmark and the Netherlands).

[17] In 2006.
[18] See Annual Report on research and technological development of the European Union in 2007, COM(2008)519 final.
[19] R&D intensity is calculated as the ratio between GERD and GDP in current euro. Therefore, growth in R&D intensity is compared to nominal growth in GERD and GDP.

TABLE I.1.2 GDP, GERD and R&D intensity – average annual growth (nominal)
(Countries are ranked in terms of average annual growth of R&D intensity, 2000-2006 [1])

GERD HAS GROWN SINCE THE PREVIOUS YEAR AT A HIGHER RATE OF GROWTH THAN GDP
GERD HAS GROWN SINCE THE PREVIOUS YEAR BUT AT A LOWER RATE OF GROWTH THAN GDP
GERD HAS DECREASED SINCE THE PREVIOUS YEAR WHEREAS GDP HAS GROWN

	Average annual growth (%) 2000-2004 [2]			Average annual growth (%) 2004-2006 [3]			Average annual growth (%) 2000-2006 [1]		
	GDP	GERD	R&D intensity	GDP	GERD	R&D intensity	GDP	GERD	R&D intensity
Estonia	11.9	22.2	9.2	17.5	35.1	15.0	13.8	26.4	11.1
Cyprus	6.0	17.5	10.9	7.2	15.0	7.2	6.4	16.7	9.6
Latvia	11.8	10.3	-1.4	22.6	58.6	29.4	15.3	24.5	8.0
Hungary	11.9	18.6	6.0	7.2	14.5	6.8	7.2	14.5	6.8
Lithuania	8.2	15.0	6.3	14.4	18.0	3.1	10.2	16.0	5.2
Spain	7.5	11.8	4.1	8.0	14.9	6.4	7.7	12.9	4.8
Austria	2.9	6.8	3.8	4.9	9.8	4.6	3.8	8.1	4.2
Czech Republic	6.5	7.3	0.7	7.1	19.3	11.3	6.7	11.1	4.1
Romania	32.3	33.9	1.2	18.2	28.2	8.4	27.5	32.0	3.6
Ireland	9.2	11.8	2.5	7.7	10.7	2.8	8.5	11.4	2.6
Slovenia	6.1	6.3	0.2	6.7	12.9	5.8	6.3	8.5	2.0
Japan	-0.2	0.8	1.0	1.1	4.6	3.5	0.2	2.0	1.8
Portugal	4.2	4.6	0.4	3.8	8.0	4.0	4.1	5.7	1.6
EU-12 [4]	6.9	7.0	0.1	14.2	19.6	4.7	9.3	11.0	1.6
Denmark	3.2	5.9	2.6	5.8	4.6	-1.1	4.0	5.5	1.4
Italy	4.0	5.2	1.2	2.6	2.3	-0.4	3.7	4.6	0.9
Malta	-1.5	:	:	6.2	7.1	0.8	6.2	7.1	0.8
Germany	1.8	2.1	0.3	2.5	3.5	1.0	2.0	2.5	0.5
EU-24 [5]	4.9	5.1	0.1	6.2	6.8	0.6	5.3	5.6	0.3
Finland	3.6	4.4	0.8	5.5	4.6	-0.8	4.4	4.5	0.1
EU-3 [6]	2.6	2.2	-0.4	3.7	4.2	0.4	2.9	2.8	-0.1
EU-27	3.6	3.2	-0.4	4.9	5.2	0.3	4.0	3.8	-0.2
Greece	8.2	6.3	-1.8	7.5	9.4	1.8	7.9	7.5	-0.4
UK	5.4	3.4	-1.9	4.9	7.0	2.0	5.3	4.6	-0.6
US [7]	4.5	3.0	-1.4	6.3	6.9	0.6	5.1	4.3	-0.8
Belgium	3.6	2.1	-1.4	4.5	3.6	-0.9	3.9	2.6	-1.2
France	3.4	3.8	0.3	4.3	3.0	-1.3	4.3	3.0	-1.3
Bulgaria	9.8	8.6	-1.0	12.8	10.5	-2.0	10.7	9.3	-1.3
Netherlands	4.1	3.5	-0.6	4.3	0.9	-3.3	4.2	2.6	-1.5
Sweden	4.1	-0.7	-4.7	6.0	4.2	-1.7	6.0	4.2	-1.7
Luxembourg	5.7	5.3	-0.3	11.1	5.3	-5.2	7.4	5.3	-2.0
Poland	5.6	1.8	-3.5	7.1	6.9	-0.2	6.1	3.5	-2.4
Slovakia	9.8	3.4	-5.8	10.8	6.9	-3.5	10.2	4.9	-4.8

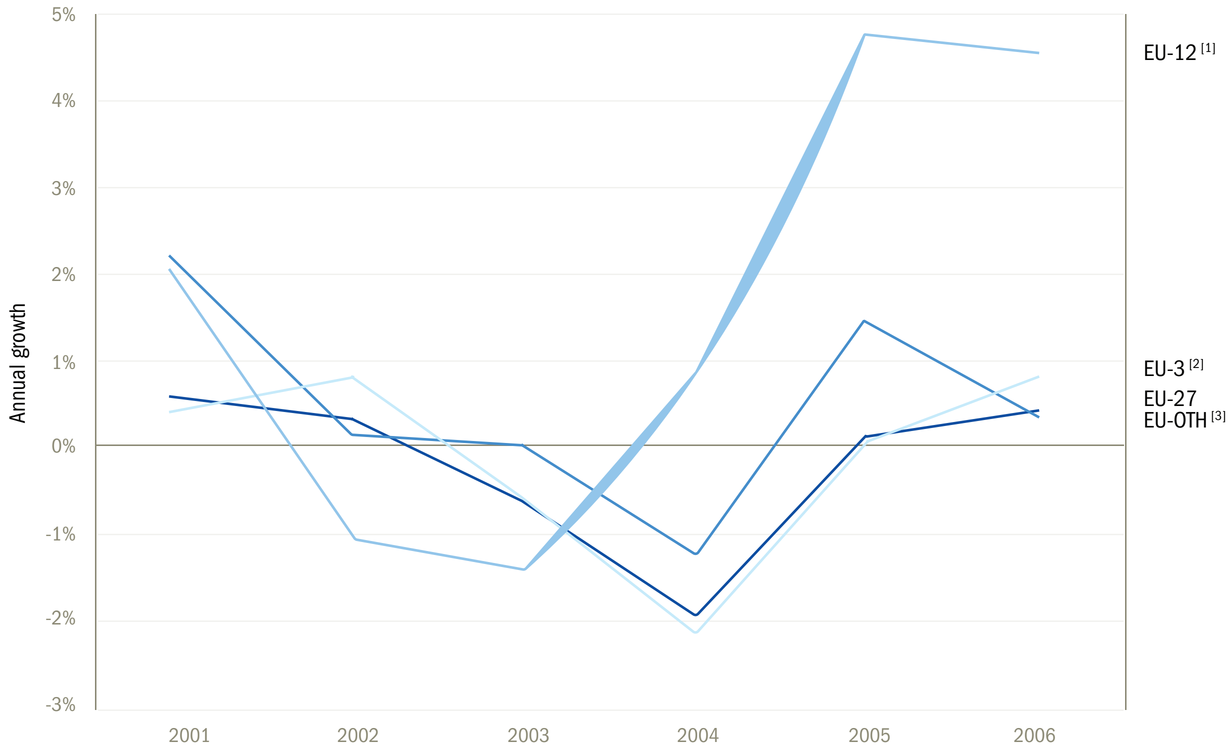
Source: DG Research
Data: Eurostat, OECD
Notes: [1] IT: 2000-2005; IE, AT, SK, FI: 2000-2007; EL: 2001-2006; FR, HU, MT: 2004-2006; SE: 2005-2006
[2] FR, HU: 2000-2003; EL, SE: 2001-2004
[3] IT: 2004-2005; SE: 2005-2006; IE, AT, SK, FI: 2004-2007
[4] EU-12: The twelve new Member States (BG, CZ, EE, CY, LV, LT, HU, MT, PL, RO, SI, SK)
[5] EU-24: All Member States except DE, FR, UK
[6] EU-3: DE, FR, UK
[7] US: GERD does not include most or all capital expenditure

The overall stability of EU-27 R&D intensity is linked to the weight of the three largest economies

Furthermore, the group of 12 Member States with high and very high R&D intensity growth identified in Figure I.1.4 accounts for only 17 % of EU-27 GDP, whereas the other Member States with limited and negative R&D intensity growth account for 83 % of EU-27 GDP. This means that the high R&D intensity growth of the 12 Member States has not been sufficient to increase R&D intensity at EU-27 level.

In this respect the weight in the EU-27 aggregate of the three largest economies of the EU (Germany, France and the United Kingdom, grouped here in EU-3) should be emphasised: EU-3 represents 51 % of EU-27 GDP and 61 % of EU-27 GERD. Figure I.1.5 compares the performance of EU-27 as a whole with that of EU-3, EU-12 (the 12 new Member States) and EU-OTH (all the other Member States, i.e. the 15 old Member States less Germany, France and the United Kingdom). The R&D intensity growth of EU-3 and EU-27 follow each other quite closely. It is interesting to note the remarkable change in the dynamics of EU-12 annual R&D intensity growth as of 2003 when the EU-12 catching up process really started. This however had almost no impact on the annual R&D intensity growth of EU-27. It is also noteworthy that the EU-OTH group has had a substantially higher R&D intensity growth than EU-3 since 2001, except in 2002 and 2006.

FIGURE I.1.5 R&D intensity — annual growth



Source: DG Research
Data: Eurostat
Notes: [1] EU-12: The twelve new Member States (BG, CZ, EE, CY, LV, LT, HU, MT, PL, RO, SI, SK)
[2] EU-3: DE, FR, UK
[3] EU-OTH: The remaining Member States (BE, DK, IE, EL, ES, IT, LU, NL, AT, PT, FI, SE)

STC key figures report 2008

The majority of Member States remain far from their national R&D intensity targets

Since 2005, each Member State has set a national R&D intensity target. The national targets may differ from the 3 % target for the EU as a whole, depending on the particular situation of each Member State regarding R&D expenditure.

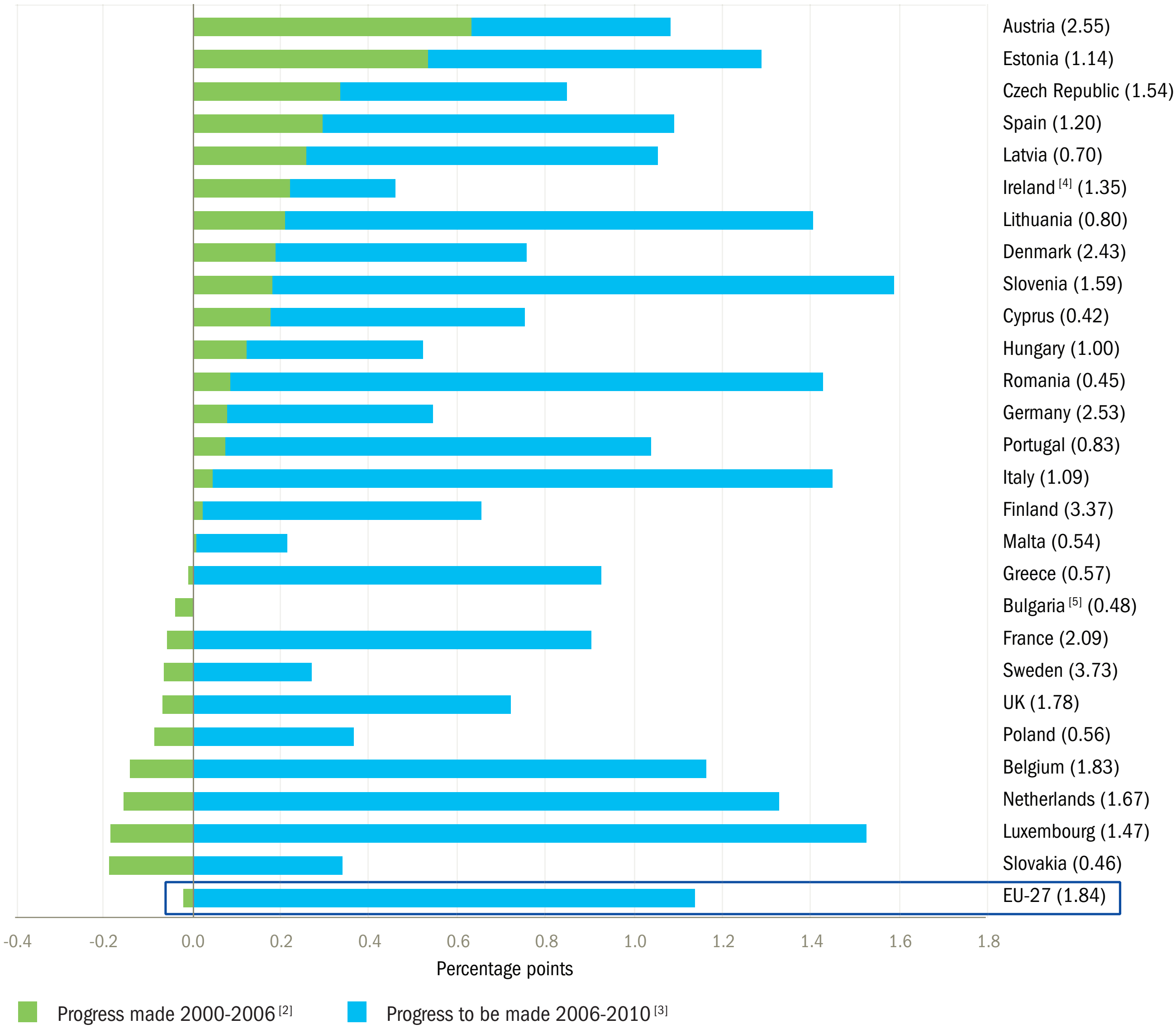
Figure I.1.6 shows in green for each Member State the difference between its R&D intensity for the latest available year [20] and its R&D intensity in 2000. For instance, R&D intensity in Austria was 0.64 percentage points higher in 2007 (at 2.55 %, shown in brackets on the graph) than in 2000 (at 1.91 %).

[20] 2005, 2006 or 2007 according to the latest data available for each country, see footnote to Figure I.1.6.

The blue bars show for each Member State the distance separating its latest [21] R&D intensity value and its R&D intensity target for 2010. Austria's R&D intensity target for 2010 of 3 % is 0.45 percentage points higher than its 2007 R&D intensity of 2.55 %. In other words, in the period 2000-2007, Austria has progressed more than halfway towards its 2010 target.

In 10 Member States, R&D intensity was higher in 2000 than in 2006 (negative green bars). These Member States are therefore further away from their national R&D intensity targets in 2006 than in 2000. Austria, Estonia and the Czech Republic are the Member States that have achieved the most substantial progress towards their targets. However, in the 13 remaining Member States (Bulgaria has not set an R&D intensity target for 2010), the progress made towards their respective R&D intensity targets is only a small part of the progress that is required to meet them. If all Member States reach their respective R&D intensity targets, EU-27 will have an R&D intensity of 2.5 % in 2010. This is below 3 %, but it would still be a substantial improvement on the current level.

FIGURE I.1.6 R&D intensity — progress towards the 2010 targets (in percentage points) in brackets: R&D intensity, 2006 [1]



Source: DG Research
Data: Eurostat, Member States
Notes: [1] IT: 2005; IE, AT, SK, FI: 2007
[2] IT: 2000-2005; IE, AT, SK, FI: 2000-2007; EL: 2001-2006; FR, HU, MT: 2004-2006; SE: 2005-2006
[3] IT: 2005-2010; FR: 2006-2012; UK: 2006-2014; EL: 2006-2015; IE, AT, SK: 2007-2010; FI 2007-2011
[4] IE: The R&D intensity target for 2010 was estimated by DG Research
[5] BG has not set an R&D intensity target

STC key figures report 2008

[21] 2005, 2006 or 2007 according to the latest data available for each country, see footnote to Figure I.1.6.

1.2 Has the financing of R&D progressed towards the public and private funding targets of 1 % and 2 % of GDP?

MAIN FINDINGS

In 20 Member States, the share of the government budget for R&D in total general government expenditure has increased between 2000 and 2007. This shows the commitment of these Member States to higher levels of R&D investment. As a result, the intensity of government funding of R&D has increased in a majority of Member States. However, at EU-27 level, this intensity has remained stable (0.63 % of GDP in 2006) due to the stagnation and decrease in Member States with a high share of EU-27 GDP.

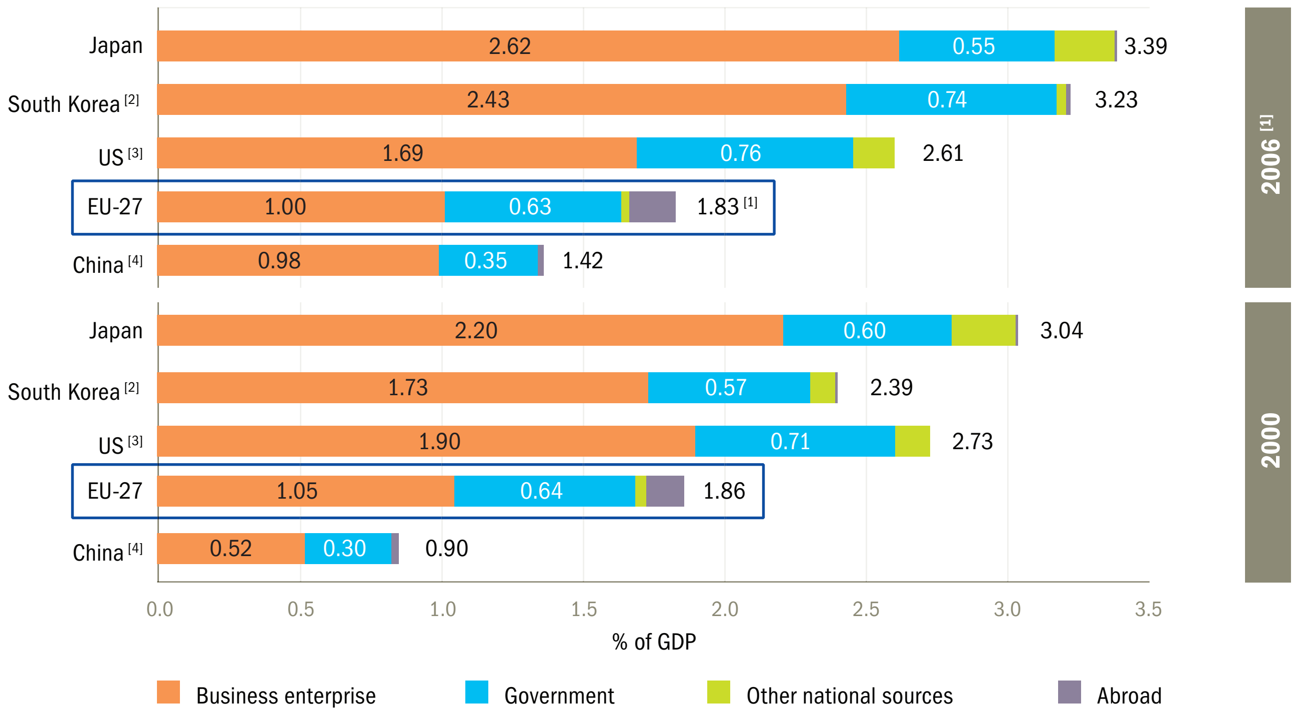
EU-27 is lagging behind the US, Japan and South Korea in terms of overall R&D intensity, due to a lower level of R&D funded (and performed) by the business sector. The intensity of business funding of R&D has increased almost exclusively in those Member States where this intensity was already low or very low. Except for Austria, EU Member States with medium and high levels of business funding have not been able to increase substantially their business R&D funding intensities. At EU-27 level, the intensity of business funding of R&D has slightly declined between 2000 (1.05 % of GDP) and 2006 (1.00 % of GDP). In the US, the decline was much more significant, although from a substantially higher level.

Since 2000 an increasing share of domestic R&D in EU Member States has been funded from foreign sources. However, so far it has not been possible to break down foreign sources of funding into public and private.

R&D financed by public sources in EU-27 has not progressed towards the Barcelona objective of 1 % of GDP

R&D is financed by government, business enterprise, other national sources (e.g. private non-profit organisations), and from abroad. Figure I.1.7 shows the differences in the levels of R&D funding intensities between EU-27, the US, Japan, South Korea and China for these four sources of funds.

FIGURE I.1.7 R&D intensities for the four sources of funds, 2000 and 2006 [1]



Source: DG Research
Data: Eurostat, OECD
Notes: [1] EU-27: 2005 (2005 is the latest year available for GERD by source of funds)
[2] KR: R&D in the social sciences and humanities is not included
[3] US: Most or all capital expenditure is not included; Abroad is included in business enterprise
[4] CN: The sum of the sectors does not add to the total

STC key figures report 2008

R&D financed by government as a % of GDP in EU-27 was equal to 0.63 % in 2005 as against 0.64 % in 2000. This is 15 % higher than in Japan, but 21 % and 17 % lower than in the US and South Korea respectively. However, the EU-27 value should be corrected for funding from abroad, which, at 0.16 % of GDP in 2005, is much higher than in Japan and South Korea [22]. The 'abroad' source of funds in EU-27 is substantial because it includes both intra-European cross-border flows of funds and funds from outside the EU. It is composed of funds from foreign companies, but also to a significant extent of Community funds. Adding Community funds to government funds in EU-27 brings R&D financed by government as a % of GDP in EU-27 closer to the levels of the US and South Korea.

R&D funding by business in EU-27 is at the same level as in China, and substantially lower than in the US, Japan and South Korea

In EU-27, R&D financed by business enterprise as a % of GDP decreased by 5 % between 2000 and 2005. The EU-27 value of 1 % in 2005 represented 38 %, 41 % and 59 % of the corresponding values for Japan, South Korea and the US respectively. If business R&D funding from the 'abroad' source of funds is added to R&D financed by business enterprise, the conclusion does not change drastically [23]: the difference in total R&D intensity between the EU and the US, Japan and South Korea is almost exclusively due to the difference in the level of private funding of R&D. R&D financed by business enterprise as a % of GDP, which has increased substantially in Japan and South Korea between 2000 and 2006, decreased in the US by 12 % over the same period, but from a higher level.

In 2006, business expenditure on R&D (BERD) amounted to € 136 billion in EU-27, compared to € 193 billion in the US and € 91 billion in Japan. In cumulative terms (in current prices), in the seven-year period 2000-2006, total BERD in EU-27 amounted to € 852 billion, compared to € 1,366 and € 675 billion in the US and Japan respectively. As a result the business sector in the US invested a total of € 514 billion more in R&D than was invested by the business sector in EU-27 in the period 2000-2006 [24].

R&D financed by business enterprise as a % of GDP has almost doubled in China between 2000 and 2006 and has now reached EU-27 level. The rapid catching up of China's total R&D intensity was driven almost exclusively by increased business funding [25]. At present it is only the substantially higher funding by the government sector and by the 'abroad' category that leaves EU-27 with a higher total R&D intensity than China.

A growing share of R&D budget in general government expenditure demonstrates increased commitments by a large majority of Member States

In 2006, Government Budget Appropriations or Outlays for R&D (GBAORD) [26] amounted to 1.62 % of general government expenditure in EU-27, a share which has been increasing at a rate of 0.3 % per annum between 2002 and 2006 (Figure I.1.8).

This modest increase at EU level hides a much more positive picture at Member State level, where the share of the R&D budget in general government expenditure has increased between 2000 and 2007 in 20 Member States [27]. In nine Member States, this share increased by 5.5 % or more per annum. These high growth rates to some extent reflect the initial low or very low levels of the R&D budgets in these Member States, but they also indicate a commitment to increasing public investment in R&D. In these Member States, the Lisbon Strategy and the associated target for R&D intensity has clearly led to a step change in the political importance attributed to research.

[22] The 'abroad' source of funds is included in the business enterprise source of funds in the US. Therefore, no direct comparison with the US is possible.

[23] R&D financed by 'abroad' amounted to 0.16 % of GDP for the EU in 2005, including public and private foreign sources. Funding from the abroad-private source of funds, although not known precisely, is therefore equal to less than 0.16 % of GDP. This compares to 1 % of GDP for the (domestic) business enterprise source of funds.

[24] Source: Eurostat, OECD.

[25] It must be noted that to some extent Chinese funding in the business sector comes from State-owned companies that respond to policy decisions and not market forces.

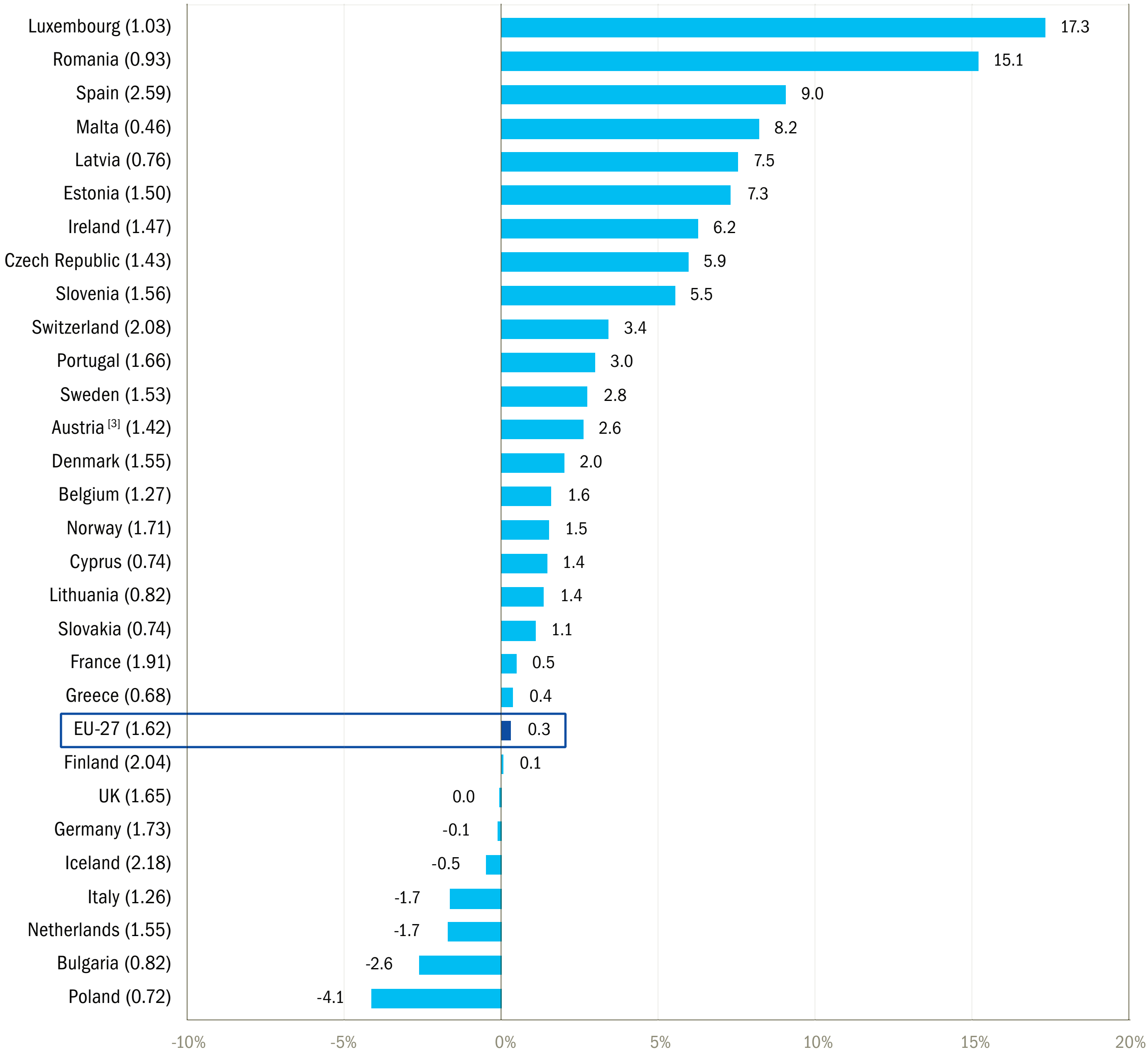
[26] For the purposes of GBAORD, the Frascati Manual recommends that central or federal government should always be included; provincial or state government should be included when its contribution is significant; local government funds (i.e. those raised by local taxes) should be excluded.

[27] See footnotes of Figure I.1.8 for the exact period covered for each country.

In 10 other Member States, the average annual growth rate of the R&D budget as a % of general government expenditure is between 1.1 % and 3.4 % over the period 2000-2007. Even though this increase is more modest, it is still a sign of the priority given to research over other government expenses by these Member States.

The share of the R&D budget in general government expenditure increased on average by 0.5 % in France, it remained unchanged in the United Kingdom, and it decreased slightly in Germany and somewhat more so in Italy. As these four Member States account for a very large share of the total government budget for R&D in EU-27, this explains the modest progress observed at EU level.

FIGURE I.1.8 GBAORD as % of general government expenditure — average annual growth, 2000-2007 [1]
in brackets GBAORD as % of general government expenditure, 2007 [2]



Source: DG Research

STC key figures report 2008

Data: Eurostat, OECD

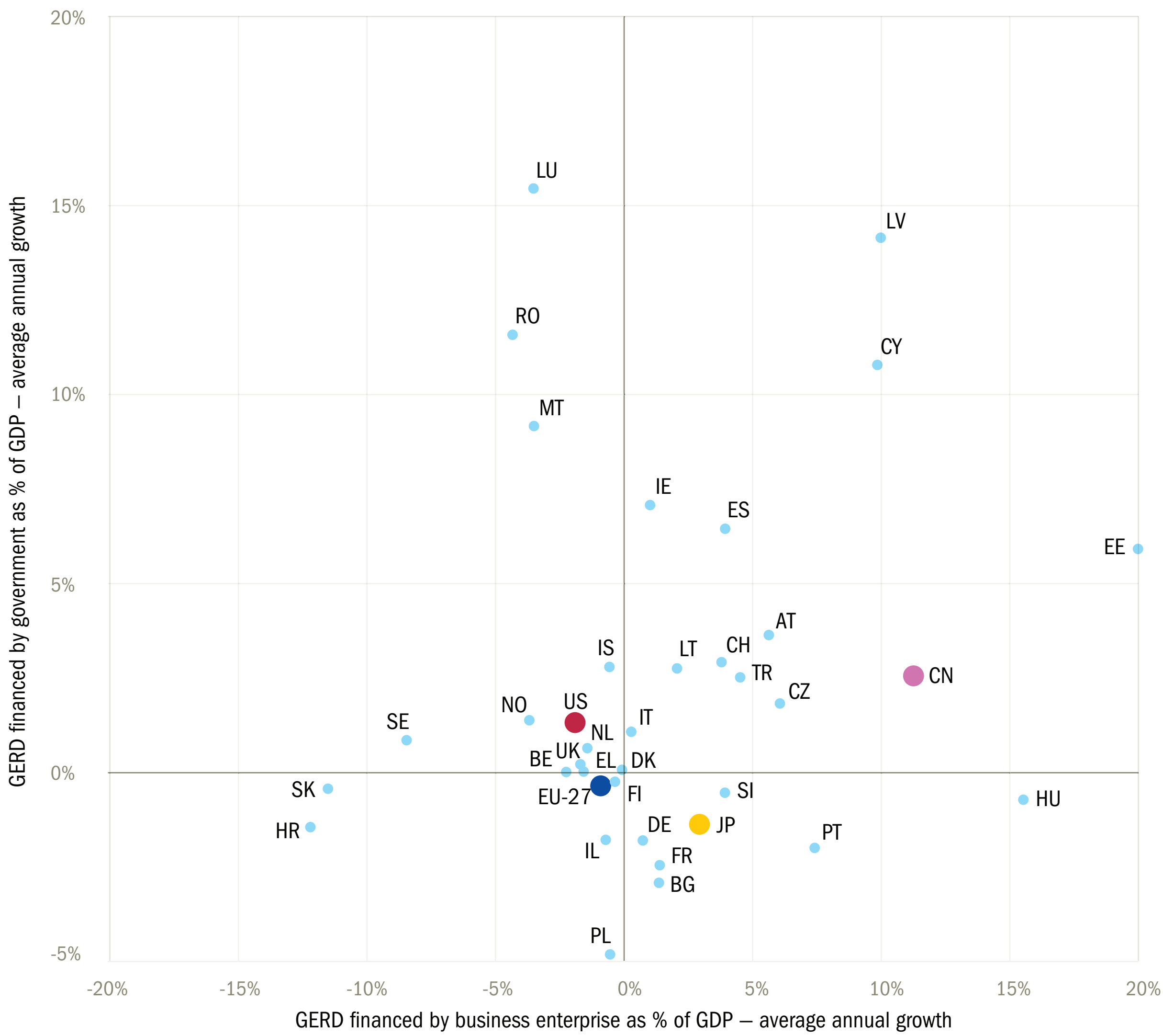
Notes: [1] CH: 2000-2004; BE, ES, FR, IT, LV, PL, IS: 2000-2006; UK: 2001-2006; DK: 2001-2007; BG, EU-27: 2002-2006; CZ, SK: 2002-2007; CY, MT: 2004-2006
[2] CH: 2004; BE, BG, ES, FR, IT, CY, LV, MT, PL, UK, EU-27, IS: 2006
[3] AT: GBAORD refers to federal or central government expenditure only
[4] Hungary is not included due to unavailability of data

The stagnation in R&D financed by government as a % of GDP in EU-27 is mainly linked to Germany, France, the United Kingdom and Italy

Figure I.1.9 shows, for each country, the respective contributions of funding by the government [28] and funding by the business enterprise sector to the evolution of R&D intensity. A majority of Member States (18) have increased direct government support for R&D (R&D financed by government as % of GDP) over the period 2000-2006 [29]. However, this intensity has not progressed at EU-27 level due to the decrease observed in Germany and France, and the limited increases in the United Kingdom and Italy.

The increased intensity of government direct support for R&D in 14 Member States, in particular in those with low R&D intensities, shows the commitment of these Member States to making progress towards higher levels of R&D investment. In addition, in recent years a number of Member States have introduced or reinforced indirect public support for R&D, in particular for business R&D through tax incentives [30], with a view to raising private sector investments in R&D (see Box 1). This increased indirect support for R&D by government, which is not taken into account in Figure I.1.9, is another sign of the commitment to achieving higher R&D intensities.

FIGURE I.1.9 GERD financed by business enterprise and by government as % of GDP average annual growth 2000-2006 [1]



Source: DG Research
Data: Eurostat, OECD
Note: [1] IT: 1996-2005; NL, IL: 2000-2003; CH: 2000-2004; BE, BG, DE, CY, LU, PT, EU-27: 2000-2005; AT: 2000-2007; SE: 2001-2003; DK, EL, IS, NO: 2001-2005; HR: 2002-2006; FR: 2004-2005; HU: 2004-2006; MT: 2005-2006

STC key figures report 2008

[28] GERD financed by government only includes direct support for R&D by government; indirect government support for business R&D through tax incentives is not considered a government source of funds. Therefore, any increase of a government's indirect support for R&D over the period 2000-2006 is not represented in Figure I.1.9.

[29] See the actual period covered for each Member State, depending on data availability, in the footnote to Figure I.1.9.

[30] This shift towards indirect public support of R&D is documented in Key Figures 2007, pp 73-75.

The intensity of government direct support for R&D has increased not only in those countries where it was low, but also in some of the Member States (Austria, Sweden, the Netherlands and the United Kingdom) and Associated States (Switzerland, Iceland and Norway) where it was already medium or high. In contrast, the intensity of business enterprise support for R&D has increased almost exclusively only in those ERA countries where this intensity was already low or very low. With the exceptions of Austria and Switzerland, ERA countries with medium and high levels of business funding have not been able to increase substantially their business R&D funding intensities. Therefore in the ERA, any increase in business enterprise funding of R&D has basically been linked to a catching-up process starting from low levels.

BOX 1: DIRECT AND INDIRECT GOVERNMENT FUNDING OF BUSINESS R&D AND TAX INCENTIVES FOR R&D

Indirect support for business R&D by government through tax incentives is not systematically quantified. National estimates for the year 2005 were made available by 13 countries (including 8 European countries) to OECD [31]: in 2005, in Belgium, the Netherlands, Portugal and Ireland, the greatest part of government support for business R&D was indirect, through tax incentives; in Norway, almost half of government support for business R&D was indirect, about one third in the United Kingdom and France, and one-quarter in Spain.

In these countries, the estimated indirect government funding of business R&D through tax incentives in 2005 ranged from 0.05 % to 0.1 % of GDP [32]. This is significant when compared to the total direct government funding of public and business R&D for EU-27 (0.63 % of GDP, Figure I.1.7).

The convergence towards higher R&D intensities is linked to an expansion of business enterprise funding of R&D

There is a clear positive correlation between a country's R&D intensity and the level of R&D funded by business enterprise: in most of the less R&D-intensive countries, government remains the main source of funds for R&D expenditure (Figure I.1.10; countries are ranked according to their R&D intensities in 2006); in contrast, in most of the more R&D-intensive countries, the business enterprise sector finances the larger part (more than 60 %) of domestic R&D activities. This of course reflects different stages of the shift towards the knowledge-intensive economy. Public investment in R&D should translate after a few years into an increased level of business activity in R&D. However, above a certain level, more comprehensive policies need to be developed to maintain at the same time an increased level of R&D intensity in public spending and the development of autonomous BERD.

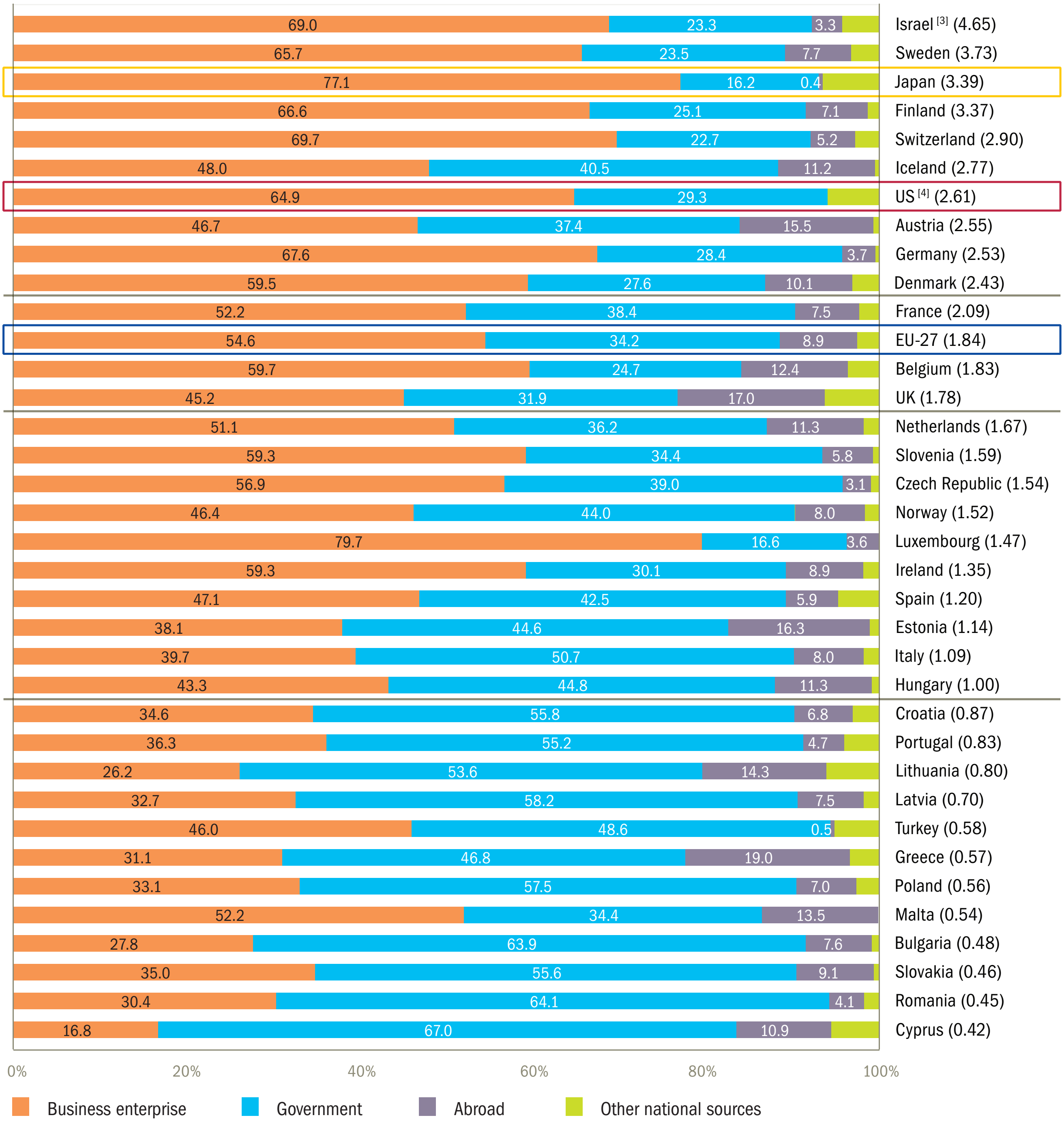
At EU level, the business sector finances about 55 % of R&D expenditure. With the addition of the share of business sector funding from abroad, the business sector probably finances more than 60 % of R&D expenditure in EU-27 (see box 2). However, the exact share of business sector funding from abroad remains unknown.

The 'abroad' source of funds is gaining importance in relation to the other sources of funds in the EU

At EU level, a greater part of total R&D expenditure was financed from abroad (private business, public institutions and international institutions) in 2005 (8.9 %) than in 2001 (7.3 %, EU-25). This trend is also observed in a majority of Member States. The 'abroad' source of funds includes both intra-EU cross-border flows as well as funds from sources outside the EU. It is not at the moment possible to separate the respective contributions of EU and non-EU sources of funds to this growth in funding from abroad (see also Chapter 4).

[31] OECD, STI Outlook 2008 – Chapter 1 - Global Dynamics in Science, Technology and Innovation, March 2008.
[32] Ibidem.

FIGURE I.1.10 R&D expenditure by main sources of funds (%), 2006 [1] ranked in terms of R&D intensity, 2006 [2] (in brackets)



Source: DG Research

Data: Eurostat, OECD

Notes: [1] NL, IL: 2003; CH: 2004; BE, BG, DK, DE, EL, FR, IT, CY, LU, PT, SE, EU-27, IS, NO: 2005; AT: 2007

[2] CH: 2004; IT, IS: 2005; IE, AT, SK, FI: 2007

[3] IL: Defence is not included

[4] US: Most or all capital expenditure is not included; Abroad is included in business enterprise

STC key figures report 2008

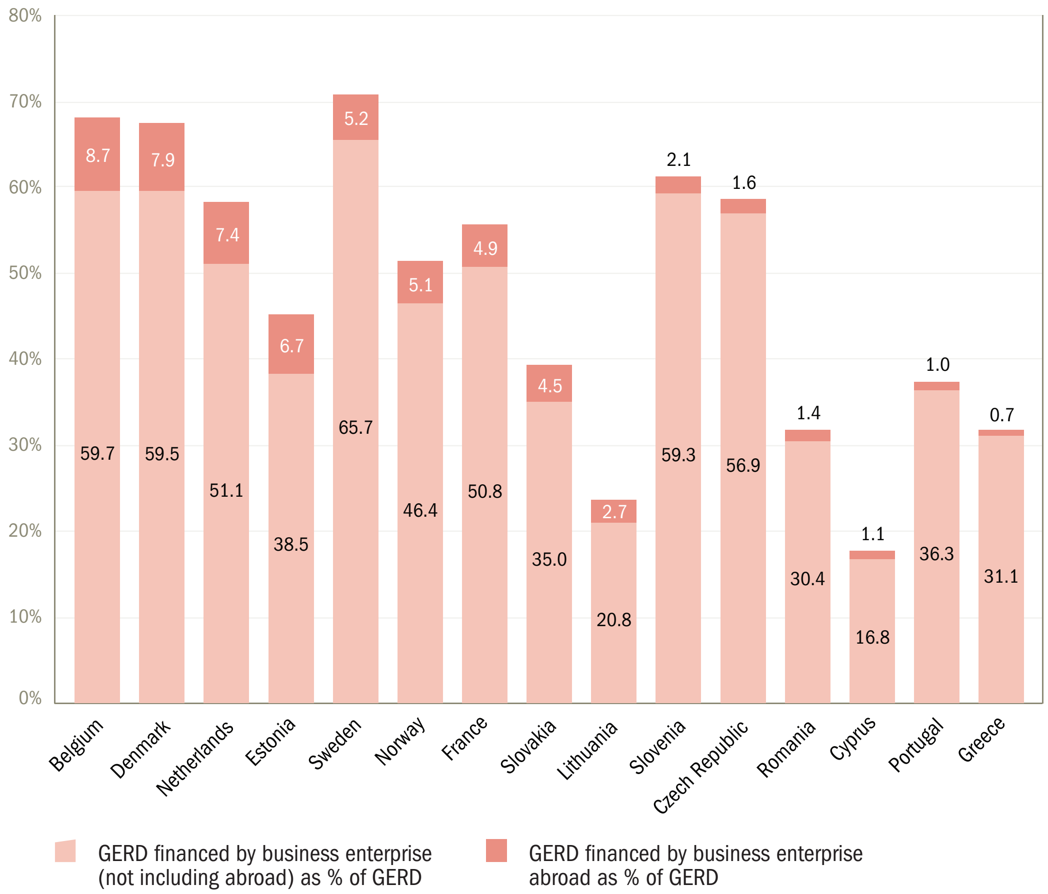
BOX 2: SOURCES OF FUNDS FOR GERD

In accordance with the Frascati Manual recommendations, five sources of funds for gross domestic expenditure on R&D (GERD) are considered: government, business enterprise, higher education, private non-profit and 'abroad'. Government, business enterprise and 'abroad' together finance more than 95 % of R&D expenditure in most Member States.

The Barcelona targets as well as the national targets specify that the financing of R&D should be broken down between public and private sectors in the ratio of one-third public to two-thirds private. In order to monitor public and private sources in each Member State properly, the 'abroad' source of funds should be split into public and private sources, so that the private portion of the 'abroad' source for R&D can be added to the business enterprise source of funds and the public portion can be added to the government source of funds. At EU level, 'abroad' finances 8.9 % of GERD. In some countries it finances a much greater part of GERD (the United Kingdom: 19.2 %). As a consequence, in all cases, the shares of GERD financed by private and public sources of funds are higher respectively than the shares of GERD financed by business enterprise and government.

However, a public/private breakdown for the 'abroad' source of funds is only available for a limited number of countries and is not completely up to date. Figure I.1.11 shows that, for most countries where this breakdown is available, a significant part of GERD is financed by private sources from abroad. In particular, private sources in Belgium and Denmark account for more than two thirds of the funding of GERD, when the private portion of the 'abroad' source of funds is added to funding by business enterprise.

FIGURE I.1.11 GERD financed by the private sector as % of total GERD, 2005 [1]



Source: DG Research
Data: Eurostat
Note: [1] FR, SI: 2003; CH: 2004; DK, CY, PT, RO, SE: 2006

STC key figures report 2008

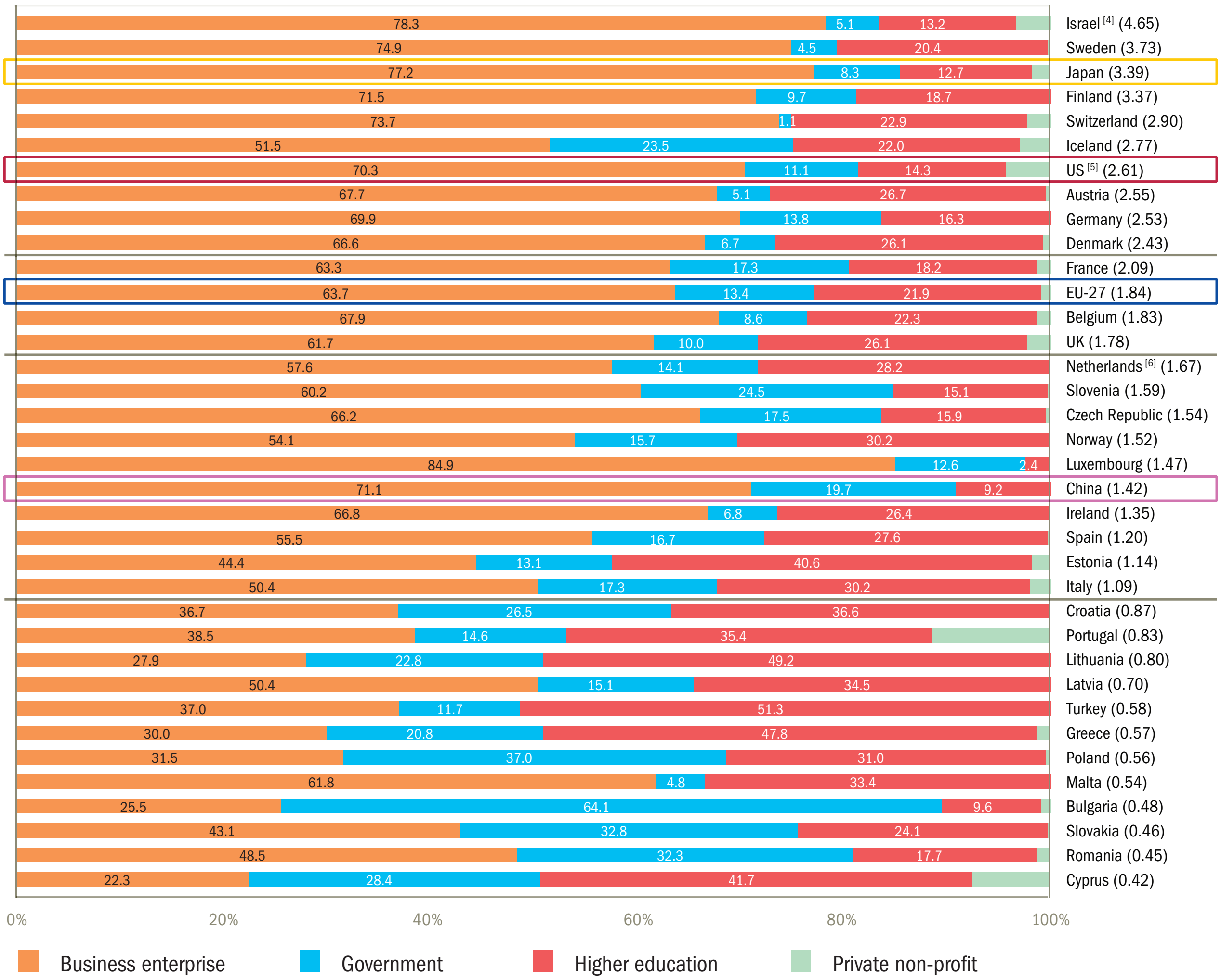
1.3 How is public sector R&D distributed between government and higher education?

MAIN FINDINGS

In most countries, the higher education sector performs a larger part of public R&D than the government sector. This trend is continuing, with an increasing share of public R&D now being performed by the higher education sectors of most Member States. The government sector is more important than the higher education sector as a performer of R&D in only six of the new Member States.

In 2006, around 35.3 % of total R&D expenditure, amounting to 0.65 % of GDP, was performed in the EU-27 public (higher education and government) sector. In most countries, the higher education sector performs a larger part of R&D than the government sector. However, in a number of new Member States, the government sector is more important than the higher education sector: Bulgaria, Romania, Poland, Slovakia, Czech Republic, Slovenia (Figure I.1.12; countries are ranked according to their R&D intensities in 2006).

FIGURE I.1.12 EU-27 [1] — R&D expenditure by sector of performance, 2006 [2] ranked in terms of R&D intensity, 2006 [3] (in brackets)



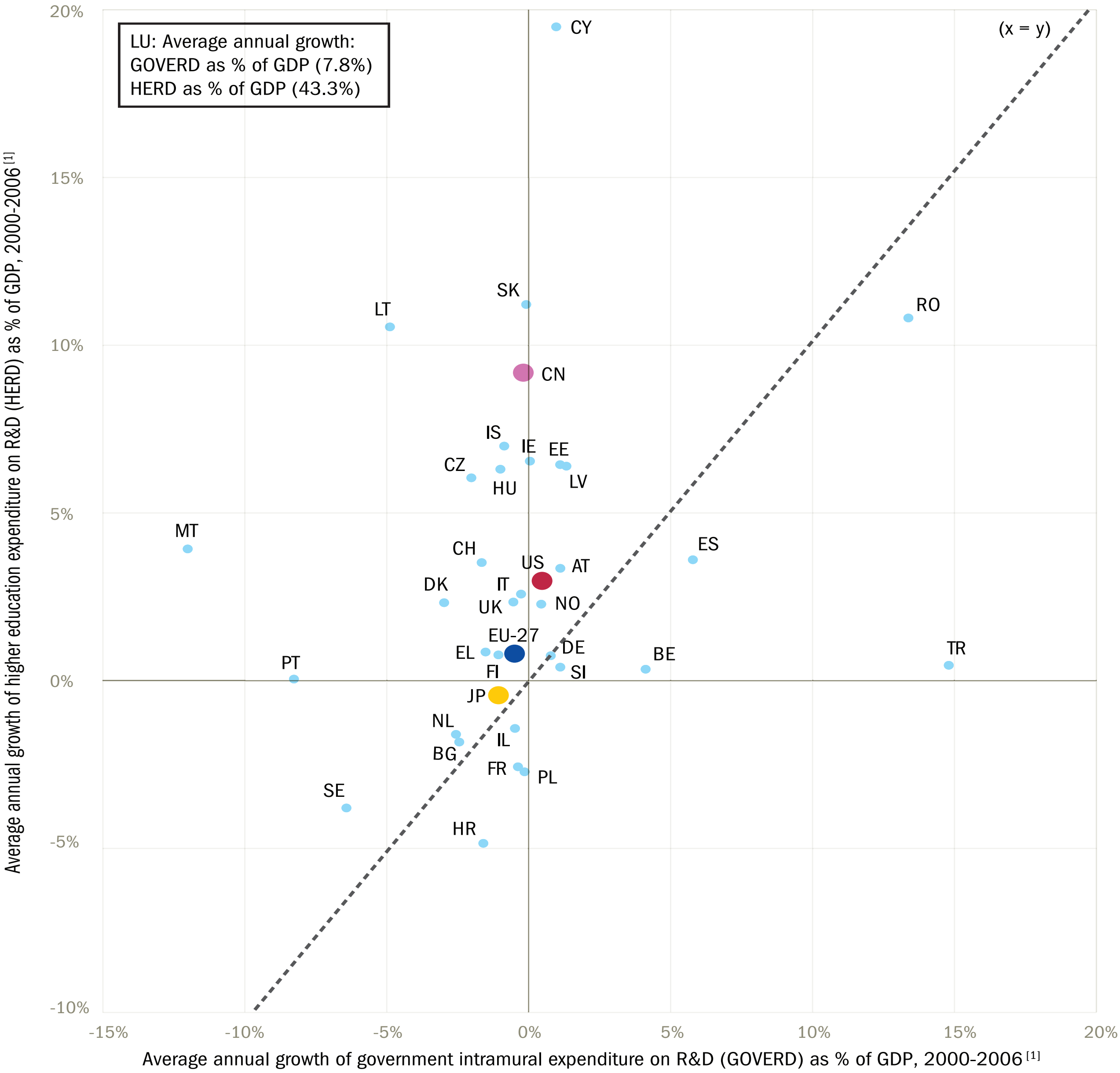
Source: DG Research
Data: Eurostat, OECD

STC key figures report 2008

Notes: [1] Hungary is not included because the sum of the sectors is not equal to 100 %
[2] CH: 2004; IT, PT, IS: 2005; IE, FI: 2007
[3] CH: 2004; IT, IS: 2005; IE, AT, SK, FI: 2007
[4] IL: Defence is not included; Higher education does not include R&D in the social sciences and humanities
[5] US: Most or all capital expenditure is not included; Government refers to federal or central government
[6] NL: The % share for the higher education sector was calculated as a residual

In recent years more R&D has been performed by the higher education sector than by the government sector in a large majority of countries. Figure I.1.13 shows that, in most countries, the average annual growth of higher education expenditure on R&D as a % of GDP has been higher than the corresponding growth of government expenditure on R&D (all countries above the dotted line x = y): in a number of countries, as well as for EU-27 as a whole, R&D expenditure in the government sector as a % of GDP has declined to the benefit of the higher education sector, in which the corresponding R&D expenditure has grown (Figure I.1.13 – upper left quadrant); in another set of countries, including the US, government expenditure on R&D as a % of GDP has grown, but higher education expenditure on R&D as a % of GDP has grown faster (Cyprus, Estonia, Latvia, Austria, the US, Norway, the United Kingdom); in some countries, R&D expenditure in both sectors as a % of GDP has declined, but to a lesser extent in the higher education sector (Japan, the Netherlands, Bulgaria, Sweden). The government sector grew more than the higher education sector only in Romania, Spain, Belgium, Slovenia and Turkey. In France, Israel, Poland and Croatia the higher education sector declined less than the government sector [33].

FIGURE I.1.13 GOVERD and HERD as % of GDP – average annual growth, 2000-2006 [1]



Source: DG Research
Data: Eurostat, OECD
Notes: [1] IT, CH: 2000-2004; PT, IS: 2000-2005; IE, FI: 2000-2007; EL, UK, NO: 2001-2006; DK, MT, AT, HR: 2002-2006; NL: 2003-2006; FR, HU: 2004-2006; SE: 2005-2006
[2] US: GOVERD refers to federal or central government expenditure only; HERD does not include most or all capital expenditure
[3] IL: GOVERD does not include defence; HERD does not include R&D in the social sciences and humanities

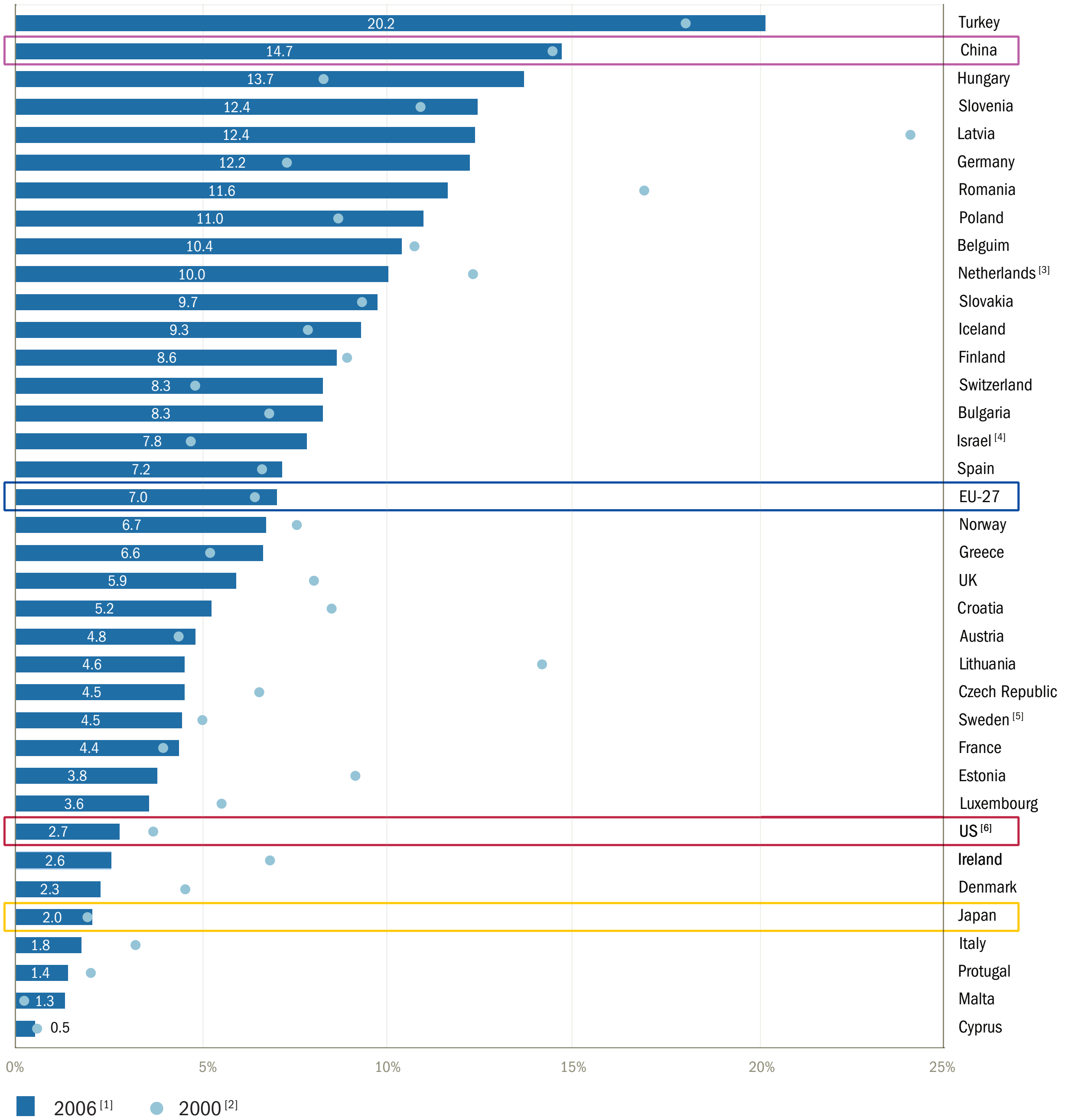
STC key figures report 2008

[33] See also Part II, Chapters 1 and 2 for an analysis of institutional vs competitive funding for higher education.

Business enterprise finances a larger part of public R&D in EU-27 than in the US and Japan [34]

Business enterprise is a relatively important source of funds for public R&D in EU-27 (7 %, Figure I.1.14), more so than in the US (2.7 %) and in Japan (2 %). The variation between the individual Member States and Associated States is quite large, with shares ranging from 20 % in Turkey to less than 2 % in Italy, Portugal, Cyprus and Malta [35]. Among the largest EU Member States, the percentage in Germany and Poland is around twice the level of the United Kingdom, three times the level of France and six times the level of Italy.

FIGURE I.1.14 Share of public sector expenditure on R&D (GOVERD + HERD) financed by business enterprise



Source: DG Research
Data: Eurostat, OECD
Notes: [1] NL, IL: 2003; AT, CH: 2004; BE, BG, DK, DE, EL, FR, IT, CY, LU, PT, SE, EU-27, IS, NO: 2005
[2] IT: 1996; EL, CY, SE, UK, IS, NO: 2001; DK, AT, HR: 2002; FR: 2004; MT: 2005
[3] NL: There is a break in series between the values for 2000 and 2003
[4] IL: GOVERD does not include defence; HERD does not include R&D in the social sciences and humanities
[5] SE: There is a break in series between the values for 2001 and 2005
[6] US: GOVERD refers to federal or central government expenditure only; HERD does not include most or all capital expenditure

STC key figures report 2008

[34] Reciprocally, business expenditure on R&D financed by government is shown in Figure I.4.1 (Part I, Chapter 4).

[35] It must be noted that, in some countries, a high share of public R&D expenditure financed by business enterprise can be the result of limited public funding of public expenditure on R&D.

1.4 Why is business sector R&D intensity lower in the EU than in the US?

MAIN FINDINGS

The US has both a larger and more research-intensive high-tech industry than the EU – these are the underlying reasons for the R&D gap between the EU and the US in manufacturing industry.

In the EU, a majority of sectors in manufacturing industry and almost all services sectors have become more research-intensive (R&D expenditure as % of value added) between 1995 and 2003; however, this has resulted in only a relatively modest increase in overall business R&D intensity (business R&D expenditure as a % of GDP) from 1.13 % in 1995 to 1.19 % in 2003. We observe that:

- **the general evolution towards a service economy in the EU (Chapter 3) implies a growing weight (in terms of GDP) for the low R&D intensity services sectors. This partly offsets the effect of increased research intensities in individual sectors on the overall business R&D intensity;**
- **the increase in research intensity in low-tech and medium-low-tech manufacturing sectors, as well as in services sectors, has a limited impact on the overall business R&D intensity of the EU, the level of which is predominantly determined by the research intensity and size of the high-tech and medium-high-tech industries;**
- **all things being equal, an increase in the research intensity of the high-tech industry in the EU up to the level of the US benchmark (about 20 % more research intensive) would contribute to an increase of 0.1 percentage points of GDP in the overall business R&D intensity in the EU (1.27 % of GDP instead of the current 1.17 %).**

As shown in Figure I.1.12, in all research-intensive countries, more than two-thirds of R&D is performed by the business sector, while in the less research-intensive countries, less than half of R&D, down to 25 % in Bulgaria and 22 % in Cyprus, is performed by this sector. In countries with intermediate R&D intensities, 60 % to 66 % of R&D is performed by the business sector.

The business sector is therefore the main performer of R&D. In EU-27, the R&D intensity of the business sector was equal to 1.17 % of GDP in 2006 [36] (divided between 1.01 % in manufacturing industry and 0.16 % in services [37]) compared to 1.16 % in 2004 and 1.20 % in 2000. In comparison, business R&D intensity decreased in the US from 2.04 % of GDP in 2000 to 1.83 % of GDP in 2006 (see Statistical Annex).

[36] i.e. a slight decrease since 2003 (1.19 %). For the breakdown of business expenditure on R&D by source of funds, see Figure I.4.1 in Chapter 4.

[37] In comparison, total business R&D intensity amounted to 1.83 % in the US in 2006: 1.18 % in manufacturing industry and 0.65 % in services. However, due to differences in the classification of industrial activity, no firm conclusions can be drawn about the level of EU-27 R&D intensity of services compared to the US. It has been shown that services R&D expenditure is largely overestimated in the US, which reciprocally implies that manufacturing R&D expenditure in the US is underestimated. As a consequence, the EU gap in manufacturing R&D is even more significant. See also Key Figures 2007, pp 29-30.

BOX 3: BERD AND EU INDUSTRIAL R&D INVESTMENT SCOREBOARD DATA

The *2006, 2007* and *2008 EU Industrial R&D Investment Scoreboards* show that the EU companies covered have increased their R&D investments in 2005, 2006 and 2007 in nominal terms by 5.3 %, 7.4 % and 8.6 % respectively. 'After many years in which the growth of R&D investment by EU companies lagged behind US companies, [the 2008] *Scoreboard* shows that the R&D investment growth of EU companies has been higher than that of US companies in 2007'[38].

TABLE I.1.3 EU-27 — Evolution of business R&D investment

	R&D investment by EU companies (Industrial R&D Investment Scoreboard)	EU-27 BERD nominal growth	EU-27 GDP nominal growth	EU-27 BERD as % of GDP
2005	+5.3 %	+3.9 %	4.3 %	1.16 %
2006	+7.4 %	+6.6 %	5.5 %	1.17 %
2007	+8.6 %	na	5.7 %	na

Source: DG Research
Data: JRC, Eurostat

STC key figures report 2008

In nominal terms, total EU-27 business expenditure on R&D (BERD) grew at a comparable rate: 3.9 % and 6.6 % in 2005 and 2006 respectively. As EU-27 BERD for 2007 is not available, the BERD growth rate for 2007 cannot be computed and compared to the 2008 *Scoreboard* growth rate (8.6 %).

In nominal terms, EU-27 GDP grew at a similar rate to EU-27 BERD: 4.3 % and 5.5 % in 2005 and 2006 respectively. As a result, business R&D intensity in EU-27 (BERD as % of GDP) grew only from 1.16 % in 2005 to 1.17 % in 2006.

However, *Scoreboard* and BERD data are not fully comparable, as there are fundamental differences between them:

- the *Scoreboard* surveys EU companies, i.e. companies whose headquarters are registered in the EU, no matter where their R&D activities are performed, whereas BERD covers all private R&D activities performed on EU territory, irrespective of the place (in the EU or outside the EU) of the headquarters of the companies or institutions financing those R&D activities;
- *Scoreboard* data are collected from audited financial accounts and reports based on International Accounting Standard (for R&D issues: IAS 38); in contrast, BERD data provided by national statistical offices are collected through official R&D surveys which follow the Frascati definitions and methodology;
- there are a number of limitations of *Scoreboard* data in relation to different practices in disclosing R&D investments in published annual reports and in defining R&D activities and costs in these reports (see the Methodological notes annexed to each *Scoreboard*);
- in the *Scoreboard* , the growth of R&D investment is calculated from a sample of the top 400 EU companies in terms of R&D investment; smaller companies are not covered;
- the period of time covered by one *Scoreboard* does not coincide with the calendar year used in BERD data; furthermore, the time period varies across companies covered in the *Scoreboard* . For example, the 'current year set' covered in the 2007 *Scoreboard* can include accounts ending on a range of dates from mid-2006 to early 2007.

Other differences concern the presentation of the data:

- BERD data follows NACE (European statistical classification of economic sectors) while the *Scoreboard* classifies companies' economic activities according to the ICB (Industrial Classification Benchmark) classification; the four groups of sectors in the *Scoreboard* (high, medium-high, medium-low and low R&D intensity) are not identical to the four groups of sectors (based on NACE) used for BERD (high-tech, medium-high-tech, medium-low-tech and low-tech);
- in the *Scoreboard* , R&D intensity is measured as the R&D/sales ratio.

[38] European Commission, The 2008 EU Industrial R&D Investment Scoreboard, October 2008.

A larger and more research-intensive high-tech industry in the US is the main reason for the R&D gap between the EU and the US in manufacturing industry

In manufacturing industry R&D intensity, measured as R&D expenditure as a % of value added, varies greatly across sectors. The manufacturing sectors are usually grouped into four types of industry: high-tech, medium-high-tech, medium-low-tech and low-tech, by decreasing order of R&D intensity [39].

Figure I.1.15 (b) [40] shows the average R&D intensity by type of industry, for both the EU and the US. The difference in R&D intensity across the four types of industry is clear-cut: in both economies, going from high-tech to low-tech, each industry type is several times less research-intensive than the one above and the research intensity is of a comparable order of magnitude (although not identical) on both sides of the Atlantic. Figure I.1.15 (b) therefore highlights how strong an influence the research intensity in high-tech and medium-high-tech industries has on the overall level of business R&D intensity in an economy.

FIGURE I.1.15 (a) Manufacturing value added – % distribution by type of industry [1], 2003 [2]

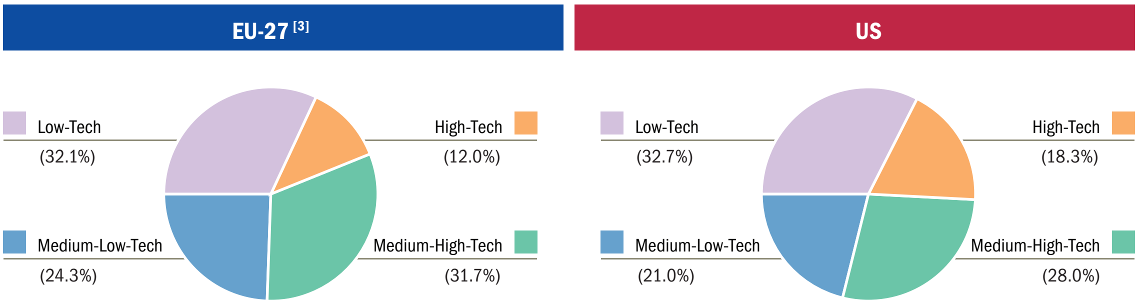
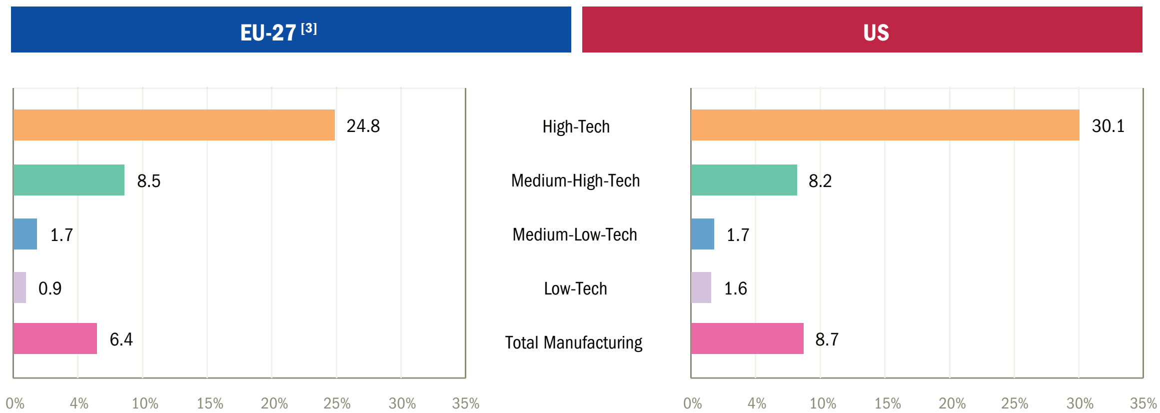
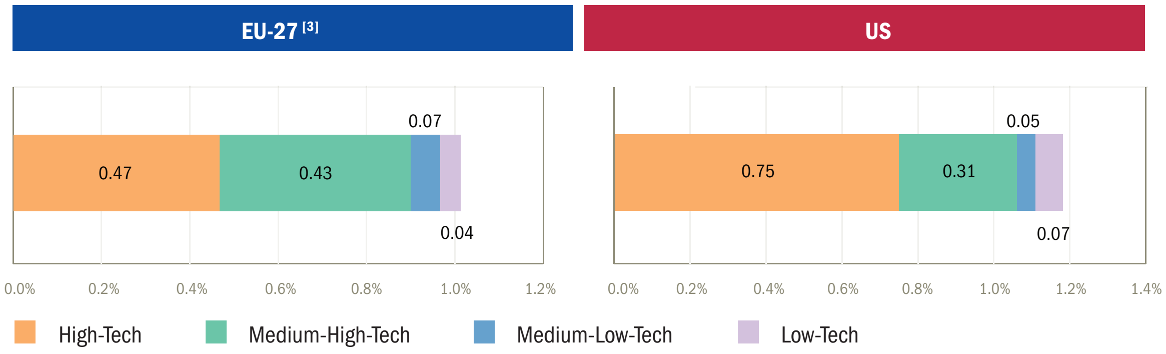


FIGURE I.1.15 (b) Manufacturing BERD as % of manufacturing value added by type of industry [1], 2003 [2]



[39] Sectors included in each of these four types of industry are listed in the Methodological Annex as well as in Figure I.1.17.
[40] 2003 is the latest year available for the US and for computing an EU aggregate. Moreover, there are changes in high-tech and medium-high-tech values compared to the 2007 edition of the Key Figures. This is due to the absence of a breakdown for value added between pharmaceuticals and other chemicals in Key Figures 2007, where total chemicals had to be included in high-tech. For value added data, the EU KLEMS database now provides a breakdown and therefore chemicals have been divided between high-tech (pharmaceuticals) and medium-high-tech (other chemicals) in Figure I.1.15 (a).

FIGURE I.1.15 (c) Manufacturing BERD by type of industry [1] as % of total GDP, 2003 [2]



Source: DG Research
Data: EU KLEMS database, Eurostat, OECD
Notes: [1] See Methodological Annex for the list of sectors included in each type of industry
[2] 2003 is the latest year available for which it is possible to compute an EU-27 aggregate for manufacturing BERD by type of industry; it is also the latest year for which data are available for the US
[3] EU-27 does not include BG, LV, LT, LU, MT, AT, PT, RO, SK

STC key figures report 2008

Putting the industrial composition of the EU and the US (Figure I.1.15 (a)) together with R&D intensity by type of industry (Figure I.1.15 (b)) gives the industrial composition and overall level of manufacturing R&D expenditure in the EU and the US (Figure I.1.15 (c)).

Panels (a) to (c) of Figure I.1.15 show that the higher level of manufacturing R&D intensity in the US (1.18 %) compared to the EU (1.01 %) is due to two factors:

- high-tech industry has a larger share of the economy in the US than in the EU (the share of high-tech industry in total manufacturing value added is 50 % higher in the US (18.3 %) than in the EU (12 %), see Figure I.1.15 (a));
- high-tech industry is about 20 % more research-intensive in the US than in the EU (Figure I.1.15 (b)). As a result, R&D expenditure in high-tech industry represents almost two-thirds of total manufacturing R&D expenditure in the US, compared to less than one-half in the EU (Figure I.1.15 (c)); expressed as a % of GDP, R&D expenditure in high-tech industry is about 1.6 times higher in the US than in the EU. All things being equal, increasing the research intensity of high-tech industry in the EU to the level of the US would bring the R&D intensity of EU manufacturing industry up to 1.11 % of GDP, instead of its current level of 1.01 % of GDP (Figure I.1.15 (c); the R&D intensity of EU high-tech industry would be equal to 0.57 % of GDP instead of 0.47 % of GDP).

In medium-high-tech industry, the situation is inverted: R&D expenditure as a % of GDP is about 1.4 times higher in the EU than in the US, due to the higher weight of a slightly more research-intensive medium-high-tech industry in the EU economy. However, given the fundamentally lower level of R&D intensity of medium-high-tech industry compared to high-tech industry, this does not compensate for the EU R&D gap with the US in high-tech industry.

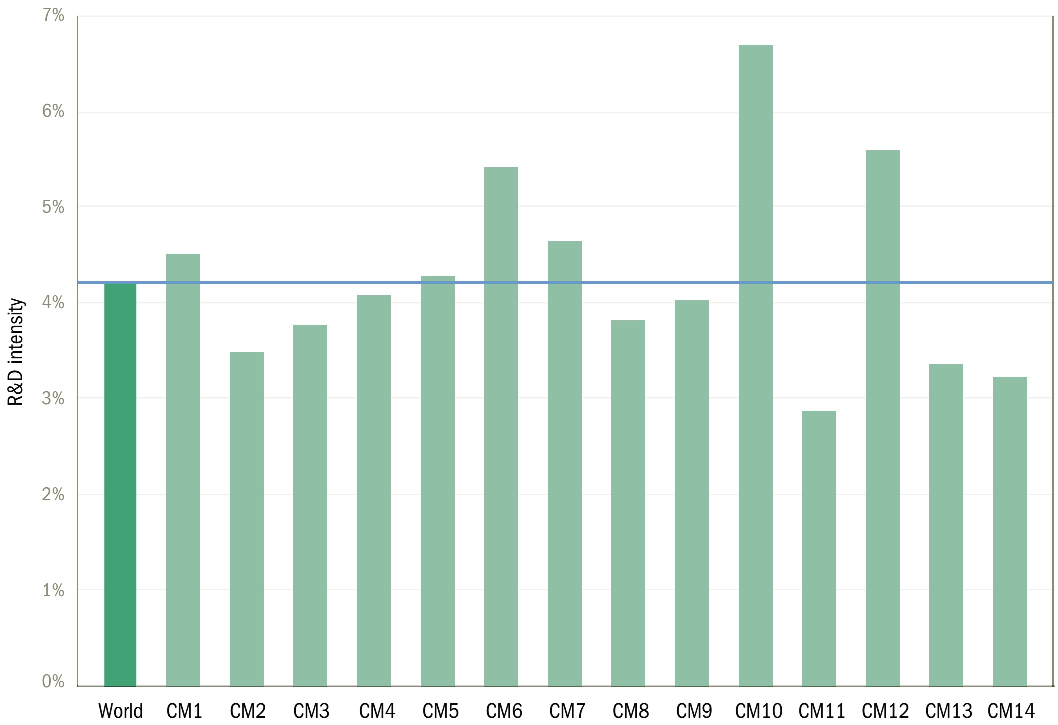
The medium-low-tech and low-tech industries account for more than half of total manufacturing value added in both the EU and the US (see Figure I.1.15 (a)). However, due to their low R&D intensities, they do not have a significant weight in total R&D intensity. The fact that low-tech industry is almost twice as research-intensive in the US as in the EU has no real quantitative impact on the R&D intensity deficit of the EU. It may nevertheless have an important impact on the innovation capacity of the EU's low-tech industry.

BOX 4: STANDARD R&D INTENSITIES IN INDUSTRIAL SECTORS

The *2006 EU industrial R&D investment Scoreboard* shows that in some sectors a long-term sector-specific relationship exists between R&D investment and sales [41] in large multinational companies operating at world level. In these sectors, a standard R&D intensity (defined in the *Scoreboard* as the ratio R&D expenditure over sales) arises, around which the variations are relatively small among major competitors.

The example of the automobile sector is developed in the *2006 Scoreboard* and shown in Figure I.1.16: the R&D intensity of 14 major car manufacturers is very close to the sector's worldwide average [42] [43]. Companies whose R&D intensities are below the sector average have tended to lose market share, whereas companies that are above have tended to increase their relative market share. However, investing beyond a certain level in R&D has not been rewarded by sufficient gains in market share to cover the cost of this extra R&D [44].

FIGURE I.1.16 R&D intensities of 14 major car manufacturers (CM [1]), 2005



Source: DG Research
Data: The 2006 EU Industrial R&D Investment Scoreboard
Note: [1] CM: Car manufacturer (2 US, 6 EU, 5 JP, 1 KR)

STC key figures report 2008

This average level of R&D intensity can be seen as an equilibrium level of R&D investment in the industry, given that competition plays within a certain strategic paradigm. As long as the strategic paradigm does not change dramatically, for example as a result of radical (disruptive) innovation, R&D intensity in this industry remains stable around the equilibrium level that has emerged from the competition between the major companies. If this holds for a number of industries across an economy, then business R&D intensity is to a large extent determined by the sectoral composition of the economy, and business R&D intensity will only evolve if the sectoral composition changes or if a change in the strategic paradigm of some sectors spurs additional R&D investment in these sectors.

[41] European Commission, 2006 EU industrial R&D investment Scoreboard, pp 71-74.
[42] Pharmaceuticals is another sector where this is equally observed.
[43] Together, these 14 car manufacturers account for over 90 % of the world car market in terms of net sales, so that they almost account for the entire world car industry.
[44] The situation for smaller companies may differ from that for large ones. Smaller companies often have a higher than average R&D intensity; they may use R&D investment as a growth strategy, or higher R&D investment is simply needed to keep up with the sector standard.

A majority of sectors in manufacturing industry and services have become more research-intensive in the EU between 1995 and 2003 [45]

Figures I.1.17 and I.1.18 show those manufacturing and services sectors that experienced a positive growth in the EU-27 [46] economy (in terms of real value added, ordinate axis) between 1995 and 2003 [47] and those sectors that have been declining over this period. They also compare growth in value added to growth in R&D expenditure (abscissa) for each sector. Sectors in which R&D expenditure has grown in real terms at a more rapid pace than value added have become more research-intensive (the research intensity of a sector is defined here as R&D expenditure as a % of value added) and are located below the dotted line in both figures. The size of the symbols is related to the size of the sectors in terms of total value added over the period 1995-2003 in the EU-27 economy (as described in the footnotes to both figures).

None of the high-tech sectors had a share of more than 5 % of total manufacturing value added in EU-27 over the period 1995-2003. 'Machinery and equipment', 'food, beverages, tobacco' and 'wood, paper, printing, publishing' had the largest weights in the EU over this time period (more than 10 % of total manufacturing value added), followed by 'motor vehicles', 'chemicals' (excluding 'pharmaceuticals') and 'fabricated metal products' (between 5 % and 10 % of total manufacturing value added). The last two are the only major sectors of the EU economy to have become less research-intensive over the period.

Value added for a number of high-tech sectors in the EU has grown in real terms at a fast pace over this period: 'aircraft and spacecraft' (4.3 % per year on average), 'pharmaceuticals' (3.5 % p.y.a) and 'medical, precision and optical instruments' (2.7 % p.y.a). In the last of these, R&D expenditure has grown in real terms at the same pace as value added, leaving the R&D intensity of this sector unchanged. In contrast, the 'pharmaceuticals' sector has become much more R&D-intensive, while the 'aircraft and aerospace' sector has become less R&D-intensive. The strong growth of the large motor vehicles sector is noteworthy, as is the even faster growth of R&D expenditure in this sector over the period considered.

A few sectors, mainly in the medium-low-tech and low-tech industries, declined in terms of value added between 1995 and 2003. All of them, except for 'coke, refined petroleum and nuclear fuel', saw their R&D intensities increase over this period through an increase, or a smaller decrease, in real R&D expenditure. Among the medium-high-tech and high-tech sectors, 'office, accounting and computing machinery' is the only sector that experienced a strong decline in the EU economy, whereas three medium-high-tech sectors ('railroad and other transport equipment', 'electrical machinery and apparatus', 'chemicals excluding pharmaceuticals') have seen a clear decrease in real R&D expenditure between 1995 and 2003.

However, taken as a whole, figures I.1.17 and I.1.18 show that in the EU a majority of manufacturing and services sectors have become more R&D-intensive between 1995 and 2003. In fact, business enterprise expenditure on manufacturing R&D in the EU [48] has increased from 5.5 % of total manufacturing value added in 1997 to 6.5 % in 2003. At the same time, business enterprise expenditure on services R&D has increased from 0.2 % of total services value added in 1997 to 0.3 % in 2003. These figures also show that services sectors are much less research-intensive than manufacturing sectors [49]. In fact, services sectors are in the order of 100 times less research-intensive than high-tech industry.

[45] 2003 is the latest year for which an EU aggregate can be computed with ANBERD data (Business R&D expenditure by economic activity).

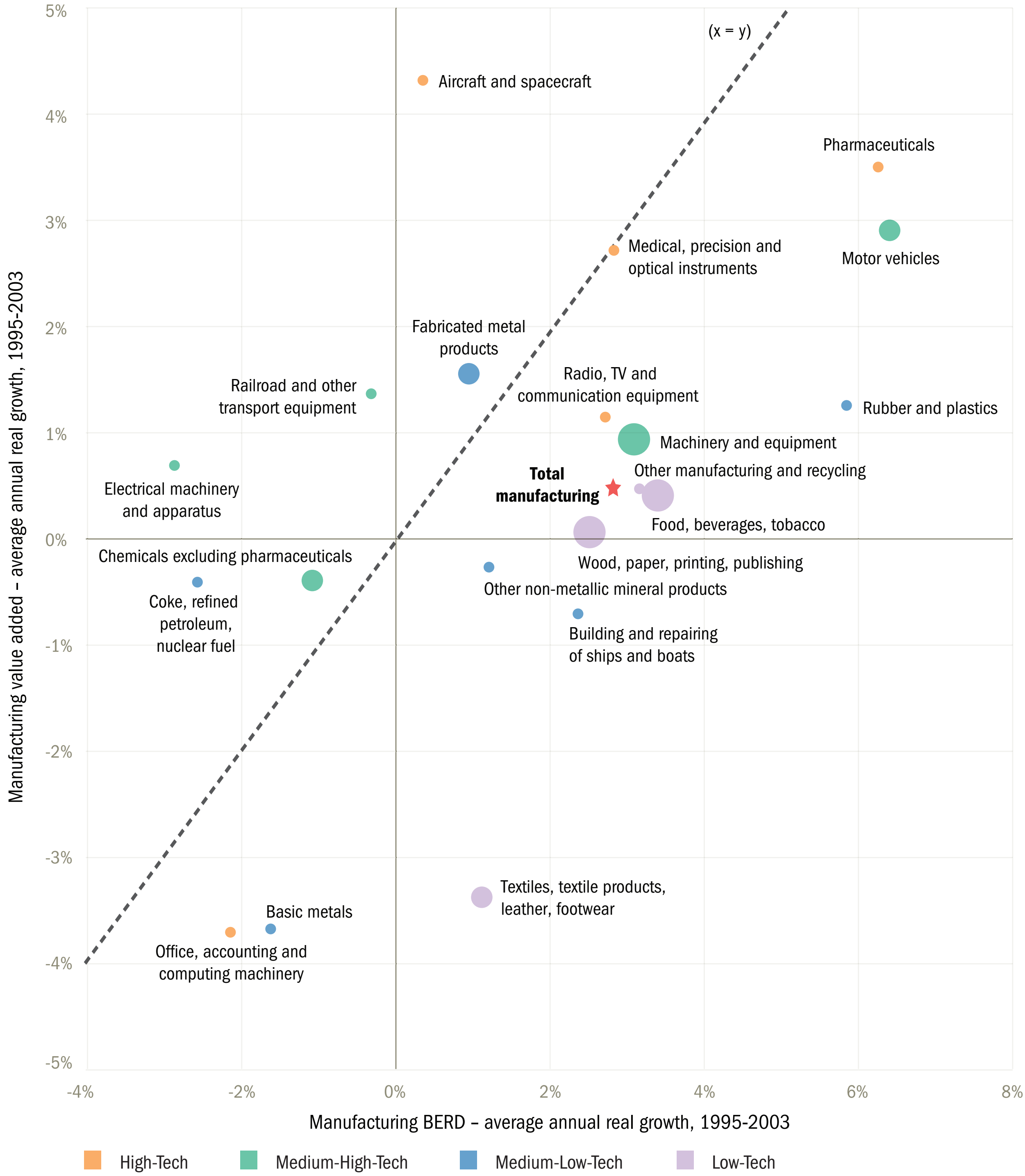
[46] In Figure I.1.17, EU-27 does not include BG, EE, EL, CY, LV, LT, LU, MT, AT, PT, RO and SK. In Figure I.1.18, EU-27 does not include BG, EL, LV, LT, LU, MT, AT, PT, RO and SK.

[47] The EU KLEMS database gives value added data by economic activity up until 2006. However, this timeframe is imposed by the ANBERD data in both Figures (see footnote above).

[48] EU includes the following Member States in this calculation: BE, CZ, DK, DE, ES, FR, IE, IT, HU, NL, PL, FI, SE, UK.

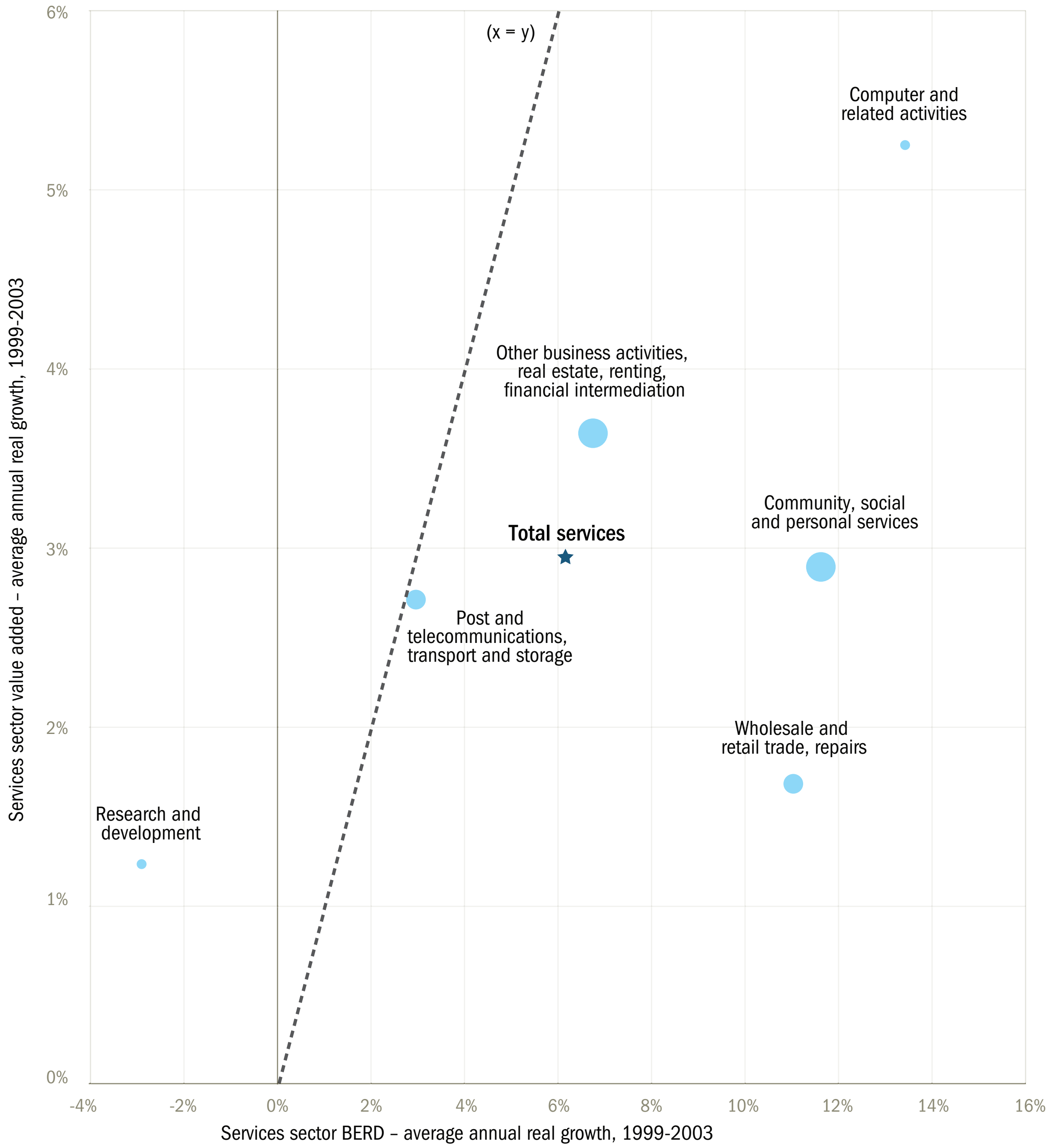
[49] It is widely recognised that current measures underestimate R&D activities in services; it is also recognised that much of the innovation activities in services are not based on R&D. However, the discussion here relates to measures of R&D intensities as they have been realised – with their limitations – in the different sectors of the economy.

FIGURE I.1.17 EU-27 [1] – Manufacturing sectors: value added versus BERD – average annual real growth, 1995-2003 [2]



Source: DG Research
Data: EU KLEMS database, Eurostat, OECD
Notes: [1] EU-27 does not include BG, EE, EL, CY, LV, LT, LU, MT, AT, PT, RO, SK
[2] 2003 is the latest available year for which it is possible to compute an EU-27 aggregate for manufacturing BERD by sector
[3] Sectors with large symbols have a share of more than 10 % of total manufacturing value added in EU-27 [1] 1995-2003; Sectors with medium-size symbols have a share of 5 %-10 %; Sectors with small symbols have a share of less than 5 %

FIGURE I.1.18 EU-27 [1] – Services sectors: value added versus BERD – average annual real growth, 1999-2003 [2]



Source: DG Research

STC key figures report 2008

Data: EUKLEMS database, Eurostat, OECD

Notes: [1] EU-27 does not include BG, EL, LV, LT, LU, MT, AT, PT, RO, SK

[2] 2003 is the latest available year for which it is possible to compute an EU-27 aggregate for services BERD by sector

[3] Sectors with large symbols have a share of more than 30 % of services value added in EU-27 [1] 1995-2003;
Sectors with medium-size symbols have a combined share of 26 %; Sectors with small symbols have a share of less than 5 %

Structural changes should aim both towards higher R&D intensities within sectors and towards a greater share of high-tech sectors in the EU economy

The rise in R&D intensity in a majority of the manufacturing and services sectors has, however, only led to a relatively modest increase in total (manufacturing and services) business R&D intensity in the EU, from 1.13 % of GDP in 1995 to 1.19 % of GDP in 2003 (followed by a slight decline to 1.17 % of GDP in 2006).

Two observations can be made in this regard. Firstly, the general evolution towards a service economy in the EU [50] implies a growing weight (in terms of GDP) for services sectors with low R&D intensities [51]. This partly offsets the effect on the overall business R&D intensity of increased research intensities in other sectors. Secondly, the increase in R&D intensity in low-tech and medium-low-tech manufacturing sectors, as well as in services sectors, has relatively little impact on the overall business R&D intensity of the EU, the level of which is predominantly determined by the research intensity and size of the high-tech and medium-high-tech industries, as shown in Figure I.1.15 (high-tech industry is about 28 times more research intensive than low-tech industry). This merely quantitative observation does not mean that R&D is not important for low-tech industries and services. However, in terms of impact on overall business R&D intensity, the effect of increased R&D intensity in (medium-) low-tech industry and in services is limited.

The structural change towards higher R&D intensity *within* sectors in the EU has, therefore, not yet been sufficient in itself to increase the knowledge-intensity of the EU economy. In particular, there could still be room for further increases in the research intensity of high-tech industry in the EU, which is about 20 % less research-intensive than in the US (Figure I.1.15 (b)) [52]. Furthermore, more could be done to shift the technology frontier in many other sectors of the economy in response to the important challenges of our age.

The lower level of business R&D intensity in the EU is also linked to the structural composition of its economy (Figure I.1.15 (a)). Given the weight of high-tech sectors in the overall level of business R&D intensity, changes in the sectoral composition of the business sector are essential in order to give rise to a higher share of high-tech industry. These changes would involve seeking to expand the current high-tech sectors and increasing the number of sectors with high-tech levels of research intensity. This brings to the forefront policy issues, such as obstacles to the development of lead markets and obstacles to the generation and growth of new firms.

[50] The share of value added of services in the EU economy grew from 68 % to 72 % between 1997 and 2005. See Chapter 3.

[51] See footnote 49.

[52] Several methodological differences make it difficult to compare the 20 % gap between the US and the EU in high-tech R&D intensity with findings in the EU Industrial R&D Investment Scoreboard (see Box 3 under section 1.4.). The 2008 EU Industrial R&D Investment Scoreboard, analysing the 1,000 EU companies and the 1,000 non-EU companies with the highest level of R&D investments, shows that the R&D intensities of EU companies are similar or even higher than those of non-EU companies. The 2008 Scoreboard states in particular that high-R&D intensity EU companies have a higher R&D intensity (12.4 %) than high-R&D intensity non-EU companies (9.6 %). When focusing exclusively on the US high-R&D intensity companies in the Scoreboard, the R&D intensities are at a similar level to the high-R&D intensity EU companies. However important methodological differences between Scoreboard data and BERD data make it impossible to directly compare them. In particular, EU BERD data cover R&D expenditures by all companies on the territory of the EU, while Scoreboard data cover R&D investments by top R&D spending EU companies wherever the actual R&D is performed in the world. Moreover, the group of 'High R&D intensity' firms in the Scoreboard does not strictly match the group of 'High-tech' sectors used in BERD data. Finally, the definition of R&D intensity is not the same for the Scoreboard data and for BERD. For more details, see box 3 in section 1.4.

Chapter 2. Investing in human resources for R&D

R&D investment is to a large extent a matter of investment in human resources. In particular, investment in education should provide large pools of both graduates from tertiary education and doctoral graduates, to ensure a proper take-up of knowledge and innovation in the wider economy and to guarantee a sufficient number of qualified personnel to carry out R&D. This chapter looks at stocks of human resources for Science and Technology (HRST), while Chapter 4 of Part II looks at the issue of mobility.

2.1 Is the pool of human resources in S&T growing? Is the number of researchers increasing?

MAIN FINDINGS

The analysis in this chapter shows that the trend and evolution since 2000 are more positive for the EU in relation to education inflows and researchers than for R&D investments.

The most significant global change since 2000 has been the doubling of the number of researchers (FTE) [53] in China.

The number of researchers (FTE) has grown twice as fast in the EU as in the US and Japan since 2000. The increase in the number of researchers in the EU has occurred primarily in the business sector. At the same time, R&D expenditure per researcher in the business sector decreased between 2000 and 2005 before increasing again between 2005 and 2006.

Despite this increase in the number of researchers in the business sector, in 2006 only 640,000 researchers were employed in the business sector in the EU compared to 1.1 million in the US. The growth of the number of researchers (FTE) per thousand labour force in the EU has been almost three times as high in the EU as in the US since 2000. However, the EU still has a much lower share of researchers (FTE) in the labour force than the US and Japan.

Three broad statistical categories that cover all human resources in science and technology are usually considered. These are:

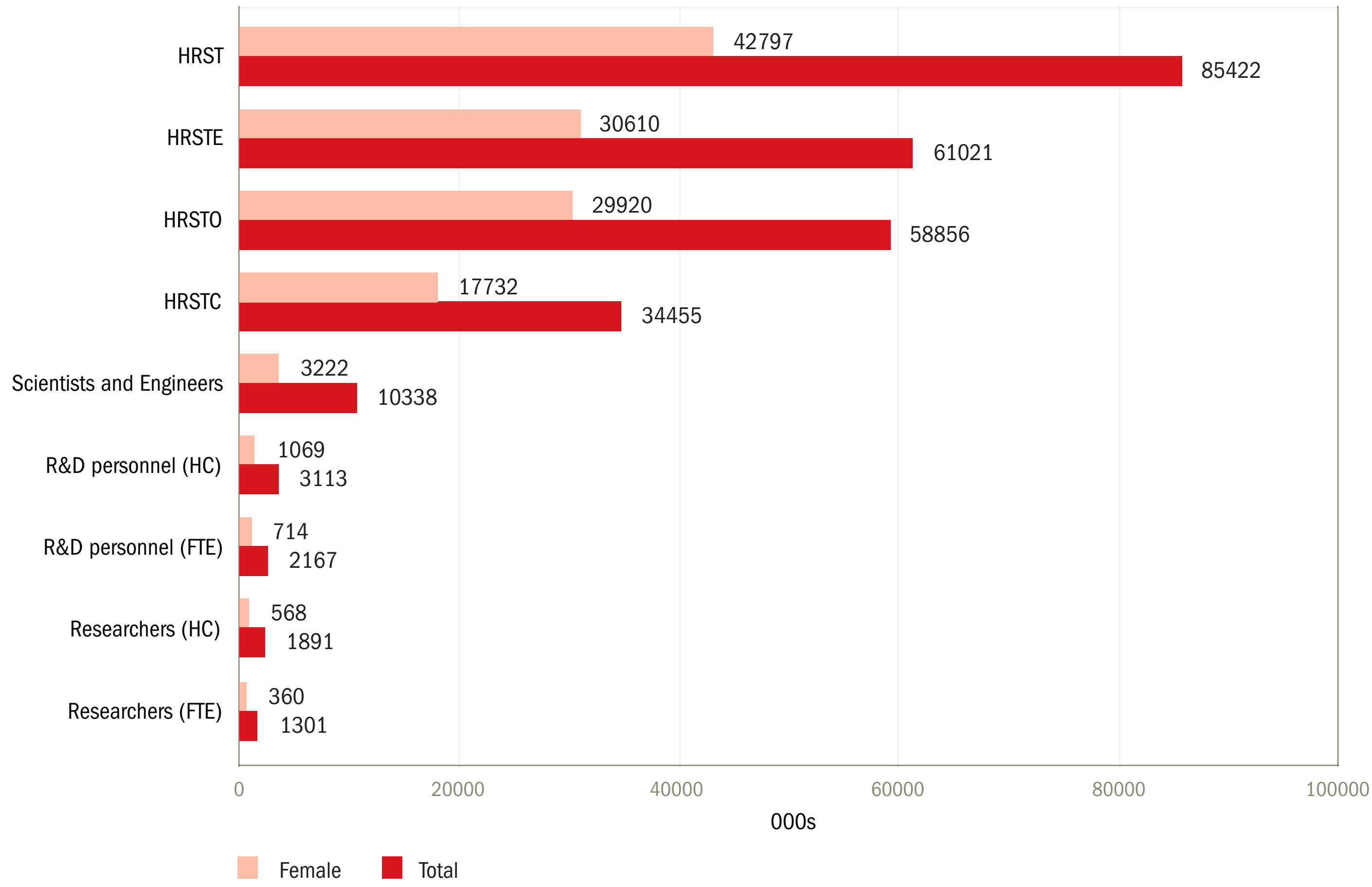
- human resources in S&T (HRST) [54];
- R&D personnel [55];
- researchers [56].

Figure I.2.1 shows the absolute numbers for each of these different categories in EU-27 in 2006. The precise definitions of these categories are to be found in the Methodological Annex.

In EU-27, total HRST amounted to 85.4 million in 2006. The number of HRST Core [57] was 34.5 million and the number of scientists and engineers [58] 10.3 million. Total R&D personnel amounted to 3.1 million in head count (HC) and 2.2 million in full-time equivalent (FTE). Total Researchers in HC and FTE amounted to 1.9 million and 1.3 million respectively (Figure I.2.1).

[53] Full Time Equivalent.
[54] The Canberra Manual proposes a definition of HRST as individuals who either have higher education or persons who are employed in positions that normally require such education.
[55] 'All persons employed directly in R&D should be counted, as well as those providing direct services such as R&D managers, administrators, and clerical staff.' (OECD, 2002, Frascati Manual, p. 92).
[56] 'Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned' (OECD, 2002, Frascati Manual, p. 93).
[57] HRST Core (HRSTC) are individuals with both tertiary-level education and an S&T occupation.
[58] Scientists and engineers are defined as 'Physical, mathematical and engineering science professionals' and 'Life science and health professionals'.

FIGURE I.2.1 EU-27 — Human resources for science and technology and the sub-groups R&D personnel (HC, FTE) and researchers (HC, FTE) — total and female (thousands)



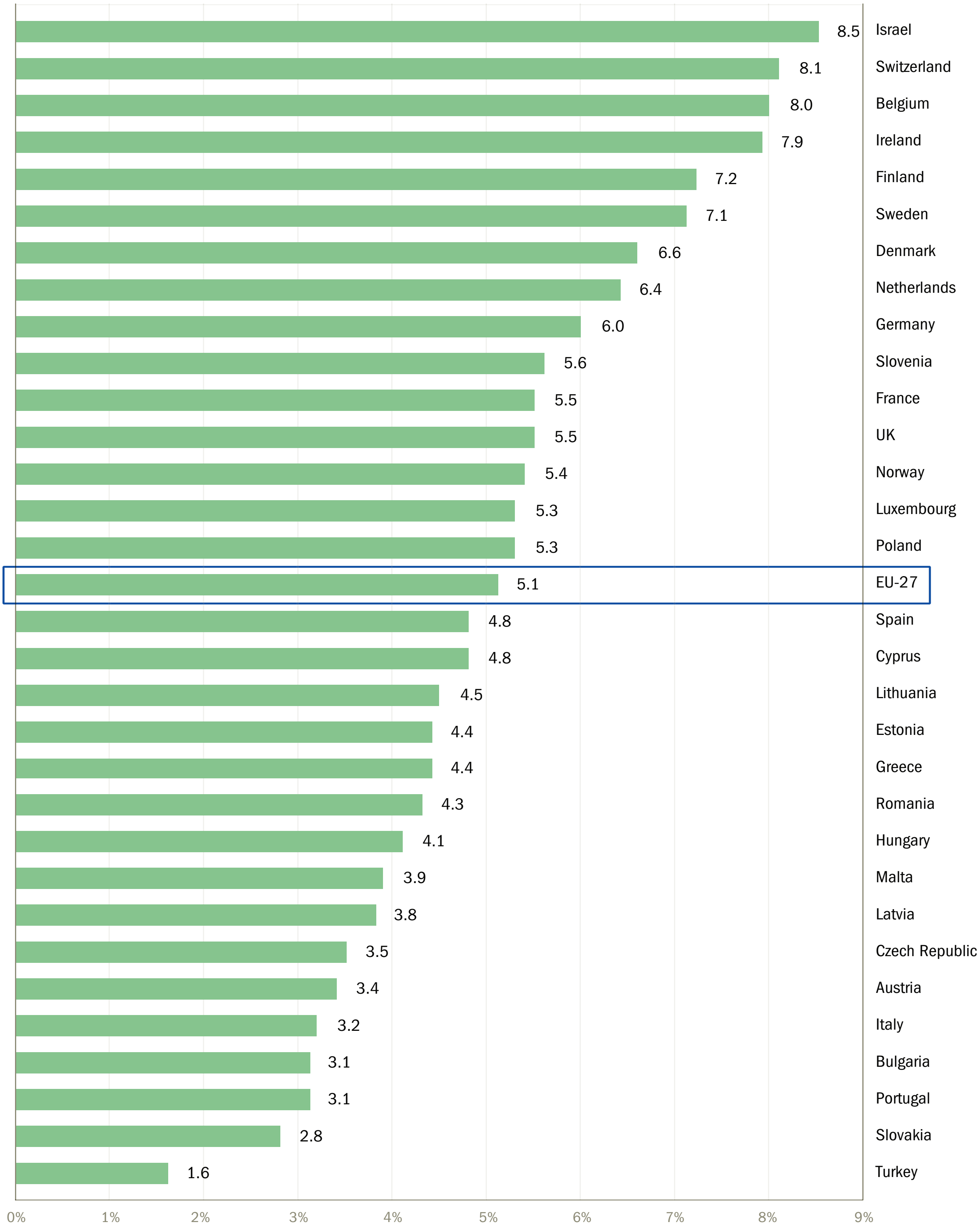
Source: DG Research
Data: Eurostat
Notes: HRST [1]: Human resources in science and technology
HRSTE [2]: Human resources in science and technology – education
HRSTO [3]: Human resources in science and technology – occupation
HRSTC [4]: Human resources in science and technology – core

STC key figures report 2008

Within the ERA, the share of HRSTC in the labour force ranged from 7.7 % in Turkey up to 27.6 % in Denmark in 2006 [59]. The corresponding share of scientists and engineers ranged from 1.6 % in Turkey up to 8.5 % in Israel (Figure I.2.2).

[59] *Source: Eurostat. See Statistical Annex.*

FIGURE I.2.2 Scientists and engineers as % of labour force, 2006



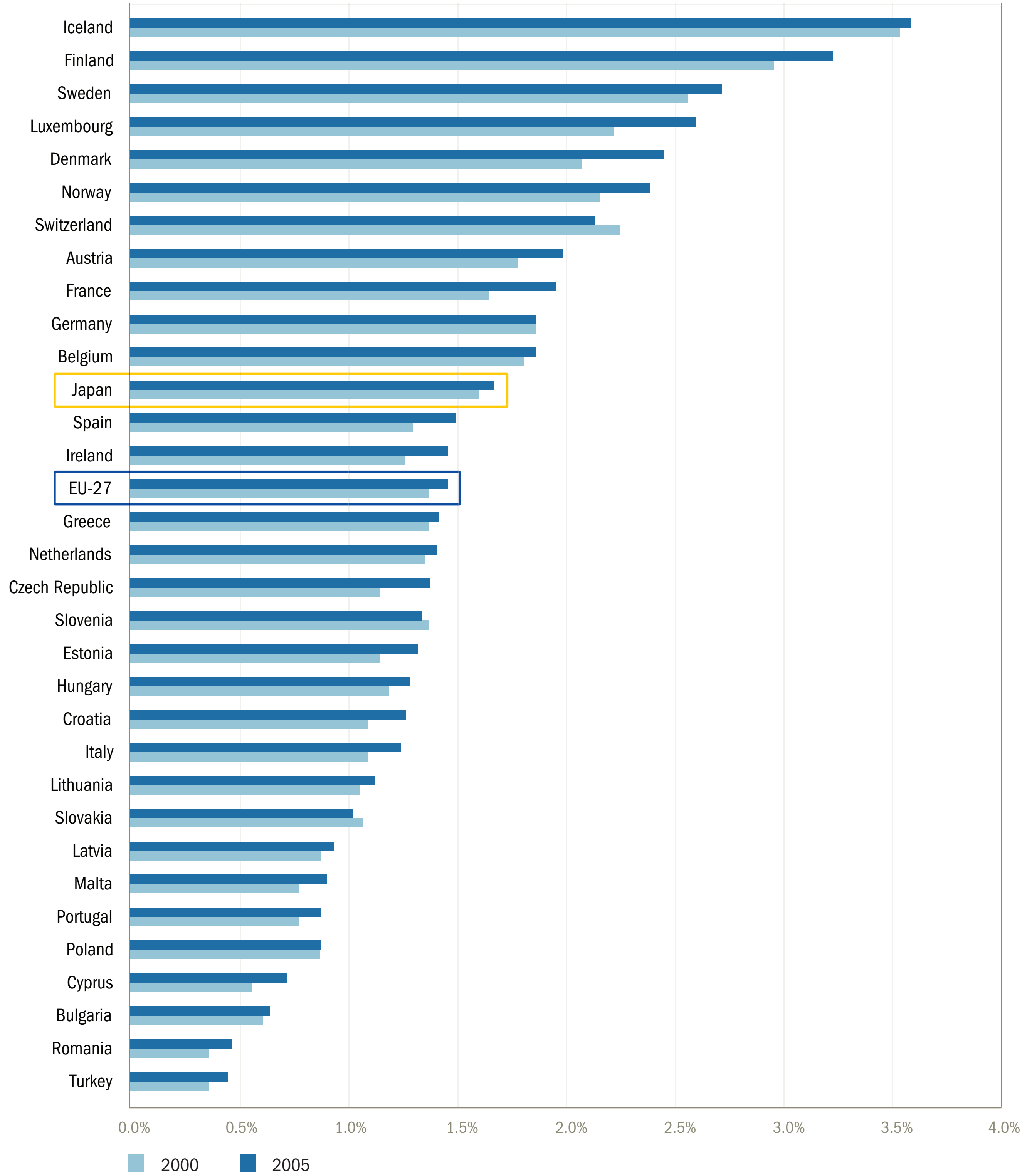
Source: DG Research
Data: Eurostat

STC key figures report 2008

The Nordic countries and Luxembourg have the highest shares of R&D personnel in total employment

Figure I.2.3 shows that R&D personnel (HC) accounted for 1.45 % of total employment in EU-27 in 2005. This compares with a value of 1.36 % in 2000. Within the ERA, shares are highest in Iceland, Finland, Sweden, Luxembourg, Denmark and Norway (between 2.44 % and 3.22 %).

FIGURE I.2.3 R&D personnel (HC) as % of total employment, 2000 [1] and 2005 [2]



Source: DG Research
Data: Eurostat
Notes: [1] EL, ES, SE, NO, JP: 2001; BE, MT, NL, AT, HR: 2002; DE, LU, IS: 2003
[2] JP: 2003; AT, HR, CH: 2004

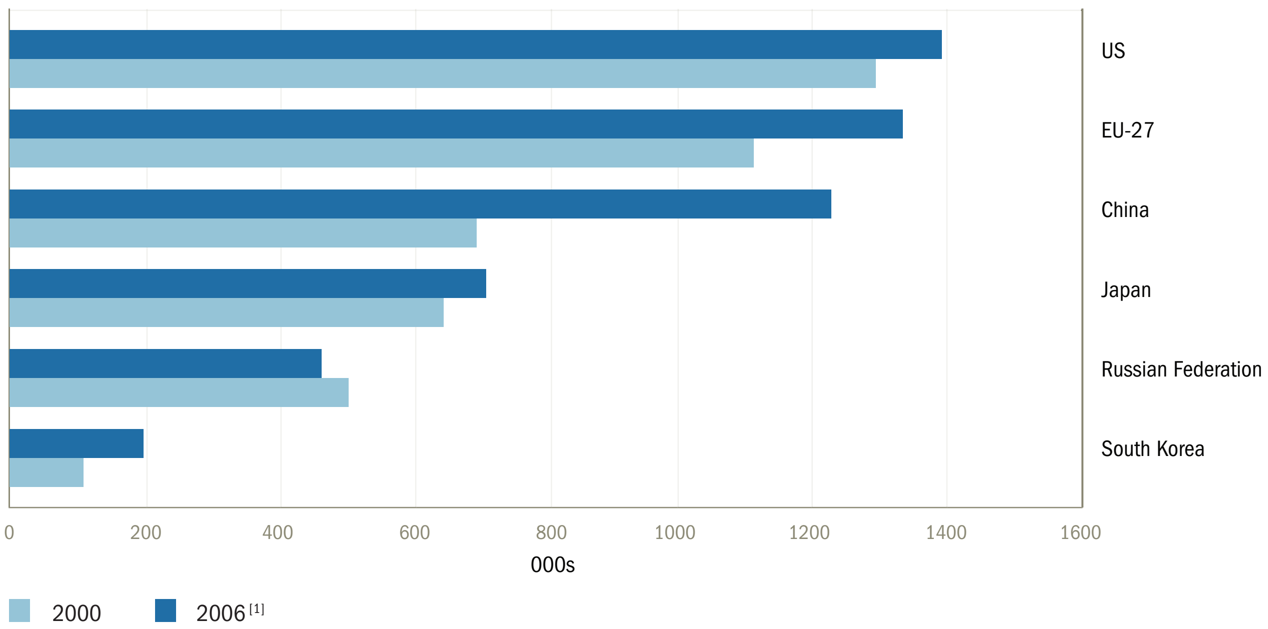
STC key figures report 2008

Since 2000 China has doubled its number of researchers, and the number of researchers has grown twice as fast in the EU as in the US and Japan

Figure I.2.4 compares the number of researchers in major research-intensive world regions or countries. In 2006, there were 1.33 million researchers [60] (FTE) in EU-27, 1.39 million in the US and 1.22 million in China. Strong increases in the number of FTE researchers have been observed from 2000 to 2006 in China (+9.9 % per annum) and South Korea (+10.8 % per annum), compared to EU-27 (+3.1 % per annum), Japan (+1.5 % per annum) and US (+1.5 % per annum). The number of researchers has grown on average twice as fast in the EU as in the US and Japan since 2000.

Within EU-27, the number of researchers (FTE) has increased in all Member States over recent years [61]. The strongest average annual growth rates have been observed in Malta, Cyprus, the Czech Republic and Denmark (more than 8 % per annum) (Table I.2.1).

FIGURE I.2.4 Number of researchers (FTE thousands) by world region, 2000 and 2006 [1]



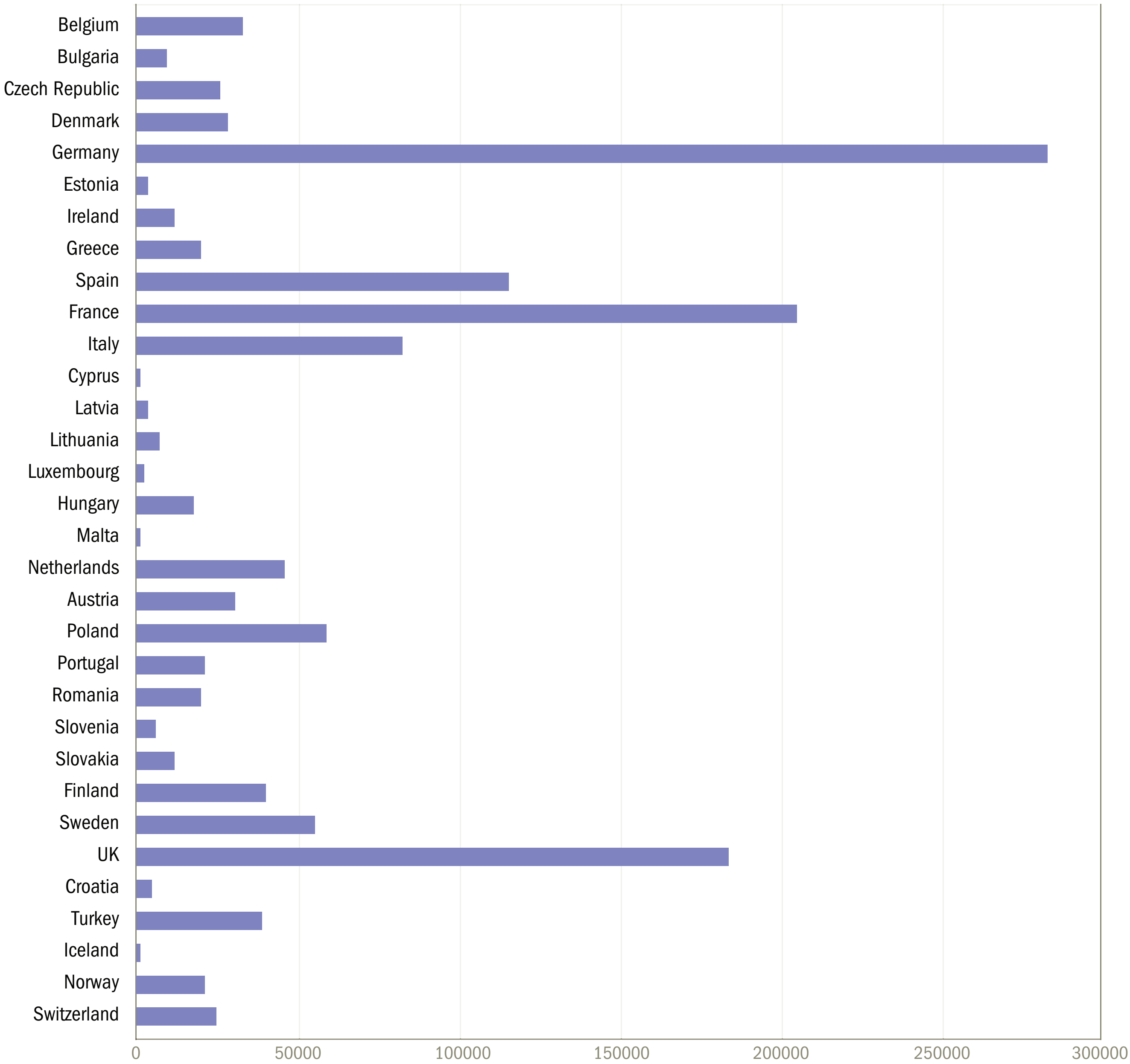
Source: DG Research
Data: Eurostat, OECD
Note: [1] US: 2005

STC key figures report 2008

Figure I.2.5. illustrates that in EU-27, the three biggest countries – Germany (282,063), France (204,484) and the United Kingdom (183,534) – account for half of the researchers. 641,000 researchers (FTE) work in the business sector in the EU, of which 58 % are in the three biggest countries. In comparison there are 1.1 million and 483,000 business researchers (FTE) in the US and Japan respectively [62].

[60] OECD estimate, slightly different from Eurostat estimate of 1.30 million.
[61] Except in Finland but data are only available for the period 2004-06 for this country.
[62] Source: Eurostat, OECD. See Statistical Annex.

FIGURE I.2.5 Number of researchers (FTE), 2006 [1]



Source: DG Research
Data: Eurostat, OECD
Note: [1] CH: 2004; FR, IT, PT, TR, IS, NO: 2005

STC key figures report 2008

The EU remains less researcher-intensive than the US and Japan

In 2006, the number of researchers (FTE) per thousand labour force was 5.6 in EU-27, compared to 10.7 in Japan and 9.3 in the US (Table I.2.1). Within the ERA, the share of researchers in the labour force is highest in Finland (15.3 researchers (FTE) per thousand labour force), Iceland (12.5), Sweden (11.7) and Luxembourg (11.4). The number of researchers per thousand labour force is lower than 5 in 11 EU Member States, as well as in Turkey and Croatia.

EU-27 experienced an increase in the number of researchers (FTE) per thousand labour force, from 5 in 2000 to 5.6 in 2006, which corresponds to an average annual growth rate of 1.9 %. In comparison, the US and Japan have had average annual increases of 0.7 % (from 8.96 to 9.27) and 1.8 % (from 9.57 to 10.66) respectively over the same period [63]. Many ERA countries had significant growth in the number of researchers (FTE) per thousand labour force, in particular the Czech Republic, Denmark and Turkey [64].

[63] 2000-2005 for the US: see footnote to Table I.2.1.

[64] Cyprus and Malta also enjoyed strong growth in the number of researchers per one thousand labour force. However, in 2006, their totals of researchers (FTE) were only 755 and 475 respectively.

TABLE I.2.1 Evolution of the total number of researchers (FTE), and per thousand labour force, 2000-2006
(Countries are ranked in terms of researchers (FTE) per thousand labour force, 2006)

	TOTAL NUMBER OF RESEARCHERS (FTE)			RESEARCHERS (FTE) PER THOUSAND LABOUR FORCE		
	2000	2006	Average annual growth 2000-2006 [1]	2000	2006	Average annual growth 2000-2006 [1]
Finland	41004	40411	-0.7	15.8	15.3	-1.7
Iceland	1859	2155	3.8	11.6	12.5	1.9
Sweden	45995	55729	3.9	10.1	11.7	2.9
Luxembourg	1646	2346	6.1	8.9	11.4	4.4
Japan	647572	709691	1.5	9.6	10.7	1.8
Denmark	19453	28653	8.1	6.8	9.8	7.7
US	1289782	1387882	1.5	9.0	9.3	0.7
Norway	20048	21653	1.9	8.5	8.9	1.0
France	172070	204484	3.5	6.7	7.4	2.1
Austria	24124	30452	6.0	6.2	7.4	4.4
Belgium	30540	33924	1.8	7.0	7.3	0.8
Germany	257874	282063	1.5	6.5	6.8	0.7
UK	161352	183534	2.6	5.6	6.2	2.0
Switzerland	26105	25400	-0.7	6.2	5.8	-1.6
Ireland	8516	12167	6.1	4.8	5.7	2.9
Slovenia	4336	5834	5.1	4.5	5.7	4.1
EU-27	1102235	1300990	2.8	5.0	5.6	1.9
Spain	76670	115798	7.1	4.4	5.4	3.4
Netherlands	42088	45852	1.4	5.2	5.3	0.4
Estonia	2666	3513	4.7	4.1	5.1	3.9
Lithuania	7777	8036	0.5	4.6	5.1	1.5
Czech Republic	13852	26267	11.3	2.7	5.1	11.0
Slovakia	9955	11776	2.8	3.9	4.4	2.4
Hungary	14406	17547	3.3	3.5	4.1	2.7
Greece	14371	19907	6.7	3.1	4.1	5.3
Portugal	16738	21126	4.8	3.2	3.8	3.5
Poland	55174	59573	1.3	3.2	3.5	1.7
Latvia	3814	4024	0.9	3.5	3.5	-0.2
Italy	66110	82489	4.5	2.8	3.4	3.7
Bulgaria	9479	10336	1.5	2.8	3.0	1.2
Malta	272	475	15.0	1.7	2.9	14.1
Croatia	8572	5232	-11.6	4.2	2.6	-10.8
Romania	20476	20506	0.0	1.8	2.1	2.3
Cyprus	303	755	16.4	1.0	2.0	12.9
Turkey	23083	39139	11.1	1.0	1.6	9.6

Source: DG Research
Data: Eurostat, OECD
Note: [1] CH: 2000-2004; FR, IT, PT, UK, US: 2000-2005; IS, NO: 2001-2005; DK, EL, SE: 2001-2006; MT, AT, HR: 2002-2006; FI: 2004-2006

STC key figures report 2008

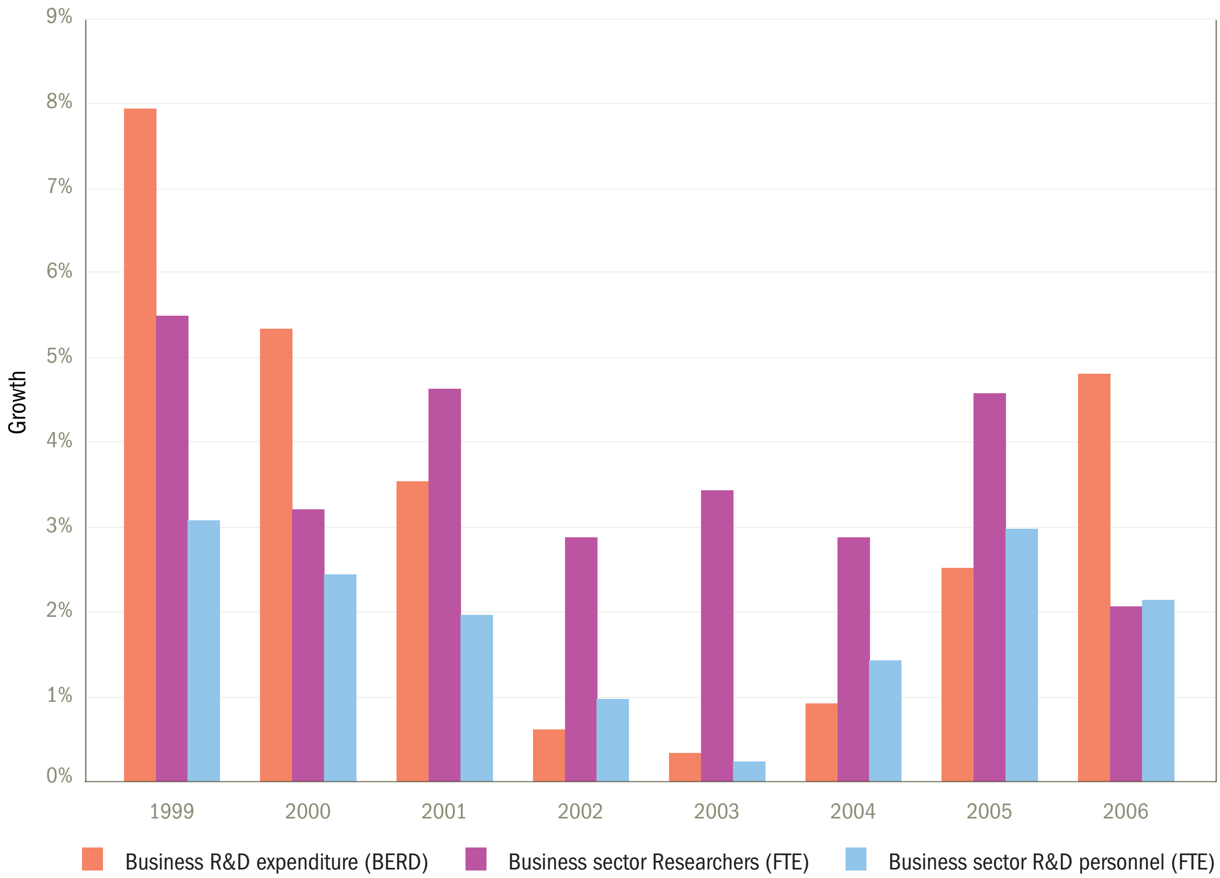
In EU-27 a majority of researchers work in the public sector, while in Japan and the US more researchers work in the private sector

EU-27 has a lower share of business researchers (49 %) than the US (79 %) and Japan (68 %). Within EU-27, the share of researchers employed in the business sector ranges from 10.9 % in Lithuania to 73.9 % in Luxembourg. Member States above the level of 60 % are Denmark, Germany, Luxembourg, the Netherlands, Austria and Sweden. Countries below 30 % are Bulgaria, Estonia, Greece, Cyprus, Latvia, Lithuania, Poland, Portugal and Slovakia [65]. There is a general correspondence in the Member States between the shares of researchers (FTE) employed in the business sector and the shares of R&D performed by business enterprise (for comparison see Figure I.1.12 in Chapter 1).

Since 2001, there has been a substantial increase in the number of business researchers in the EU and a lower cost per researcher

Since 2001, the annual growth in the number of business researchers (FTE) in EU-27 has been substantially higher than that of business R&D expenditure (Figure I.2.6). The immediate consequence is that R&D expenditure per researcher (FTE) in the business sector has decreased between 2000 and 2005 (a slight increase occurred between 2005 and 2006). This decrease can be observed in Figure I.2.7 (the dark blue line). The US experienced a similar decline until 2004, followed by an increase between 2004 and 2005.

FIGURE I.2.6 EU-27 — Business sector — R&D expenditure (BERD) [1], Researchers (FTE) and total R&D personnel (FTE) — growth against previous year

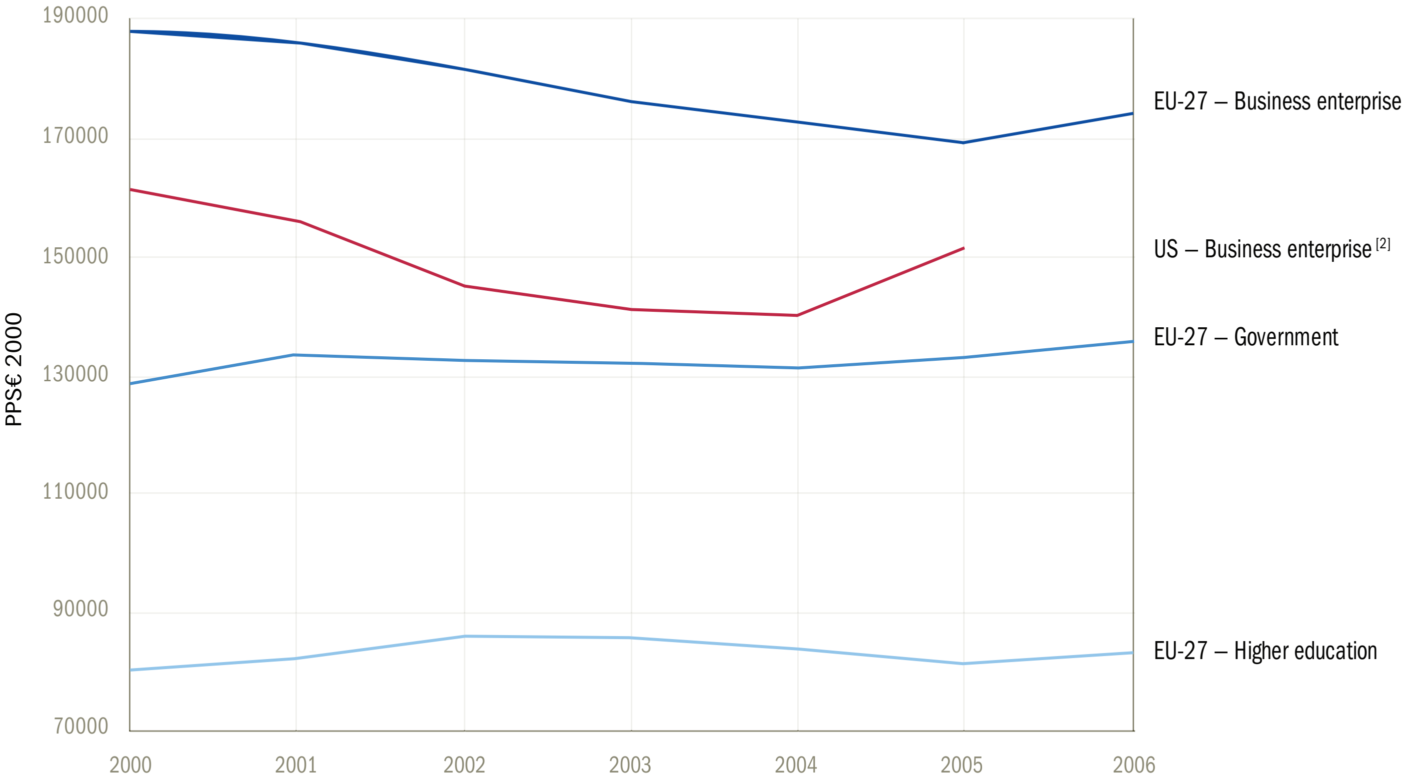


Source: DG Research
Data: Eurostat, OECD
Note: [1] The growth rates for BERD refer to real growth

STC key figures report 2008

[65] Source: Eurostat, OECD (2006).

FIGURE I.2.7 R&D expenditure (PPS€ 2000) [1] per researcher (FTE) by sector, 2000-2006



Source: DG Research
Data: Eurostat
Notes: [1] R&D expenditure in PPS€ 2000 was estimated by DG Research
[2] US: Most or all capital expenditure is not included

STC key figures report 2008

In contrast, the annual growth of R&D personnel (FTE) in the EU business sector has remained similar to that of R&D expenditure in this sector (Figure I.2.6). The ratio of R&D expenditure to R&D personnel (FTE) has therefore remained stable over recent years.

From the above observations, one can conclude that the share of business researchers (FTE) within total business R&D personnel (FTE) has increased since 2001. Fewer non-researchers per researcher in total R&D personnel is probably one of the factors behind the decrease in R&D expenditure per researcher in the business sector.

This observation qualifies the stagnation of R&D intensity in the EU business sector: since 2001, business R&D in the EU has expanded through a substantial increase in the number of researchers. This expansion has been accompanied by a reduced expenditure on R&D per researcher, with the consequence that this progression has not had an impact on overall business R&D intensity.

In the EU public sector, the number of researchers (FTE) has also grown faster than R&D expenditure since 2003, although the difference is less pronounced than in the business sector. As in the business sector, the annual growth of R&D personnel (FTE) in the public sector has remained in line with that of R&D expenditure in the sector. As a result, the proportion of researchers (FTE) in total R&D personnel (FTE) has increased slightly since 2003 in the EU public sector (government and higher education), but the effect on R&D expenditure per researcher (which is influenced by other factors as well) is still limited (Figure I.2.7, light blue lines). In the EU on average, the R&D expenditure per researcher (FTE) in the business sector is 30 % higher than in the government sector and twice as high as in the higher education sector.

2.2 Is the EU training more researchers?

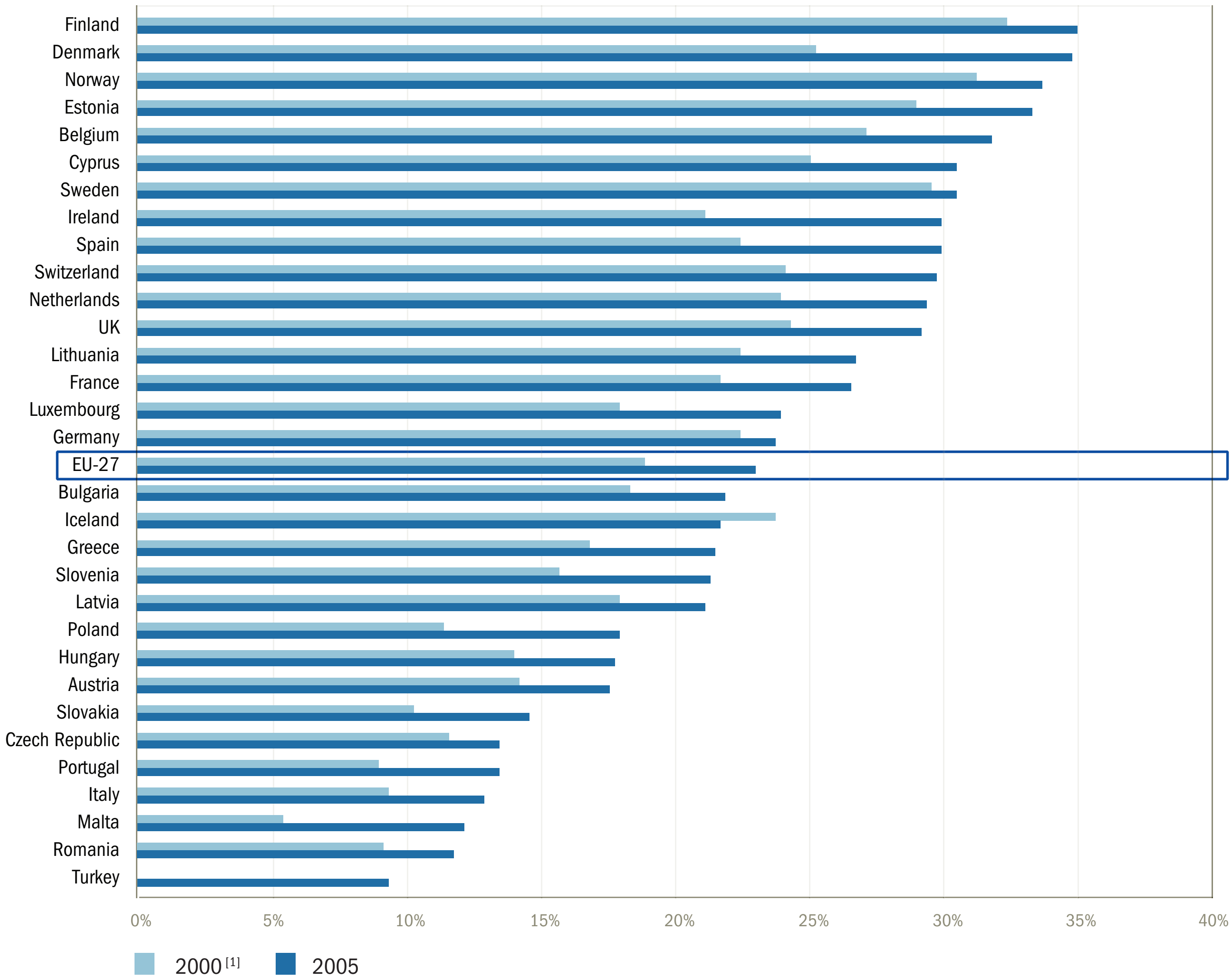
MAIN FINDINGS

The EU has produced more tertiary graduates and doctoral graduates than the US and Japan since 2000. Furthermore, the growth rates in the numbers of tertiary graduates and doctoral graduates were much higher in the EU than in the US. In 2005, 100,000 doctoral degrees were awarded in EU-27 compared to 53,000 in the US and 15,000 in Japan. The Nordic countries have in general achieved the highest growth rates for graduates, science and technology professionals, R&D personnel and researchers.

The share of population with tertiary education increased in all ERA countries

The diffusion and dissemination of new knowledge within a society and the absorption of new products, processes and services, largely depends on the general level of education of the population. Tertiary education does not only supply qualified personnel for R&D activities but also a more broadly qualified labour force for all economic activities. The share of adult population with tertiary education could be seen as a rough output of investment in education over several decades [66].

FIGURE I.2.8 Share of population aged 25-64 with tertiary education (%), 2000 [1] and 2005



Source: DG Research
Data: Eurostat
Note: [1] LT: 2001

STC key figures report 2008

[66] The population covered is 25 to 64 years old. The tertiary education of adults currently aged around 64 years started about 45 years ago.

Figure I.2.8. shows that on average in EU-27, 22.9 % of adults had achieved a tertiary level of education in 2005. Within EU-27, the share ranges from slightly more than one third in Finland, Denmark and Norway, to around 13 % in Italy, Malta and Romania. Expansion of tertiary education has continued over recent years. Attainment of tertiary qualification has risen in all Member States, from 18.9 % in 2000 to 22.9 % in 2005 on average in EU-27.

The six largest Member States in terms of population had more than 70 % of tertiary education graduates in EU-27 in 2005

France and the United Kingdom have the largest numbers of graduates from tertiary education, with 665,000 and 633,000 respectively in 2005, followed by Poland (501,000). In the science and engineering [67] fields, France and the United Kingdom also have the highest numbers of tertiary graduates, with 179,000 and 140,000 respectively, followed by Germany (93,000), Spain (79,000) and Poland (71,000) [68].

From 2000 to 2005, in EU-27 the number of tertiary graduates in the science and engineering fields increased more slowly than the total number of graduates, 4.8 % per annum compared to 5.9 %. In some Member States, the average annual growth rates in science and engineering were higher than 10 % (Estonia, Poland, Portugal, Romania and Slovakia) (see Statistical Annex).

The number of tertiary graduates has strongly increased in the EU since 2000, well above the US and Japan

The total number of tertiary graduates (ISCED 5 and 6 [69]) in EU-27 was 3.8 million in 2005 compared to 2.8 million in 2000, i.e. the number of tertiary graduates has increased strongly by 5.9 % per annum on average since 2000 [70]. Over the same period of time, the population of young people aged 20-29 has decreased by 1.2 million (from 67.2 million to 66 million), i.e. by 0.4 % per annum on average [71]. Therefore, the number of tertiary graduates per thousand population aged 20-29 increased on average by 6.3 % per annum in EU-27 (Table I.2.2).

The share of tertiary education graduates in the population aged 20-29 has increased strongly in the EU since 2000

Table I.2.2. also shows that the graduation rate for 2005 (calculated as the total number of tertiary graduates [72] per thousand population aged 20-29) was 56.9 on average for EU-27. It varies by a factor of nearly three within EU-27. It was highest in Lithuania, Ireland, France and the United Kingdom, at more than 80 graduates per thousand population aged 20-29, but it increased in all ERA countries between 2000 and 2005.

In science and engineering, the number of tertiary graduates per thousand population aged 20-29 was 12.9 on average in EU-27, ranging from about 3.5 in Cyprus and Malta to 22.4 in France.

[67] Grouping together the two fields 'science, mathematics and computing' and 'engineering, manufacturing and construction'.
[68] Source: Eurostat.
[69] International Standard Classification of Education. Levels 5 and 6 refer respectively to the first stage of tertiary education (not leading to an advanced research classification) and the second stage of tertiary education (leading to an advanced research classification).
[70] It should be noted that a given student is counted as a graduate as many times as he/she obtains a degree. In 2006, more students have taken several degrees (e.g. bachelor and master) than in 2000, which contributes to the growth of the number of graduates in relation to the Bologna process. The number of persons obtaining a degree has grown less quickly than the number of graduates (see Statistical Annex).
[71] The share of young people in the total population has decreased as well (by 0.7 % per annum on average for the 20-29 age group) (see Statistical Annex).
[72] Graduates of all ages.

TABLE I.2.2 Tertiary graduates per thousand population aged 20-29 by field of education, 2005 and average annual growth, 2000-2005
(Countries are ranked in terms of science and engineering graduates per thousand population, 2005)

	All fields		Science		Engineering		Science and Engineering	
	2005	Average annual growth 2000-2005	2005	Average annual growth 2000-2005	2005	Average annual growth 2000-2005	2005	Average annual growth 2000-2005
Ireland	85.0	4.1	13.8	-1.7	10.2	2.7	23.9	0.0
France	83.2	5.9	10.2	1.3	12.2	5.2	22.4	3.3
Lithuania	86.2	10.5	4.5	11.9	14.3	5.2	18.8	6.6
UK	82.3	4.3	11.6	0.7	6.6	-2.3	18.2	-0.5
Finland	59.1	0.7	5.2	3.7	12.5	1.5	17.7	2.1
Switzerland	69.8	:	6.5	:	9.5	:	16.1	:
Denmark	78.7	7.7	6.6	8.4	8.3	2.3	14.9	4.7
Sweden	53.9	7.2	4.4	3.4	9.9	4.6	14.3	4.2
EU-27	56.9	6.3	5.7	5.4	7.2	5.0	12.9	5.2
Liechtenstein	29.9	:	2.3	:	10.4	:	12.7	:
Portugal	45.7	6.0	5.3	21.8	6.9	9.6	12.2	14.0
Estonia	59.6	7.8	6.3	19.2	5.7	1.9	12.1	9.0
Spain	43.5	2.0	4.6	2.8	7.3	4.4	11.9	3.8
Poland	78.4	5.8	5.2	21.6	5.8	4.6	11.1	10.8
Belgium	61.2	3.4	5.0	5.8	5.8	-0.5	10.9	2.1
Romania	46.0	20.6	2.3	15.4	8.1	18.8	10.4	18.0
Greece	37.5	0.0	5.6	0.0	4.6	0.0	10.2	0.0
Slovakia	39.5	9.3	3.6	18.0	6.6	12.3	10.2	14.1
Iceland	67.7	10.0	6.1	1.4	3.9	8.5	10.0	3.8
Italy	42.2	10.8	2.9	8.2	7.0	12.4	9.9	11.1
Slovenia	53.8	6.8	2.2	12.0	7.7	0.2	9.9	2.2
Latvia	77.8	10.7	3.7	4.0	6.1	6.5	9.8	5.5
Germany	35.6	2.6	3.9	6.1	5.8	1.4	9.7	3.1
Austria	31.7	5.4	3.2	12.3	6.4	3.2	9.7	5.8
Norway	56.7	2.8	4.6	2.6	4.3	2.3	9.0	2.5
Bulgaria	41.2	1.5	2.0	7.4	6.6	5.2	8.7	5.7
Netherlands	54.4	7.6	4.1	15.3	4.6	3.1	8.6	7.8
Czech Republic	34.8	9.3	2.8	2.8	5.5	12.9	8.3	8.8
Croatia	31.7	:	1.9	:	3.8	:	5.7	:
Turkey	20.3	6.9	1.9	7.1	3.8	4.8	5.7	5.5
Hungary	48.7	5.4	1.7	15.1	3.4	-1.1	5.2	2.9
Former Yugoslav Republic of Macedonia	17.6	7.8	1.5	9.9	2.5	-2.1	4.0	1.5
Cyprus	30.0	1.2	2.9	13.2	0.5	-21.5	3.5	0.4
Malta	45.8	5.0	1.8	3.4	1.7	-1.8	3.4	0.6

Source: DG Research
Data: Eurostat
Note: Luxembourg is not included due to unavailability of data

STC key figures report 2008

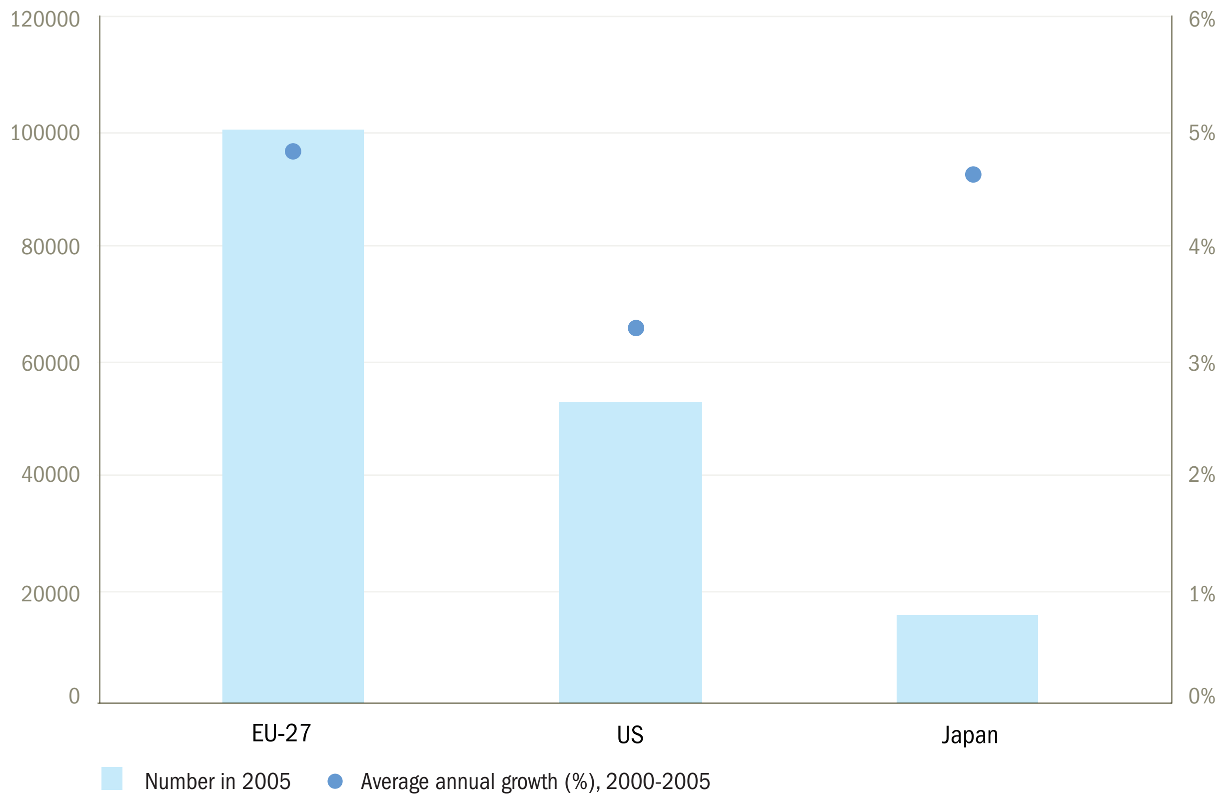
EU-27 produced twice as many doctoral graduates as the US

In 2005, some 100,000 doctoral degrees were awarded in EU-27 compared to 53,000 in the U.S. and 15,000 in Japan (Figure I.2.9 and Statistical Annex). Within EU-27, the six largest Member States in terms of population had more than 70 % of doctoral graduates in 2005, a similar share to that of tertiary education graduates. Germany (more than 24,000) and the United Kingdom (around 16,000) alone accounted for about 40 % of total doctoral graduates in EU-27, far ahead of France and Italy (less than 9,000). In science andb engineering [73], three Member States awarded more than 5,000 doctoral degrees each in 2005: Germany, the United Kingdom and France. These were followed by Italy, Spain and Poland, each of which awarded between 1,800 and 3,900 doctoral degrees in these fields [74].

Over the period 2000-2005, the number of doctoral graduates grew more in EU-27 than in the US and Japan

The number of doctoral degrees awarded in EU-27 increased over the period 2000-2005 by 4.8 % per annum (Figure I.2.9). This was a higher rate of increase than in the US (+3.3 % per annum) and Japan (+4.6 % per annum). All ERA countries experienced growth except France, Lithuania and Sweden [75]. Growth was particularly high (more than 10 % per annum) in Iceland, Romania, Latvia, Italy, Slovakia, the Czech Republic, Portugal and Ireland (not shown in Figure I.2.9).

FIGURE I.2.9 Number of doctoral graduates, 2005 and average annual growth (%), 2000-2005

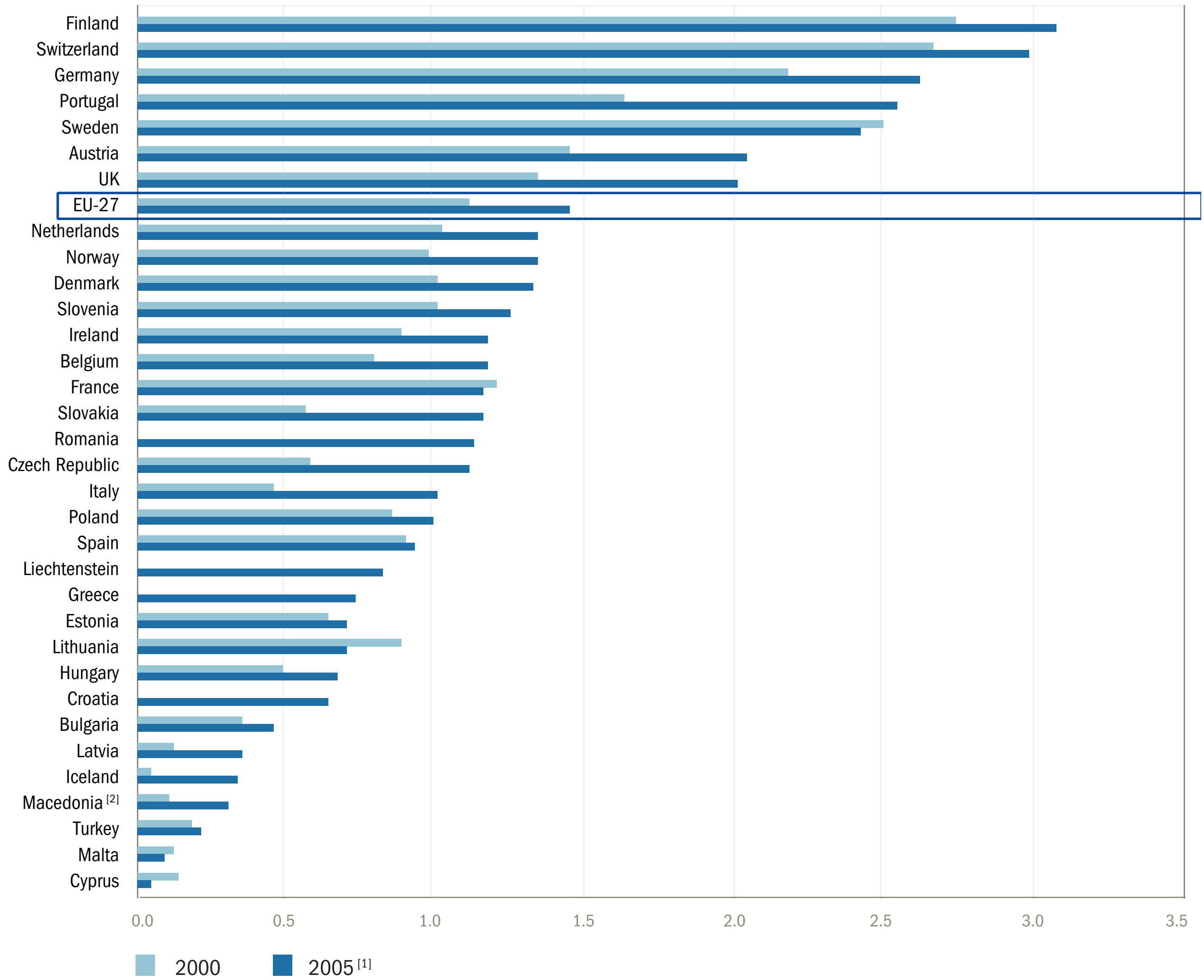


Source: DG Research
Data: Eurostat

STC key figures report 2008

[73] Grouping the two fields 'science, mathematics and computing' and 'engineering, manufacturing and construction'.
[74] Source: Eurostat.
[75] Excluding Cyprus and Malta where the number of doctoral graduates is limited, and thus the evolution not very significant (see Statistical Annex).

FIGURE I.2.10 Doctoral graduates per thousand population aged 25-34, 2000 and 2005 [1]



Source: DG Research
Data: Eurostat
Note: [1] IT, CH: 2004
[2] Former Yugoslav Republic of Macedonia

STC key figures report 2008

Within the ERA, Finland, Switzerland, Germany and Portugal have the highest share of doctoral graduates in the population aged 25-34

In 2005, EU-27 had on average 1.4 doctoral graduates [76] per thousand population aged 25-34 (Figure I.2.10). Among the ERA countries, this ratio is higher than 2.5 in Finland, Switzerland, Germany and Portugal, closely followed by Sweden, Austria and the United Kingdom (ratio 2 or higher).

In science and engineering (not shown on the Figures above), the number of doctoral degrees awarded in EU-27 increased by 3.5 % per annum, slightly less than in all fields (see Statistical Annex). Within the ERA, most countries experienced growth over the period 2000-2006, with the exceptions of Germany, France, Lithuania, Hungary, Romania and Sweden. In 'science, mathematics and computing', the number of doctoral degrees awarded in EU-27 increased by 2.8 % per annum, while in 'engineering, manufacturing and construction' the number increased by 5.2 % per annum.

The share of doctoral degrees awarded in science and engineering fields is higher in EU-27 (41 %) than in the US (36 %) and Japan (38 %) (see Statistical Annex). Within EU-27, the share is highest in Greece (62 %), Cyprus (60 %), Ireland (57 %) and France (56 %). Three other Member States are above 50 % (Latvia, the Czech Republic and Belgium) [77].

[76] Of all ages.
[77] Source: Eurostat.

Chapter 3. The scientific and technological outputs of R&D activities and their high-tech outcomes

Increasing investment in R&D and increasing the number of researchers are two of the main challenges facing Europe in the area of R&D. However, it is equally important to ensure the efficiency and effectiveness of increased R&D investment, in order to have a high performing research system.

This chapter examines scientific and technological output using bibliometric indicators and patents, which are currently the most established proxies for measuring scientific and technological outputs. Bibliometric indicators give information about where codified knowledge is produced and in which scientific fields. They also inform about the uneven impact and use of this knowledge. As such, bibliometric indicators are a measure of the scientific performance – both in terms of quantity and quality of scientific work – in a country, region or research institution. Patents on the other hand are a measure of the inventiveness of a country or company (see section 3.2 below).

3.1 Has the EU increased its efficiency in producing scientific publications since 2000?

MAIN FINDINGS

In 2006, EU-27 remained the largest producer of scientific publications in the world. However, the EU contributes much less than the US to high-impact publications.

China's share of world scientific publications has more than doubled within six years and is now larger than the Japanese share.

The EU is not specialised in the faster-growing scientific disciplines.

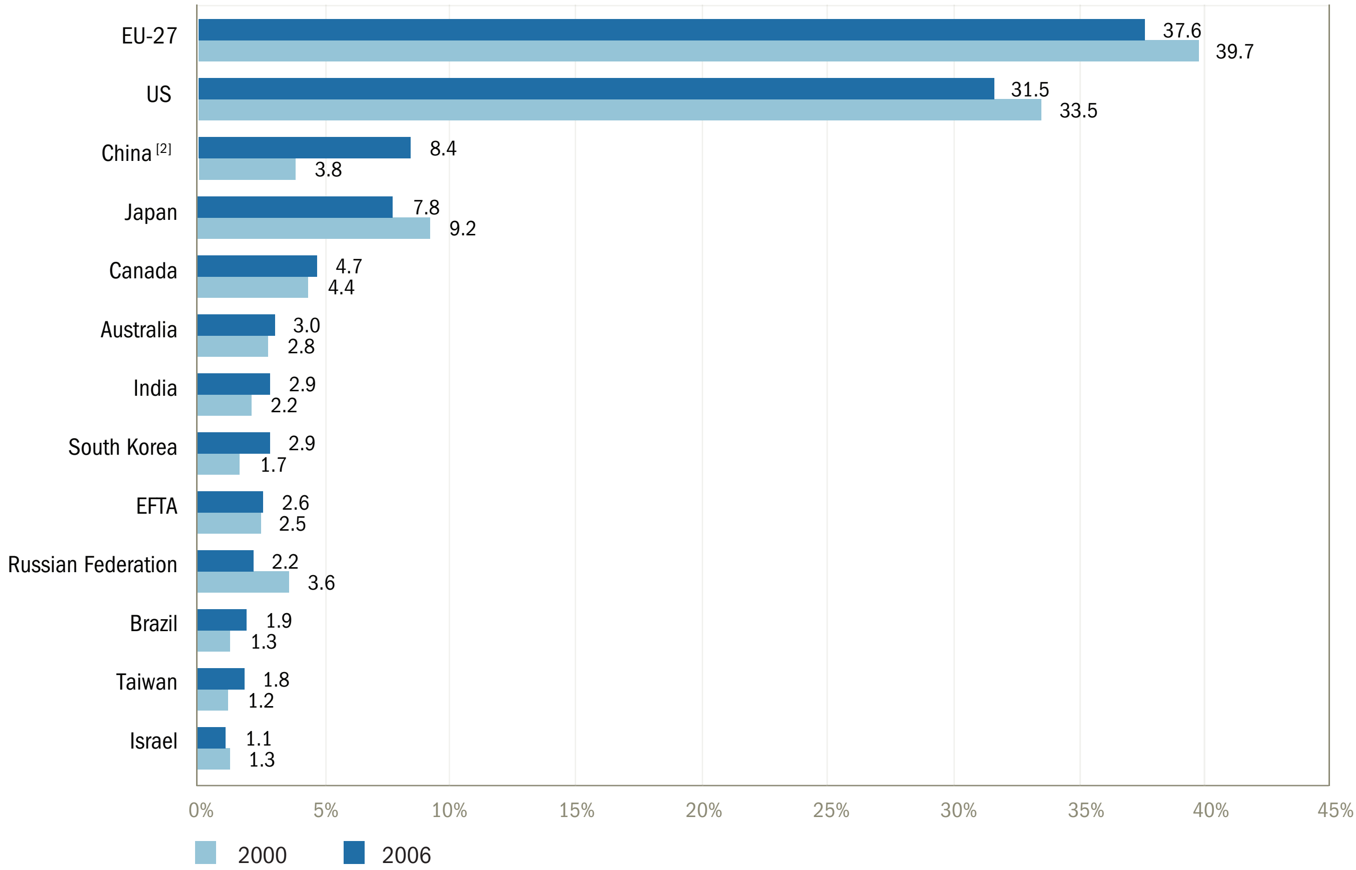
EU-27 remains the largest producer of scientific publications in the world

In 2006, 37.6 % of the world peer-reviewed scientific articles were signed by at least one author in the EU, compared to 31.5 % in the US (Figure I.3.1).

Between 2000 and 2006, the total number of scientific publications produced each year grew by about 18 % in both the EU and the US and by only 5 % in Japan. It grew by 178 % in China. As a result, the Chinese share of world scientific publications has more than doubled within six years and is now larger than the Japanese share [78]. The shares of a number of other emerging countries have increased as well, although at a less rapid pace. As a result, even though EU and US publications remain predominant, the rapid development of research capacities in other parts of the world has reduced their shares in total world publications over recent years.

[78] Figure I.3.1 shows, for each world region, the share of all scientific publications in the world that were signed by at least one author working in this world region. In other words, a given publication is counted as many times as there are world regions among its authors. For that reason, the shares of world regions sum up to more than 100 %. An increase in the Chinese share does not imply an automatic decrease in the EU, US or Japanese shares. If the latter occurs concomitantly, it means that a growing share of scientific publications involves Chinese authors without involving EU, US and Japanese authors.

FIGURE I.3.1 World shares of scientific publications (%) [1], 2000 and 2006



Source: DG Research

STC key figures report 2008

Data: Thomson Scientific/CWTS, Leiden University

Notes: [1] Full counting method was used at country level. At the aggregate EU level, double countings were avoided
[2] CN: Hong Kong is included in the data for 2000

Scientific output is positively correlated to public expenditure on R&D, but it also depends strongly on the scientific specialisations of countries

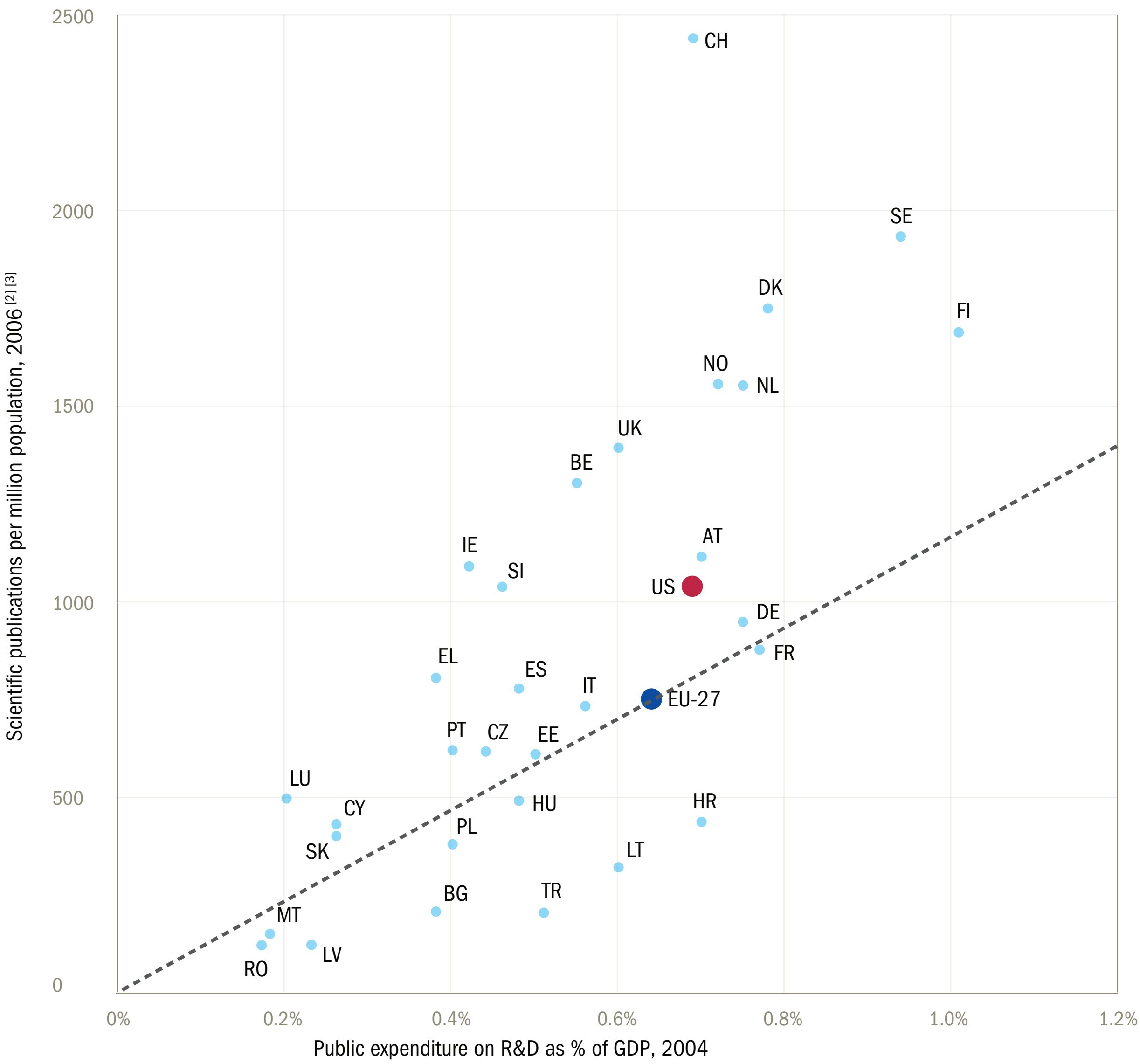
Figure I.3.2 shows the relationship between scientific publications per million population and public expenditure on R&D as a % of GDP. The broken line passes through the points where the ratio between output (scientific publications per million population) and input (public expenditure on R&D as a % of GDP) is equal to the EU-27 average. Member States above or below this line have a better or worse output-input ratio than the EU average. Overall, there is a clear positive correlation between the intensity of public R&D and scientific output relative to population.

Figure I.3.2 also shows that for comparable levels of public expenditure on R&D as a % of GDP, individual countries have widely different outcomes in terms of scientific publications per million population. Public expenditure on R&D as a % of GDP is for example less than 8 % higher in the US (0.69 %) than in the EU (0.65 %) [79], whereas the number of scientific publications per million population is more than 38 % higher in the US (1,047) than in the EU (756). In other words, with comparable public R&D intensities, in pure quantitative terms the output relative to the population is higher in the US (quality and impact of scientific output are considered in the next section). Similarly, a number of ERA countries such as Switzerland, the Nordic countries, the Netherlands, the United Kingdom and Belgium rank higher than the US in terms of publications per million population. However, such differences between highly performing research systems are to a large extent linked to the particular scientific specialisations of different countries. The US is for example more specialised than the EU in publications-intensive disciplines such as 'clinical medicine', 'health sciences', 'biomedical sciences' and 'basic life sciences' (see Figure I.3.4). This specialisation effect may be even more pronounced for some of the smaller countries.

[79] 2004 data: in order to take into account the gap between R&D input and scientific output (latest year available: 2006), a two-year lag between public expenditure on R&D and scientific publications per million population has been employed.

At the other end of the scale, the new EU Member States as well as the candidate countries have in general a limited number of publications per million population, even when public R&D intensity is relatively high. It cannot be excluded that for some of these countries this is a result of scientific specialisation in relatively less publication-intensive disciplines. However, the poorer performance of several of these countries probably also reflects the lower international competitiveness of their science base, since researchers in a given country can more easily publish their work in international peer-reviewed journals if they are well integrated and connected within the leading research communities in the world.

FIGURE I.3.2 Scientific publications in relation to public expenditure on R&D [1] [4]



Source: DG Research

STC key figures report 2008

Data: Thomson Scientific/CWTS, Leiden University, Eurostat, OECD

Notes: [1] In order to take into account the gap between R&D input and scientific output, a two year lag between public expenditure on R&D and scientific publications per million population has been applied

[2] EU-27: Scientific publications – full counting method was used at country level. At the aggregate level, double countings were avoided

[3] 2006 population average; US: 2006 mid-year estimate

[4] The dotted line links the origin to EU-27 – for the points on this line the ratio between the two values is equal to that of EU-27

The EU contributes less than the US to high-impact publications

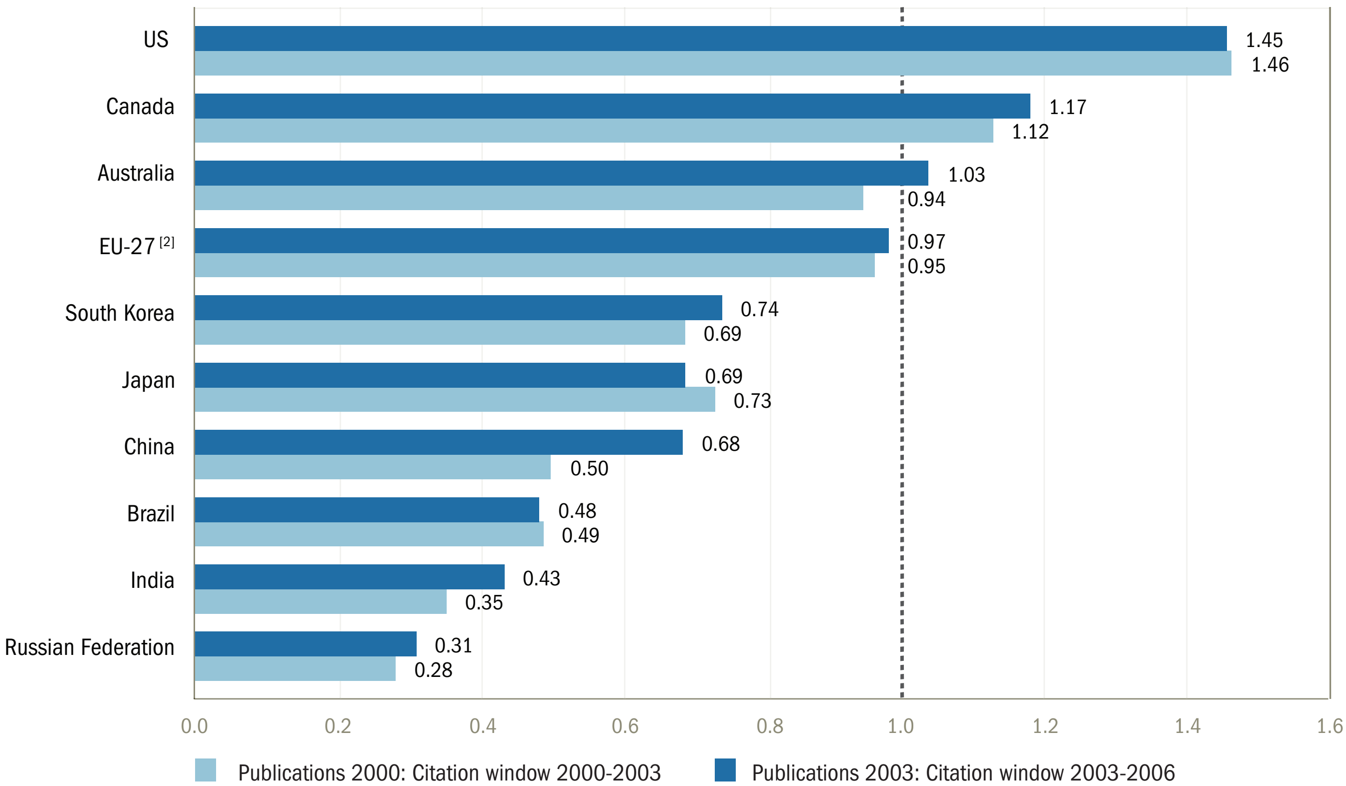
The number of citations that a scientific publication receives is a measure of its relevance and utility for scientific progress [80]. Highly-cited publications have the largest impact on international scientific work. Figure I.3.3 compares the share of a world region or country in the total number of publications to its share in the 10 % most cited publications only. A ratio above 1 indicates that the world region/country contributes more to the 10 % most cited publications than expected, given its total publication output.

Figure I.3.3 shows that the US ranks first in terms of highly-cited publications, far ahead of Canada, Australia and EU-27. The US share in the world's 10 % most cited publications is about 1.5 times higher than its share in total world publications. In contrast, the EU share in the world's 10 % most cited publications is slightly lower than its share in total world publications. In conclusion, overall the US publishes less than the EU but it has a much higher proportion of highly-cited publications. Furthermore, while the EU slightly improved its performance between 2000 and 2003, it still produced less highly-cited publications than would be expected given its overall share in world publications.

It is also noticeable that over this three-year period, China caught up with South Korea and Japan [81]. This progress of China may reveal different and not necessarily mutually exclusive phenomena:

- a clear 'publication strategy' (researchers in China now target much more high-level international journals);
- an improved quality/impact of Chinese research, so that researchers have access more easily to top journals;
- an internationalisation of Chinese research, with a better integration of Chinese researchers in international research networks (including the hosting of more researchers coming from outside China).

FIGURE I.3.3 Contribution to the 10 % most cited scientific publications [1], 2000-2003 and 2003-2006



Source: DG Research

STC key figures report 2008

Data: Thomson Scientific/CWTS, Leiden University

Notes: [1] The 'contribution to the 10 % most cited scientific publications' indicator is the ratio of the share in the total number of the 10 % most frequently cited scientific publications worldwide to the share in the total number of scientific publications worldwide. The numerators are calculated from the total number of citations per publication for the publications published in 2000 and cited between 2000 and 2003 and from the total number of citations per publication for the publications published in 2003 and cited between 2003 and 2006. A ratio above 1.0 means that the country contributes more to highly-cited, high-impact publications than would be expected from it's share in total scientific publications worldwide

[2] EU-27 does not include BG and RO

[80] Relevance and utility are of course not the only determinants of the number of citations that a publication receives. A number of other factors enter into play. Citations are only an imperfect proxy. A discussion of the limitations and biases goes beyond the scope of this section.

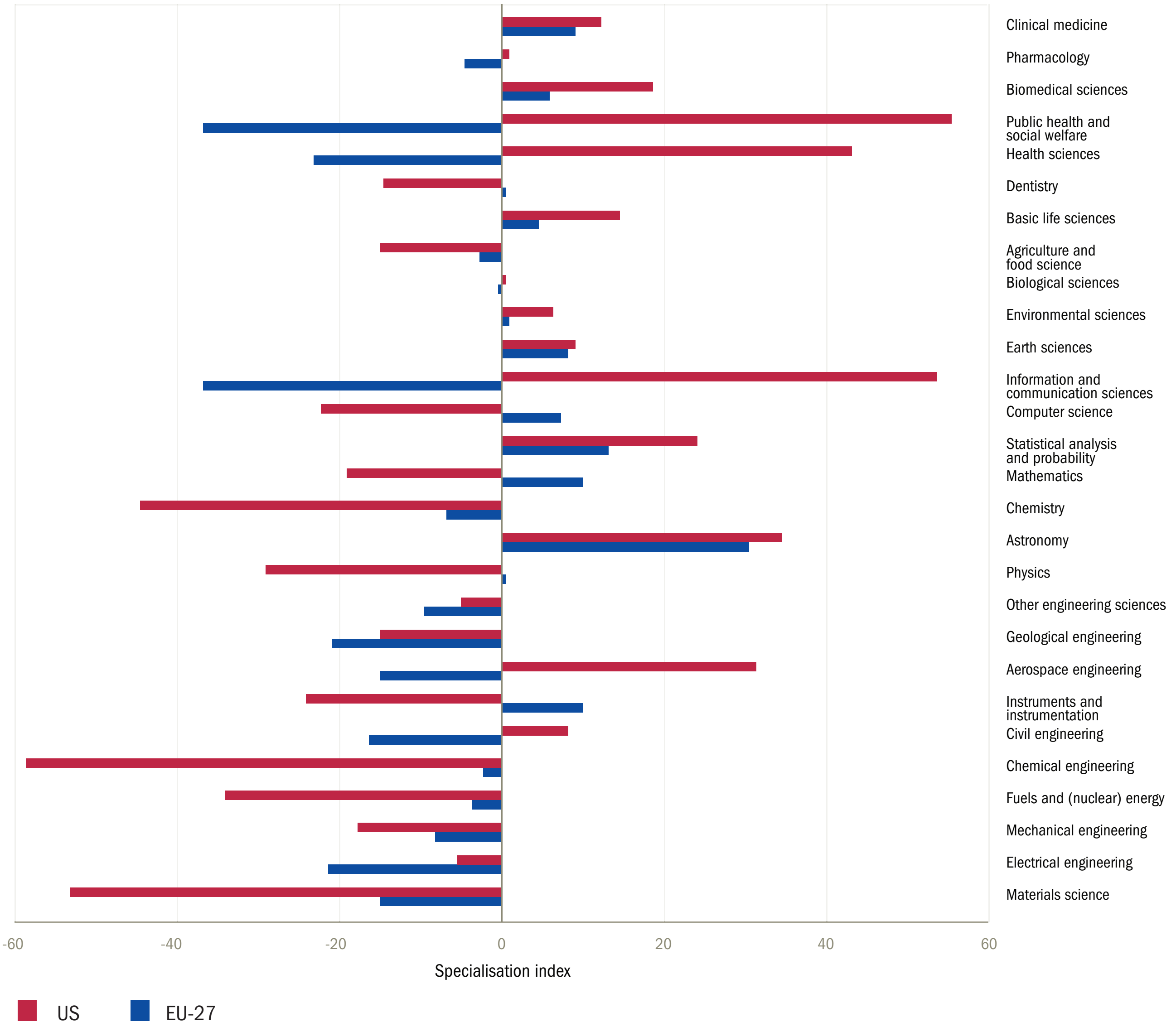
[81] Data are based on articles published in peer-reviewed science journals indexed by the Web of Science (WoS), an international bibliographical database produced by Thomson Scientific. The WoS is biased in favour of English-language journals and covers only very partially research in social sciences and humanities. The predominance of English-speaking countries in highly-cited scientific publications probably reflects in part this bias.

The EU is not specialised in the most dynamic research disciplines

A scientific specialisation index can be computed on the basis of the ratio between the share of a scientific field in the total number of publications of a country and the share of this field in the total number of publications in the world. This specialisation index is constructed so that it is centred on zero and stays within a range of +100 to -100 [82]. A positive value for a given field in a particular country points to the fact that the field has a higher weight in the portfolio of this country than its weight in the world.

The specialisation pattern of the EU in 2004-2006 as shown in Figure I.3.4 has become slightly more pronounced in comparison with 2002-2004, but has not changed fundamentally. The EU does not have many strong relative specialisations in sciences: only in 'astronomy' is the EU-27 world share significantly higher than its share in total world publications. In most disciplines the EU is close to its average world share. This is to be expected to some extent as EU-27 produces the highest share of world total output. However, the US has a similar share in total world output and displays a more pronounced specialisation pattern.

FIGURE I.3.4 EU-27 and US — Scientific specialisations based on scientific publications, 2004-2006 [1]



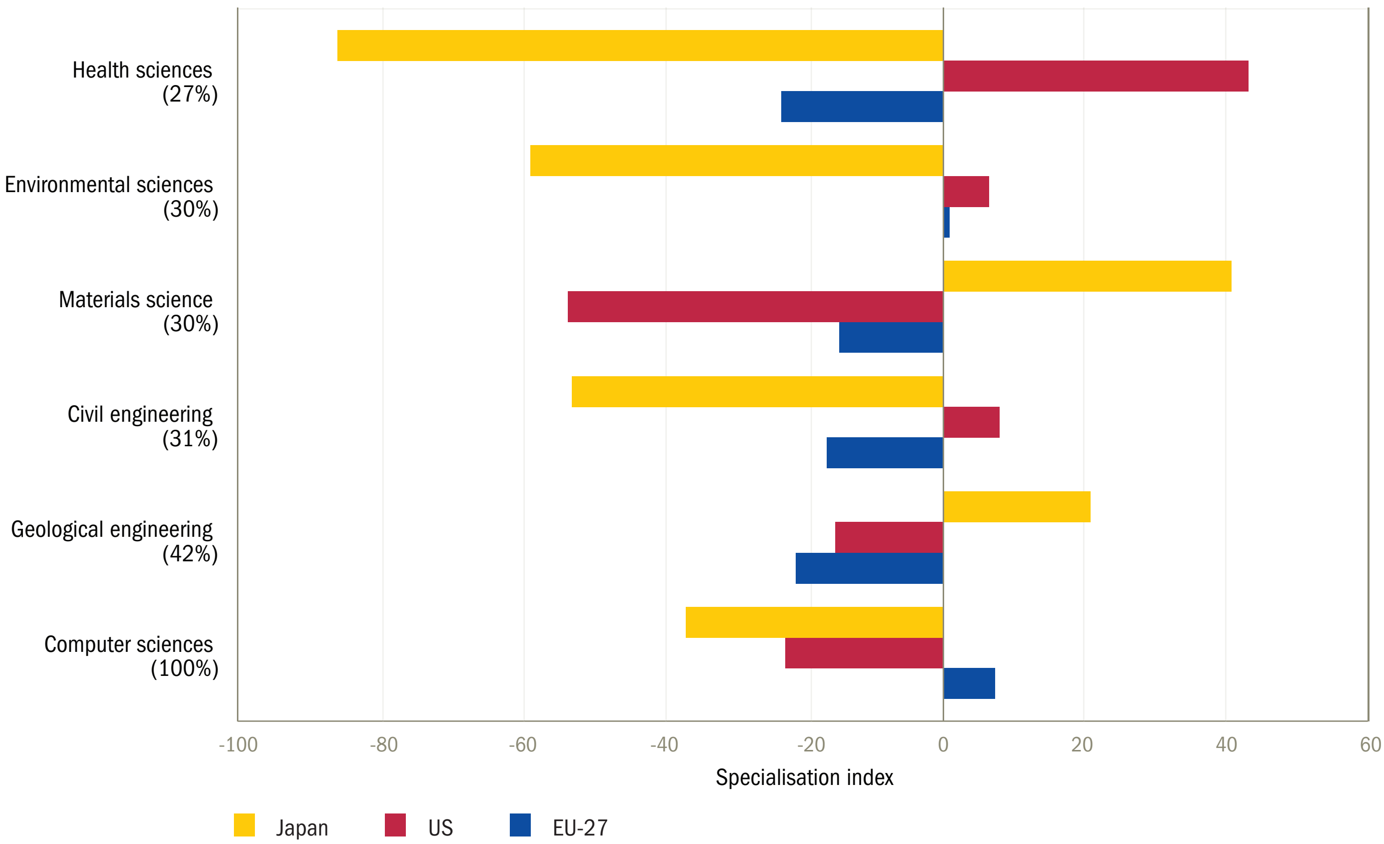
Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University
Note: [1] Social sciences and multidisciplinary sciences are not included

STC key figures report 2008

[82] Scientific publications registered in the Science Citation Index (SCI) and the Social Science Citation Index (SSCI) provided by Thomson Reuters. The number of publications has been aggregated in two periods, 2000-2002 and 2004-2006, to allow for robust comparisons. The formula used is the hyperbolic tangent function for the ratio of the share of a domain or discipline in a country compared to the share of the domain in the total for the world: $RCA_{ki} = 100 \times \tanh \ln \{(A_{ki}/\Sigma_i A_{ki})/(\Sigma_k A_{ki}/\Sigma_{ki} A_{ki})\}$, with A_{ki} indicating the number of publications of country k in the field i, whereby the field is defined by the nine scientific domains or 27 scientific disciplines used in the classifications.
LN centres the data on zero and the hyperbolic tangent multiplied by 100 limits the RCA values to a range of +100 to -100. The RCA indicator allows the assessment of the relative position of a field i in a country beyond any size effect. Neither the size of the field nor the size of the country has an impact on the outcome of this indicator. Therefore, it is possible to directly compare countries and fields.

From a strategic point of view it is interesting to focus in particular on EU specialisation in scientific fields which are more dynamic in terms of publication activity i.e. those scientific disciplines for which the number of publications has grown the most between the periods 2000-2002 and 2004-2006 [83]. These are mostly small fields in terms of scientific output ('materials science' is the largest with 5.85 % of total world publications in the period 2004-2006), but of high relevance for future socio-economic development. In the six disciplines where the growth was highest (the numbers in brackets on Figure I.3.5), the EU has no strong specialisation, while the US is specialised in 'health sciences' and Japan is specialised in 'materials science' and 'geological engineering'. However, the EU is not really under-specialised in any of these six fast-growing fields, while the US and Japan have marked under-specialisations respectively in 'materials science' and 'health sciences'. The EU has managed to maintain a relative specialisation in 'computer sciences', which has expanded very strongly, doubling between the two reference periods, up to 4.81 % of total world publications.

FIGURE I.3.5 Specialisations in high-growth scientific disciplines, 2004-2006; in brackets: growth rate (%) of the number of scientific publications between the periods 2002-2004 and 2004-2006



Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University

STC key figures report 2008

[83] The growth rate for each scientific discipline is calculated on the basis of the total number of publications in this discipline in the period 2004-2006 compared to the total number of publications in this discipline in the period 2002-2004.

3.2 Has the EU's inventiveness, as measured by patent applications, improved since 2000? [84]

MAIN FINDINGS

There has been some increase in EU-27 inventiveness as measured by patent applications. In addition, between 2000 and 2005, PCT patent applications [85] with EU-27 inventors increased in number somewhat more rapidly than those with US inventors, but less rapidly than those with inventors from Asian countries.

US and Japanese inventions are concentrated to a higher degree than the EU in enabling technologies (biotechnology, ICT and nanotechnology). The Asian countries for their part account for a rapidly growing share of ICT patents in the world.

Within the EU, 40 NUTS 2 regions accounted for more than two-thirds of all EU-27 EPO patent applications in 2001-2003. Half of these regions are German *Länder*.

PCT [86a] patent applications with EU-27 inventors have increased in number more rapidly than those with US inventors, but less rapidly than those with inventors from Asian countries [86b]

Overall, PCT patent applications with EU-27 or US inventors accounted for almost two-thirds of all PCT patent applications in 2005 (Table I.3.1). The number of patent applications with EU-27 inventors filed under the PCT has increased by 13 % between 2000 and 2005 compared to an increase of 9.6 % for patent applications with US inventors. In comparison, the numbers of PCT patent applications from Asian countries have increased dramatically: Japan (100 %), South Korea (161 %), China (137 %), India (241 %). Except for Japan, these growth rates are from relatively small absolute numbers. Nevertheless, as a result of this growth, the world share of the EU and the US (added together) has declined by 15.4 % (from 75.7 % to 64.0 %) between 2000 and 2005, whereas Japan's share has increased by 55.6 % (from 10.5 % to 16.3 %) and South Korea, China, and India have all increased their shares by at least 80 %.

[84] *As a measure of inventiveness patents have two shortcomings. First, not all inventions are patented. Second, not all patents have the same value. In particular, only some of the patents granted are used commercially and actually lead to major technological improvements. Therefore, the number of patents may not show precisely the full impact of a given level of inventiveness in a country or company. Still, developments in patenting give some indication of the level of inventiveness.*

[85] *Patent applications filed under the Patent Cooperation Treaty (PCT), at international phase, designating the EPO.*

[86a] *The Patent Cooperation Treaty (PCT) is an international treaty, administered by the World Intellectual Property Organization (WIPO), signed by 133 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single 'international' patent application instead of filing several separate national or regional applications. Indicators based on PCT applications are relatively free from the 'home advantage' bias (proportionate to their inventive activity, domestic applicants tend to file more patents in their home country than non-resident applicants). The granting of patents remains under the control of the national or regional patent offices (see Eurostat, Statistics in focus Patent statistics procedures and statistics: an overview, 19/2006). When compiling patent indicators for international comparisons, the alternative is to use triadic patent families. However, the time lag for consolidated statistics on triadic patents is much longer and comparisons for 2005 have to be based only on estimates (see OECD Patent Manual 2008, pp 44-46).*

[86b] *Asian countries came late to using the PCT procedure. This high increase does not only reflect an increase in patenting activity, but a more systematic use of PCT procedures by these countries.*

TABLE I.3.1 Patent applications filed under the PCT [1], by priority year and residence of inventor

TOTAL PATENT APPLICATIONS

	TOTAL		% SHARE	
	2000	2005	2000	2005
World	102699	134982	100	100
US	40798	44720	39.7	33.1
EU-27	36948	41733	36.0	30.9
Japan	10748	21982	10.5	16.3
> Total Triad	**88495**	**108435**	**86.2**	**80.3**
South Korea	1959	5105	1.9	3.8
China	1571	3721	1.5	2.8
Canada	2243	2594	2.2	1.9
Australia	1750	2013	1.7	1.5
Switzerland	1502	1891	1.5	1.4
Israel	1521	1724	1.5	1.3
India	268	916	0.3	0.7
Russian Federation	589	676	0.6	0.5
Norway	596	618	0.6	0.5
Singapore	265	458	0.3	0.3
South Africa	423	346	0.4	0.3

BIOTECHNOLOGY PATENT APPLICATIONS

	TOTAL		% SHARE	
	2000	2005	2000	2005
World	9590	6842	100	100
US	4719	2718	49.2	39.7
EU-27	2299	1701	24.0	24.9
Japan	774	1195	8.1	17.5
> Total Triad	**7792**	**5613**	**81.3**	**82.0**
Canada	235	223	2.5	3.3
South Korea	119	156	1.2	2.3
Australia	129	151	1.3	2.2
Israel	113	101	1.2	1.5
China	911	88	9.5	1.3
Switzerland	91	87	0.9	1.3
Singapore	27	53	0.3	0.8
India	28	50	0.3	0.7
Russian Federation	21	30	0.2	0.4
Norway	24	20	0.3	0.3
South Africa	5	7	0.1	0.1

ICT PATENT APPLICATIONS

	TOTAL		% SHARE	
	2000	2005	2000	2005
World	38497	49217	100	100
US	17259	17050	44.8	34.6
EU-27	11938	12228	31.0	24.8
Japan	4534	8985	11.8	18.3
> Total Triad	**33731**	**38264**	**87.6**	**77.7**
South Korea	831	2281	2.2	4.6
China	221	2074	0.6	4.2
Canada	881	1029	2.3	2.1
Israel	833	742	2.2	1.5
Australia	585	550	1.5	1.1
Switzerland	414	405	1.1	0.8
Singapore	158	251	0.4	0.5
India	49	205	0.1	0.4
Russian Federation	165	195	0.4	0.4
Norway	160	166	0.4	0.3
South Africa	99	55	0.3	0.1

NANOTECHNOLOGY PATENT APPLICATIONS

	TOTAL		% SHARE	
	2000	2005	2000	2005
World	864	898	100	100
US	441	386	51.0	42.9
EU-27	215	239	24.8	26.6
Japan	122	126	14.1	14.1
> Total Triad	**777**	**751**	**90.0**	**83.6**
South Korea	4	32	0.5	3.6
Israel	12	14	1.4	1.6
Singapore	5	14	0.5	1.5
China	5	14	0.6	1.5
Canada	19	13	2.2	1.4
Switzerland	15	11	1.8	1.2
Norway	2	7	0.2	0.8
Russian Federation	4	5	0.4	0.6
Australia	10	3	1.1	0.3
India	2	3	0.3	0.4
South Africa	1	2	0.2	0.2

Source: DG Research
Data: OECD
Note: [1] All patent applications filed under the Patent Cooperation Treaty (PCT), at international phase, designating the EPO

STC key figures report 2008

US inventions are more focused on biotechnology, ICT and nanotechnology than EU inventions

Biotechnology, ICT and nanotechnology often function as enabling technologies for other areas, and therefore, they have a particular role in facilitating new inventions in other industries. If we compare the world share of total PCT patent applications invented in the EU with the corresponding shares of PCT applications in biotechnology, ICT and nanotechnology, we can see that for EU-27 the shares in biotechnology, ICT and nanotechnology are much lower than the EU's share in world PCT applications. The opposite is the case for the US. This indicates a concentration of US inventions, or specialisation, in these three areas and implies that a larger proportion of EU-27 inventions are made in other fields.

The world number of biotechnology patents has sharply declined since 2000

In biotechnology, the number of PCT patent applications has declined considerably between 2000 and 2005. The decline has taken place mainly in the US, EU and China. Japan increased its number of biotechnology patent applications by more than 50 %. South Korea, Australia, India, Singapore, the Russian Federation and South Africa also increased their numbers of patent applications, but from much lower levels. Overall, EU-27 maintained its global share of biotechnology patents. As a result the relative specialisations of the Triad are converging, but with the US still in the lead. China is losing ground in biotechnology patents.

Asian countries account for a rapidly growing share of ICT patents in the world

In ICT, covering more than 35 % of PCT patent applications, the numbers of US and EU-27 inventions have remained relatively stable, whereas they have doubled in Japan and South Korea and increased tenfold in China. As a consequence, the US world share of PCT patent applications in ICT fell from 45 % in 2000 to 35 % in 2005.

The US accounts for more than 40 % of nanotechnology inventions, but the EU has increased its share slightly to 26 %

The number of PCT patent applications is much smaller in nanotechnology, which is still largely dominated by US inventions (42.9 %). The EU increased its share slightly from 25 % to 26.6 % between 2000 and 2005. The EU therefore improved slightly its negative specialisation in nanotechnology, while the positive specialisation of the US and Japan slightly deteriorated. China's priorities were directed to other technology developments, ICT in particular.

Across all fields, EU-27 patenting activity is less important in high technology fields than in other technology fields

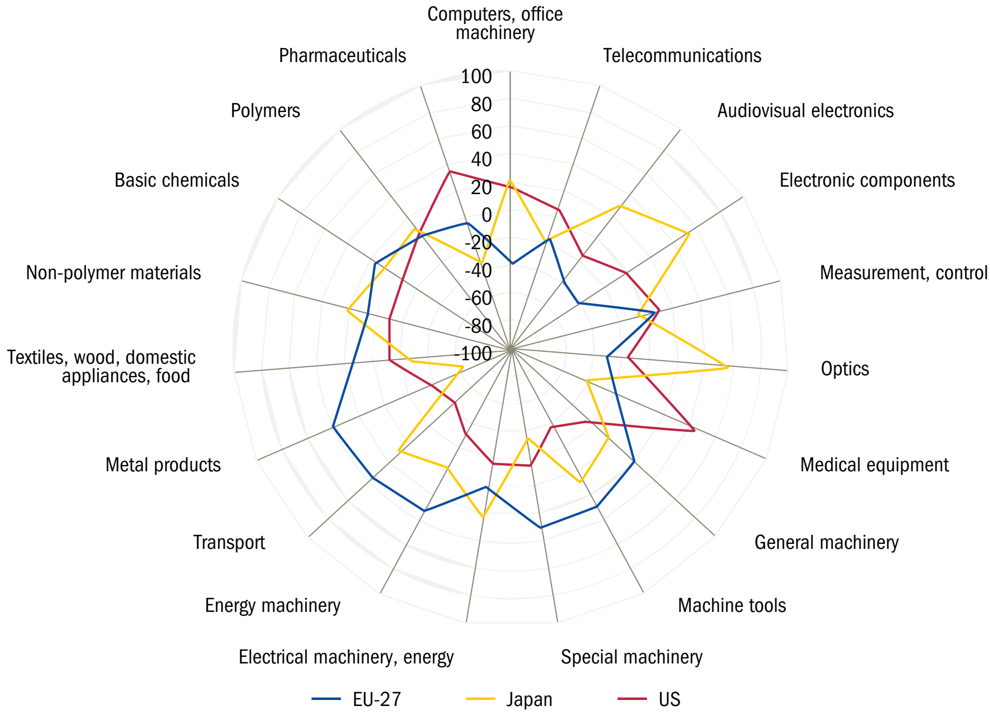
As is the case for scientific output, it is possible to calculate a specialisation index for technological output, based on the ratio between the share of a technological domain in the total number of PCT patent applications [87] of a country and the share of this domain in the total number of PCT patent applications in the world. This specialisation index is constructed in the same way as the scientific specialisation index above [88]; it is centred on zero and stays within a range of +100 to -100. A positive value for a given domain in a particular country points to the fact that the domain has a higher weight in the portfolio of this country than its weight in the world.

EU-27 is less specialised in high technology fields such as 'pharmaceuticals', 'computers, office machinery', 'telecommunications' and 'electronics' than in medium technology fields such as 'general machinery', 'machine tools', 'metal products' and 'transport' (Figure I.3.6). In contrast, the strongest specialisation of the US is in 'medical equipment' (this US specialisation has increased over time), followed by 'pharmaceuticals'. Japan shows strong specialisation in 'electronics' and 'optics'.

[87] At international phase, designating the EPO.

[88] The technology specialisation index is computed according to the following formula: the hyperbolic tangent function for the ratio of the share of a domain or discipline in a country compared to the share of the domain in the total for the world: $RCA_{ki} = 100 \times \tanh \ln \{(A_{ki}/\Sigma_i A_{ki})/(\Sigma_k A_{ki}/\Sigma_{ki} A_{ki})\}$*, with* A_{ki} *indicating the number of PCT patent applications (at international phase, designating the EPO) of country k in the field i.*
LN centres the data on zero and the hyperbolic tangent multiplied by 100 limits the RCA values to a range of +100 to -100.
The RCA indicator allows the assessment of the relative position of a field i in a country beyond any size effects. Neither the size of the field nor the size of the country has an impact on the outcome of this indicator. Therefore, it is possible to directly compare countries and fields.

FIGURE I.3.6 Technology specialisations (2004-2005)



Source: DG Research
Data: Fraunhofer ISI, EPO, WIPO

STC key figures report 2008

The technological specialisation pattern of the EU is less dynamic than in the US and Japan

The technological specialisation pattern of the EU as shown in Figure I.3.6 appears more rigid over time than that of its competitors [89]. Compared to 1999-2000, the EU has slightly reinforced its specialisations in sectors such as 'machine tools', 'measurement and control', 'energy machinery', 'transport' and 'pharmaceuticals'.

Compared to 1999-2000, the US has slightly strengthened its specialisation in 'medical equipment' and 'pharmaceuticals'. This is consistent with the US specialisation in 'health sciences' highlighted in section 3.1 above. On the other hand, US specialisations in 'electronics' and 'optics' sharply decreased between 1999-2000 and 2004-2005. Japan has increased its lead in 'optics' and reinforced 'basic chemicals' and 'polymers' technologies at the expense of ICT technology, in line with the evolution of its scientific specialisation described above (a stronger position in 'materials sciences' and a relative decline in 'computer sciences').

Within the ERA, countries with higher R&D intensities have more patent applications per million population

The number of patent applications filed at the European Patent Office [90] (EPO) per million population varies considerably across countries and in particular across Member States, from 629 in Liechtenstein [91] and 419 in Switzerland to 1 each in Turkey, Romania and China (Figure I.3.7 [92]). As expected, there is a positive correlation between patenting activity and business R&D intensity (in brackets for 2004 on Figure I.3.7 [93]). In other words, the Member States with high levels of business enterprise expenditure on R&D have higher numbers of patent applications per million population.

[89] Caclulations by Fraunhofer ISI (2008).

[90] For comparisons between ERA countries, EPO patent applications are a better basis than PCT patent applications as they are more numerous for each ERA country than PCT patent applications.

[91] Liechtenstein is a particular case due to its comparatively small population which means that just a small change in the number of patent applications may result in big changes in the number of patent applications per million population.

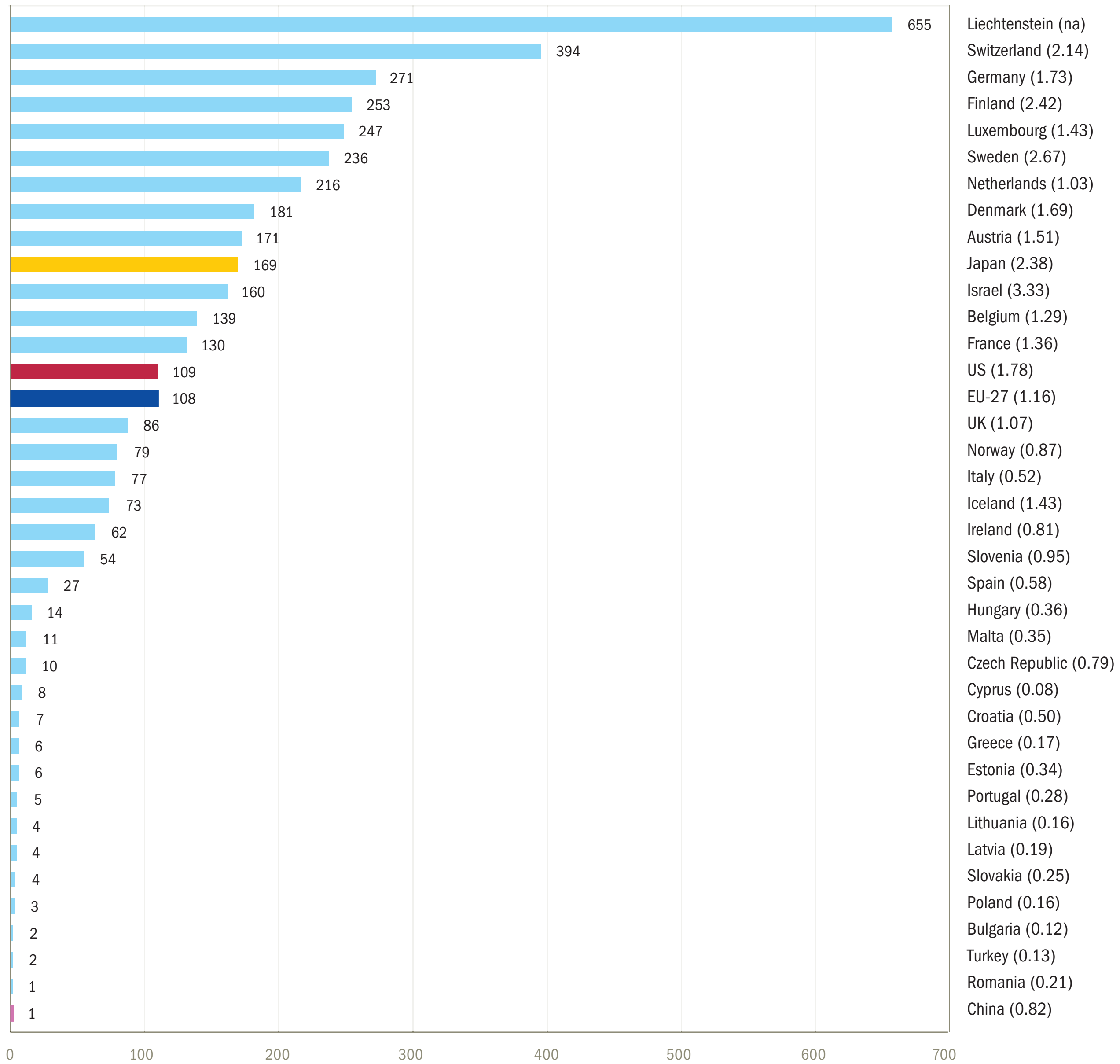
[92] The patent data were updated in Eurostat's reference database in November 2007 on the basis of a slightly different methodology from that previously employed. As a consequence, data on Figure I.3.7 are not comparable to that on Figure II.4.1 (p. 94) in Key Figures 2007. From 2007 onwards Eurostat's production of EPO and USPTO data has been based almost exclusively on the EPO Worldwide Statistical Patent Database. The worldwide statistical patent database 'PATSTAT' was developed by the EPO in 2005. The new methodology for EPO data is very similar to the methodology of the OECD:

- *for the patent applications to the EPO all direct applications (EPO-direct) are taken into account;*
- *for PCT applications (applications following the procedure laid down by the Patent Cooperation Treaty – PCT) made to the EPO, however, only those that have entered the regional phase are counted. As PCT patent applications at international phase designating the EPO are no longer included in the calculation of patent applications to the EPO, the values shown are lower than in previous publications.*

[93] See also Key Figures 2007, European Commission, figure p. 96.

The ERA countries with high numbers of patent applications per million population are all smaller countries (with the exception of Germany). This is evidence that these countries have efficient and effective research systems. However, this also reflects to some extent the specialisation patterns of these countries (as in the case of scientific publications, see section 3.1). Finally, Figure I.3.7 shows that Japan and the US are more active in applying for EPO patents than EU-27, despite the 'home advantage' bias (domestic applicants tend to file more patents in their home country than non-resident applicants).

FIGURE I.3.7 EPO patent applications per million population, 2004 [1]; in brackets: business R&D intensity, 2004 [2]



Source: DG Research
Data: Eurostat
Notes: [1] By priority year
[2] IS: 2005

STC key figures report 2008

EU technology development is regionally clustered

Only 40 regions at NUTS 2 [94] level (out of 268) had more than one thousand EPO patent applications in the period 2001-2003. These 40 regions accounted for more than two-thirds of all EU-27 EPO patent applications. Half of the regions are German *Länder* (Table I.3.2). In other Member States the technology potential is more concentrated. In France, for example, the Île de France region (Paris region), which is the top European region in absolute terms, has a patent portfolio that is 8.5 times larger than that of the fortieth region, Hamburg.

[94] The NUTS 2 classification is a statistical construct that does not always allow for a balanced comparison.

TABLE I.3.2 EU-27 — Technology specialisation — the top 40 NUTS 2 regions [1]
(Regions are ranked in terms of patent intensity)

	Number of patents (2001-2003)	Patent intensity (per million employment)	Growth index (1995=100)
Noord-Brabant (NL)	5708	2211	409
Stuttgart (DE)	7382	1587	202
Oberbayern (DE)	7275	1480	192
Karlsruhe (DE)	3703	1154	190
Mittelfranken (DE)	2230	1091	189
Tübingen (DE)	2301	1032	212
Rheinhessen-Pfalz (DE)	2258	982	117
East Anglia (UK)	2275	959	209
Freiburg (DE)	2531	928	166
Etelä-Suomi (FI)	2535	897	201
Darmstadt (DE)	3891	888	122
Köln (DE)	4042	868	159
Unterfranken (DE)	1307	866	181
Berkshire, Bucks. and Oxfordshire (UK)	2187	823	178
Oberpfalz (DE)	1059	812	217
Länsi-Suomi (FI)	1067	774	216
Düsseldorf (DE)	3950	730	138
Île de France (FR)	8501	678	149
Sweden (SE)	8049	669	153
Schwaben (DE)	1475	628	173
Braunschweig (DE)	1122	621	270
Rhône-Alpes (FR)	3658	604	151
Detmold (DE)	1251	583	212
Hannover (DE)	1309	578	191
Inner London (UK)	1582	514	210
Hamburg (DE)	1017	508	191
Münster (DE)	1344	497	165
Arnsberg (DE)	1944	489	166
Hampshire and Isle of Wight (UK)	1087	477	165
Berlin (DE)	1731	462	163
Denmark (DK)	3642	437	179
Emilia-Romagna (IT)	1974	420	186
Lombardia (IT)	3995	386	167
Schleswig-Holstein (DE)	1143	383	210
Provence-Alpes-Côte d'Azur (FR)	1268	323	172
Veneto (IT)	1521	288	178
Piemonte (IT)	1419	287	143
Zuid-Holland (NL)	1245	282	133
Outer London (UK)	1130	231	128
Cataluña (ES)	1124	154	227

Source: DG Research
Data: Fraunhofer ISI, EPO, WIPO
Note: [1] Denmark and Sweden are included at country level

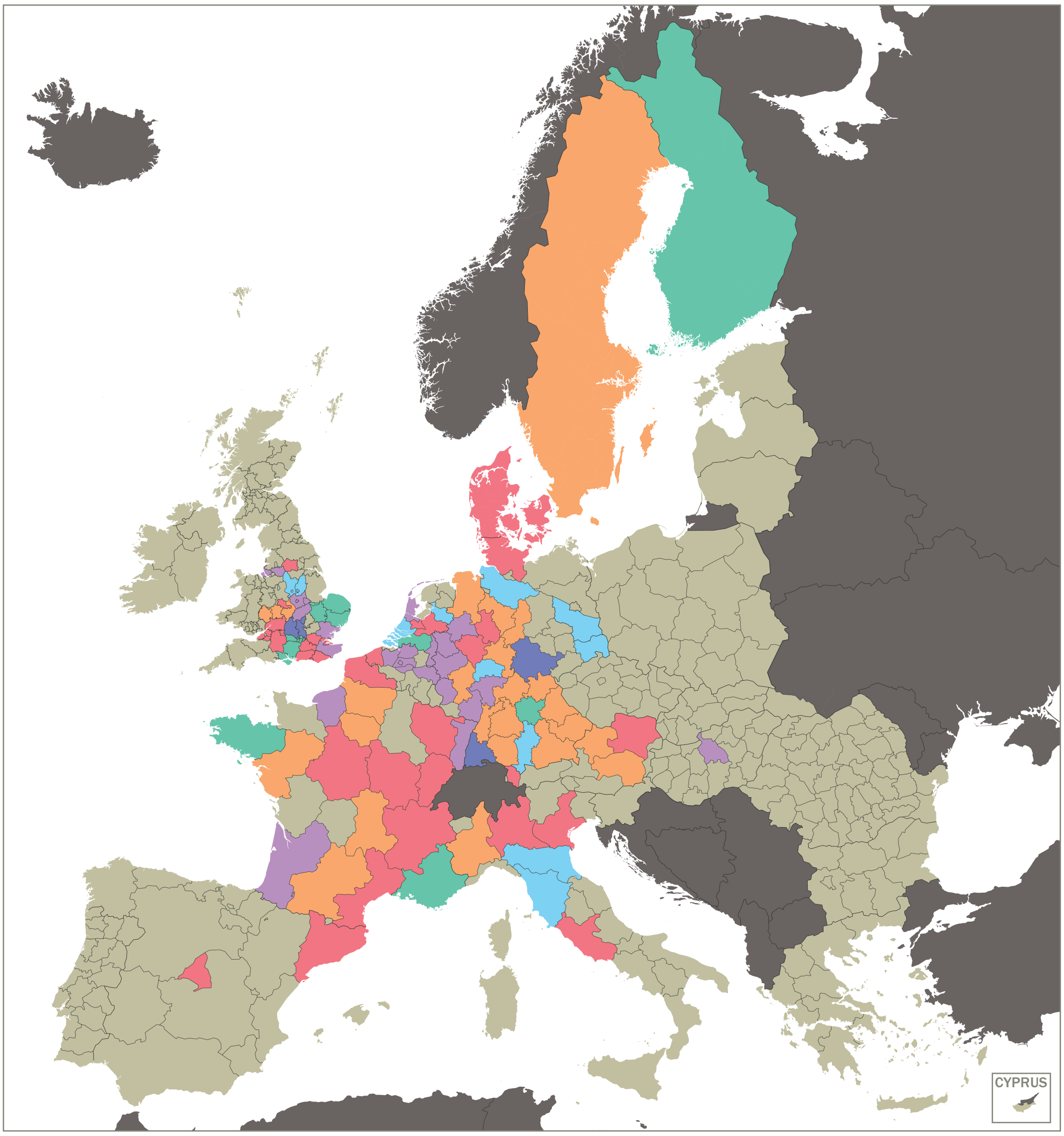
STC key figures report 2008

Noord-Brabant (NL) had the highest number of patent applications to the EPO in 2001-2003 per million employment, at more than 2,200 compared to only 678 from Île de France (FR). The latter also had a growth rate far below the average, while Noord-Brabant (NL) had four times more patent applications in 2001 than in 1995. Other dynamic regions in the top 100 are Dresden (DE), Bretagne (FR), Braunschweig (DE) and Thüringen (DE). Also included in the top 100 regions are such low R&D intensity regions as Cataluña (ES). The inclusion of these regions can often be explained by the presence in the region of an important technology producer [95].

Technological specialisations differ across regions

The map below (Figure I.3.8) shows, for each of the top 100 NUTS 2 regions in terms of number of EPO patent applications [96], the technological domain (aggregated into six categories) which has the highest specialisation index. The map highlights that the most important technology domains differ widely across regions, offering a potential for exploiting synergies. In addition, these top regions often have clustered specialisations which combine different strengths.

FIGURE I.3.8 EU-27 – fields of maximum technological specialisation for the 100 NUTS 2 regions [1] with the highest numbers of EPO patent applications, 2001-2003



Electrical Engineering | Instruments | Chemistry | Mechanical Engineering | Transport | Other | not included in the sample

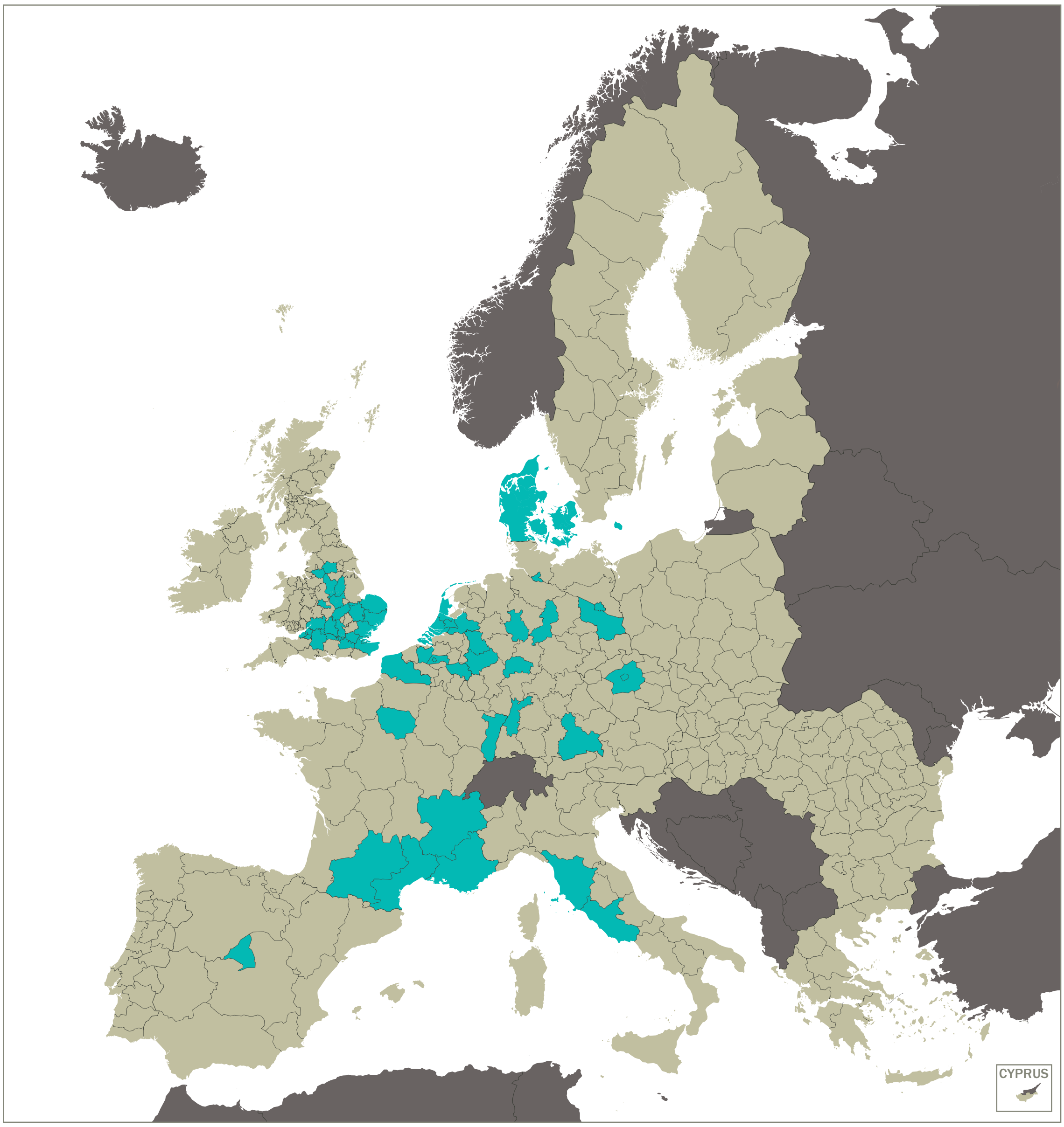
Source: DG Research
Data: Fraunhofer ISI, EPO
Note: [1] Denmark, Sweden and Finland are included at country level

STC key figures report 2008

[95] The province of Noord-Brabant in the Netherlands is the location of the headquarters of Philips.
[96] This section is based on 'Exploring regional technology specialisations: implications for policy' (V. Peter and R. Frietsch), a Regional Key Figures of the ERA Booklet, edited by DG RTD, forthcoming in 2008. It analyses the top 100 of 280 regions in the EU at the NUTS 2 administrative level.

Figures I.3.9 (a) and (b) show the geographical distribution of specialisations in ICT and biotechnology. The distribution of regional specialisations in high-tech is often different from that of national specialisations. In particular, strong regional specialisations are often diluted at country level in large countries (neither ICT nor biotechnology are specialisations in France, Italy and Germany).

FIGURE I.3.9 (a) EU-27 – technological specialisation in biotechnology at NUTS 2 regional level [1], 2001-2003



Source: DG Research
Data: Fraunhofer ISI
Note: [1] Denmark is included at country level

FIGURE I.3.9 (b) EU-27 – technological specialisation in information and communication technologies (ICT) at NUTS 2 regional level [1], 2001-2003

Source: DG Research
Data: Fraunhofer ISI, EPO
Note: [1] Finland is included at country level

STC key figures report 2008

3.3 Has the EU moved towards a more knowledge-intensive economy since 2000?

MAIN FINDINGS

The high costs of patents in Europe could explain some of the difficulties that Europe has in moving towards a more knowledge-intensive economy.

China has become the largest exporter of high-tech products in the world due to the growth of its computers and office machinery exports, mostly to the detriment of US and Japanese exports. The EU world market share of high-tech exports started to decline more recently.

The importance of services in the EU economy continues to increase while that of manufacturing industry continues to decline. Services accounted for 72 % of total EU-27 value added in 2005 and 67 % of total employment in 2006, whereas manufacturing industry was responsible for 17 % of EU-27 value added and employed 18 % of all workers.

Within manufacturing industry, medium-tech industry remains the largest sector in terms of value added and employment in the EU. Within the EU, between 2000 and 2005, medium-tech industry value added increased further in nominal terms, while high-tech industry value added decreased slightly. The decrease of high-tech was more pronounced in the US and Japan in the same period. However, the share of high-tech industry in total manufacturing industry remains significantly lower in the EU than in the US and in Japan.

The share of knowledge-intensive high-tech services in total services has been relatively stable over the 2000-2005 period in most countries. With a share of 6 to 8.5 % of value added in services it has reached a relatively stable level across the EU Member States, US and Japan.

Chapter 3.2. indicated that although there has been an increase in the number of patent applications with EU-27 inventors filed under the international Patent Cooperation Treaty (PCT) between 2000 and 2005, the growth of PCT patent applications from Asian countries has been dramatically higher (see footnote 86b).

In the EU, small and medium sized enterprises face initial costs for a patent application that are over 20 times higher than the corresponding costs in the US and costs for maintaining this patent protection that are over 60 times higher than the corresponding costs in the US.

A major barrier against the exploitation of EU inventiveness are the very high costs involved in patent application and in the maintenance of a patent covering a large number of countries in Europe. This particularly affects the readiness of small and medium-sized enterprises to assume the costs and risks of a broad portfolio of patents.

BOX 5: COSTS OF PATENT APPLICATION AND MAINTENANCE

Initial costs involved in a patent application for SMEs/Small entities (in euro)

EPO [97]	(A)	20175
US-PTO	(B)	928
JPO	(C)	1540
Ratio	(A/B)	21.7

Maintenance fees of Patents for SMEs/Small entities for 20 years (in euro)

EU-27 [98]	(A)	159930
US-PTO [99]	(B)	2627
Ratio	(A/B)	60.9

Indicators measuring the move towards a larger knowledge-intensity in Europe

High-tech products are products resulting from significant R&D investment. They include products in ICT, aerospace, scientific instruments and pharmaceuticals [100]. High-tech exports have usually been used as an indicator of the capacity of a country to exploit R&D outcomes and transform them into advanced goods to be sold on global markets. However, as discussed below, globalisation, including the advent of China as a big exporter of high-tech products, means that using high-tech exports as an indicator of a knowledge-based economy becomes less straightforward. This chapter also analyses other indicators of knowledge-intensity in the economy, such as value added and employment type in manufacturing and services sectors.

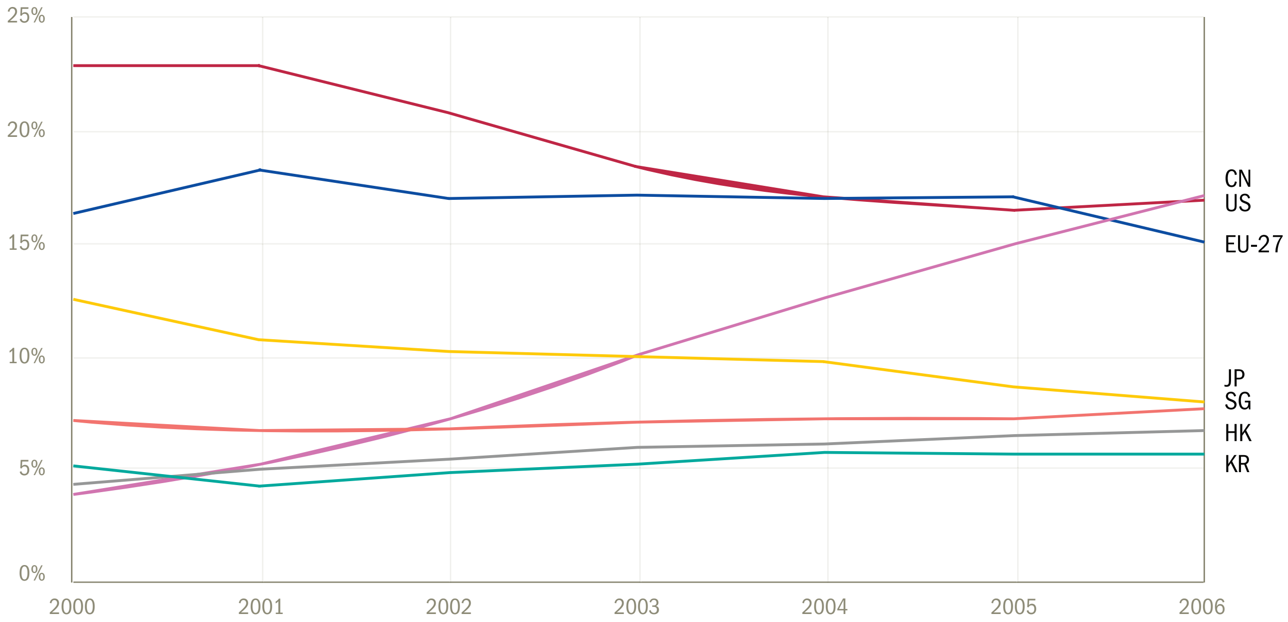
China has become the largest exporter of high-tech products in the world

Figure I.3.10 shows that the period 2000-2006 is marked by three major developments in high-tech exports:
- a sharp decline of the US share (from 22.9 % to 17.0 %) and of the Japanese share (from 12.7 % to 8.1 %);
- a stable EU share (around 17-18 %) until 2006 when it drops to 15.2 %;
- a large increase of China's share from 4.1 % in 2000 to 17.1 % in 2006, i.e. an average annual growth rate of 27 %. China was the top exporter of high-tech products in the world in 2006.

Other Asian countries remain important exporters of high-tech products, but not at the level of China. Singapore's share of global high-tech exports grew from 7.3 % in 2000 to 7.9 % in 2006. South Korea remains the seventh largest exporter of high-tech products (5.9 % in 2006), after Hong Kong [101] (6.9 % in 2006). Each of the other main high-tech exporters [102] accounts for less than 4 % of all high-tech exports in the world. Among them, only India saw its share increase between 2000 and 2006, but it remains very small (0.2 % in 2000 up to 0.3 % in 2006).

[97] The initial cost for a patent application for small entities (including translation costs) covering 12 Member States and Switzerland (source: EPO 2003).
[98] Total of maintenance fees covering the 27 EU Member States for 20 years (source: NPOs – 2006).
[99] Total of maintenance fees during 20 years covering the USA (source USPTO – 2007).
[100] The exhaustive list of high-tech products currently in use is based on the Standard International Trade Classification (SITC) Rev. 3 and can be found in the OECD working paper 'Revision of the high-technology sector and product classification' available at: http://www.olis.oecd.org/olis/1997doc.nsf/LinkTo/NT00000E3E/$FILE/12E77471.PDF. SITC has been revised in 2006 (SITC Rev. 4) and a new classification of high-tech products is being elaborated but is not yet in use.
[101] Special administrative region of China considered separately in high-tech trade statistics.
[102] Malaysia, Mexico, Canada, Philippines, Thailand, Brazil, Indonesia, India, the Russian Federation, Australia, by decreasing order of world share of high-tech exports.

FIGURE I.3.10 Exports of high-tech products [1] — world market shares, 2000-2006



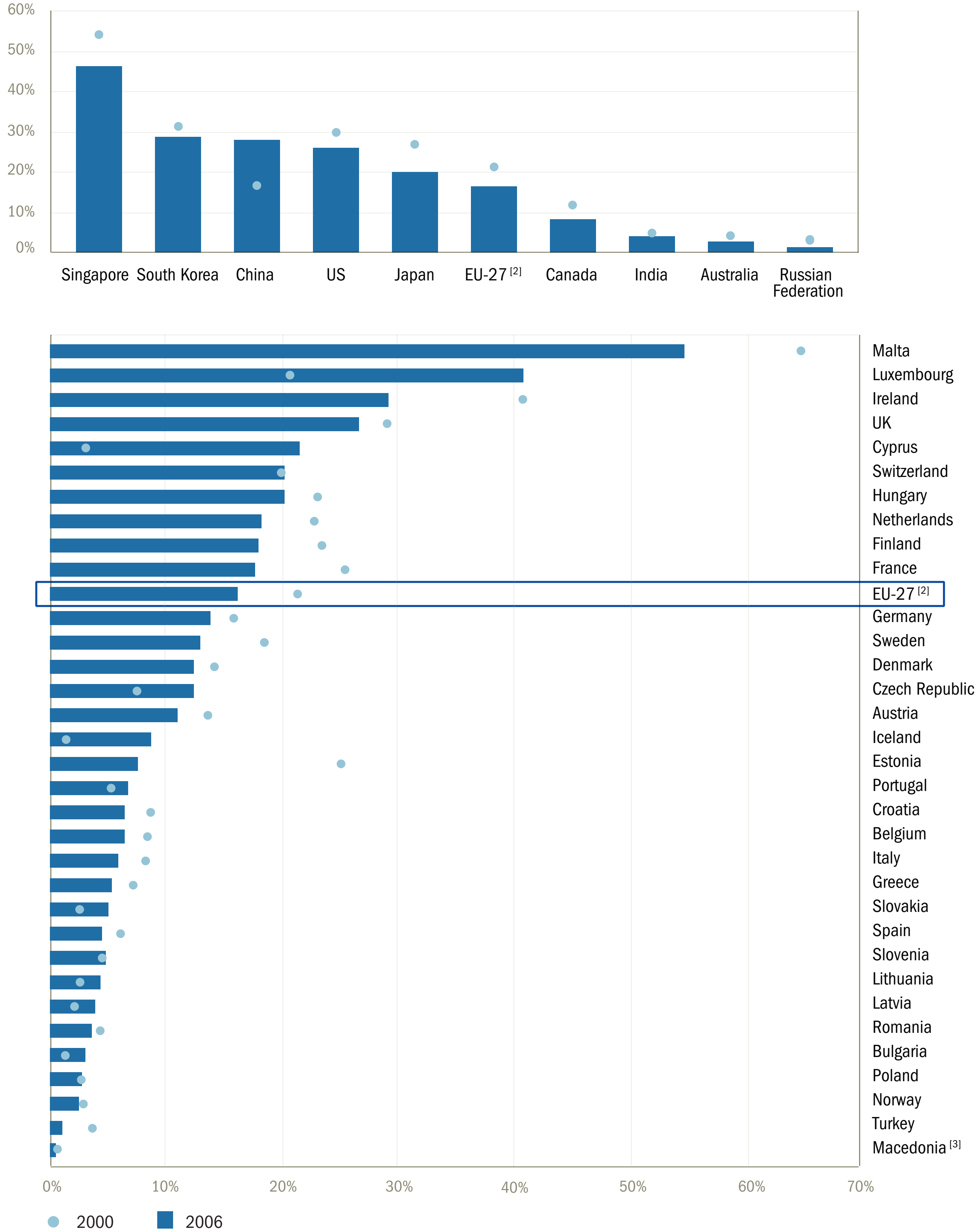
Source: DG Research
Data: Eurostat
Note: [1] Intra-EU exports are not included

The large production of ICT products in China explains why China's high-tech exports are now higher than those of the US and EU-27

The extent to which countries' exports are more or less focused on high-tech products can be seen in Figures I.3.11. Between 2000 and 2006, the share of high-tech exports in total national exports decreased in all economies except for China where it increased by 68 % (Figure I.3.11). The decrease is marked in Japan (-26 %), EU-27 (-22 %), Singapore (-15 %) and the US (-13 %). In 2006, almost 30 % of China's exports were exports of high-tech products, which is the same level as South Korea, Japan and the US. The strong increase in China's exports of products in the computers and office machinery sector as well as in the electronics and telecommunications sector between 2000 and 2006 is the main reason for this increase in Chinese high-tech exports.

However, in order to interpret high-tech exports as an indicator for a knowledge-based economy, a distinction should ideally be made between different types of high-tech exports. For some ICT goods the manufacturing process has become a mass-production process with relatively low skilled labour. Countries such as China with a low-cost labour force have had a competitive advantage and they have consequently taken over the manufacturing part of the value chain for many such products. However, other high-tech products such as aerospace involve more complex production processes, which require a highly qualified labour force. The consequence is that high-tech exports do not as such necessarily reflect the knowledge intensity of an economy. The examples of Ireland and Malta, which are specialised in ICT exports, further illustrate this statistical effect, because their R&D intensities are quite low although their export industries are highly focused on the manufacturing of ICT products for multinational enterprises. The current nomenclature of high-tech trade was established in the mid-nineties on the basis of the R&D intensity of the economic sectors over the eighties and early nineties. A revision of this nomenclature may lead to a different picture of high-tech trade in the years to come.

FIGURE I.3.11 High-tech exports as % of total national exports, 2000 and 2006 [1]



Source: DG Research
Data: Eurostat
Notes: [1] HR, MK: 2002 and 2006; IN, SG: 2000 and 2005
[2] The value for EU-27 does not include intra-EU exports
[3] Former Yugoslav Republic of Macedonia

Between 2000 and 2005 medium-tech industry increased its share of value added in EU-27, the US, and Japan

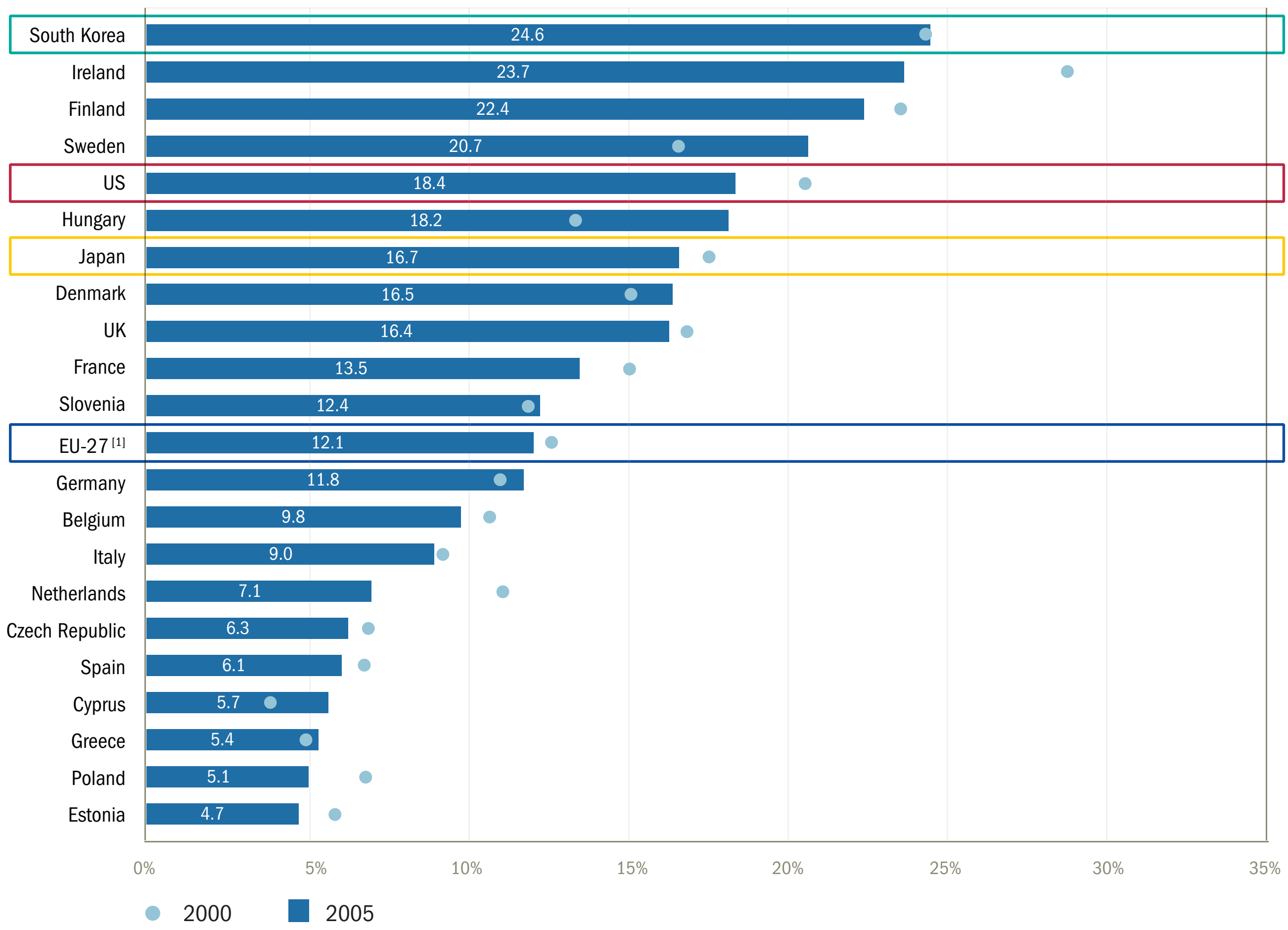
In line with the decrease of the share of exports of high-tech products in total national exports, the share of the high-tech industry's value added in total national manufacturing value added declined somewhat between 2000 and 2005 in the EU, the US and Japan (Figure I.3.12).

In the US and Japan, value added in all high-tech sectors, with the exception of 'pharmaceuticals' in the US, has declined between 2000 and 2005. In the US, the decline in high-tech was accompanied by a continuous growth of value added in all other manufacturing industries, particularly in medium-low-tech industry. In the EU the decline in the share of high-tech value added was limited, since a large decrease of value added in 'office, accounting and computing machinery' and 'radio, TV and communication equipment' was to a large extent outweighed by a growth of value added in 'pharmaceuticals' and 'medical, precision and optical instruments'.

However, the size of the high-tech industry in relation to other manufacturing industries is still significantly smaller in the EU economy than in the US, Japan and South Korea

As a share of total manufacturing industry, and despite its recent decline, the high-tech industry is still 50 % larger in the US and one third larger in Japan than in the EU (Figure I.3.12) [103]. As high-tech sectors are the most R&D-intensive sectors in an economy, their relatively smaller share in the EU economy explains in part the R&D intensity gap between the EU and the US and Japan (see also Figure I.1.15).

FIGURE I.3.12 High-tech value added as % of total national manufacturing value added, 2000 and 2005



Source: DG Research
Data: EU KLEMS database, OECD
Note: [1] Data are not available for the following countries: BG, LV, LT, LU, MT, AT, PT, RO, SK. These countries are not included in the EU-27 aggregate

STC key figures report 2008

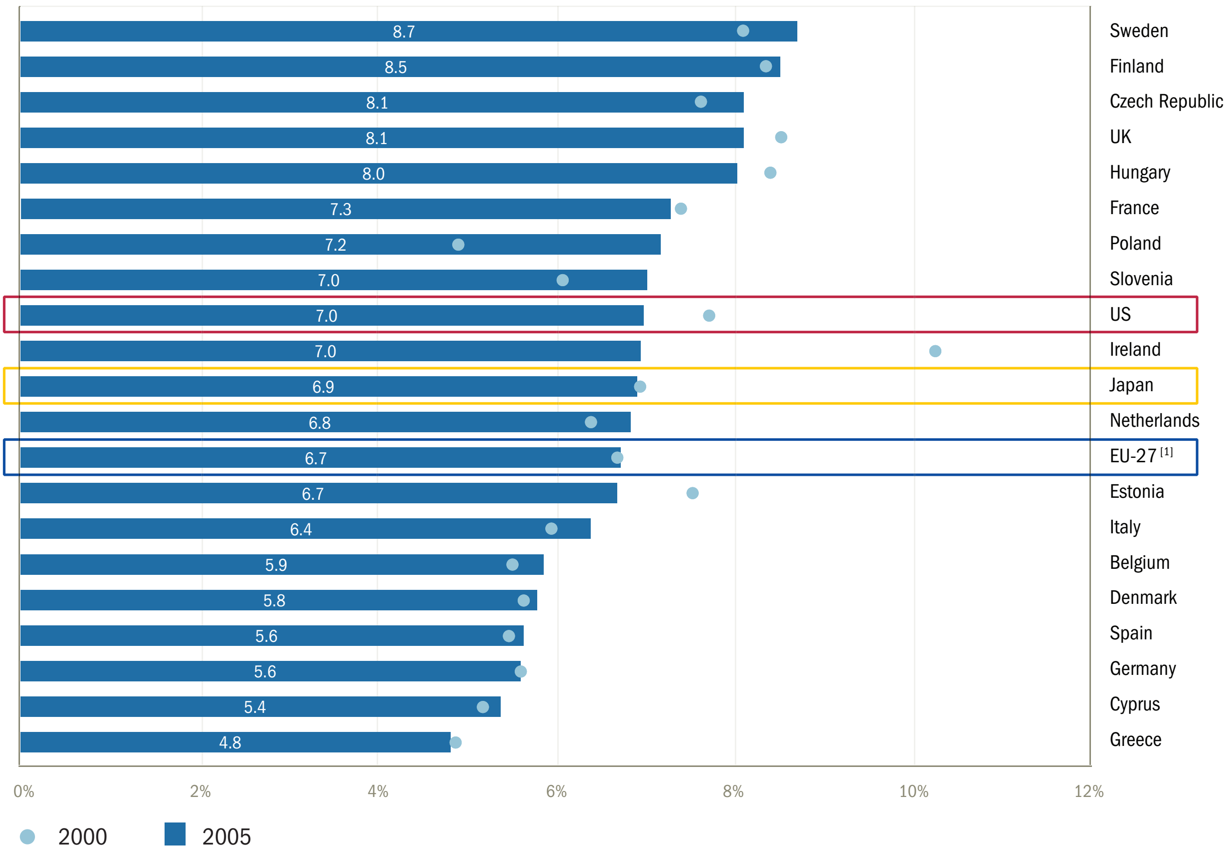
[103] In the 2007 edition of Key Figures the share of high-tech value added in total manufacturing value added in the EU-27 amounts to 19 % in 2003. Due to data availability restrictions, this value included all chemicals, in addition to pharmaceuticals. 'Chemicals' other than 'Pharmaceuticals' is classified here as a medium-high-tech sector. Excluding 'Chemicals' value added from high-tech value added leads to a significantly lower share of the latter in total manufacturing value added in the EU (18.4 % in 2000 and 17.9 % in 2005 when 'Chemicals' is included).

Shares of knowledge-intensive high-tech services in total national services are relatively similar and stable in the EU, US and Japan

In the EU the share of value added of manufacturing decreased from 20 % in 1997 to 17 % in 2005, while the share of services grew from 68 % to 72 %. Knowledge-intensive high-tech services (KIS_HT) [104] in particular are an important indicator of the overall knowledge intensity of an economy. The development of KIS_HT is closely linked to the growing specialisation of industries and the need for more specialisation in other services and in manufacturing sectors.

KIS_HT accounted for about 7 % of value added in total services in the EU, the US and Japan (Figure I.3.13). The share of KIS_HT did not change between 2000 and 2005 in the EU and in Japan, while it decreased by about one percentage point in the US. Within the EU, the shares of KIS_HT in total services are also relatively similar, with most countries having shares of between 6-8.5 % of KIS_HT in total services.

FIGURE I.3.13 Value added of knowledge intensive high-tech services as % of total national services value added, 2000 and 2005



Source: DG Research

STC key figures report 2008

Data: EU KLEMS database

Note: [1] Data are not available for the following countries: BG, LV, LT, LU, MT, AT, PT, RO, SK. These countries are not included in the EU-27 aggregate

Two thirds of the workers in EU-27 are employed in services

In 2006, 18.4 % of workers in EU-27 were employed in the manufacturing sector and 66.6 % in services (Figure I.3.14). 15 % were employed in other sectors of the economy, such as 'agriculture, hunting and forestry', 'mining and quarrying', 'electricity, gas and water' and 'construction'. Employment in high-tech manufacturing and in medium-high-tech manufacturing represented 1.3 % and 5.9 % respectively of total employment.

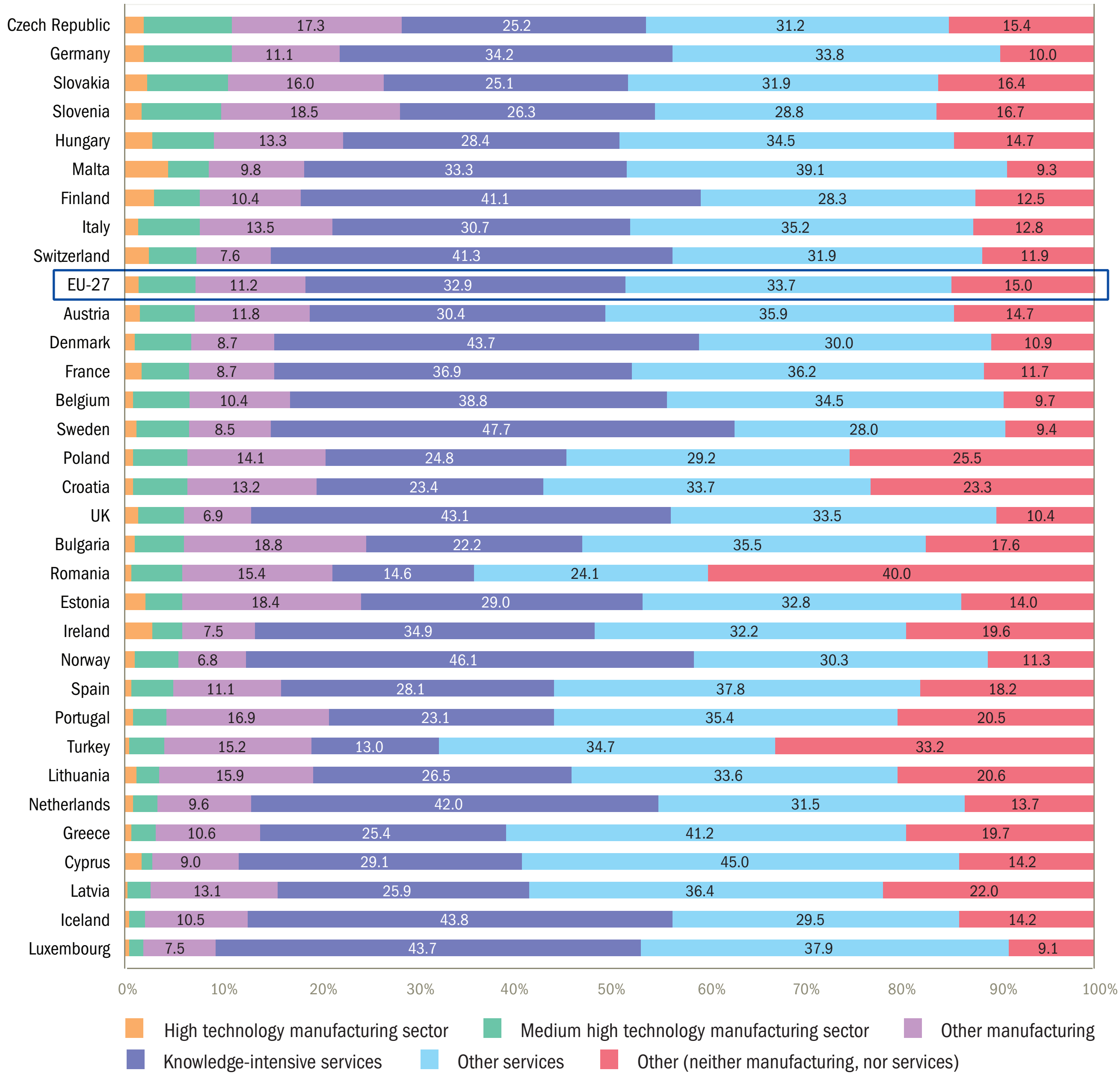
[104] KIS_HT include the following sectors: 'Post and telecommunications', 'Computer and related activities', 'Research and development'.

High-tech and medium-high-tech industries have the largest shares of employment in total manufacturing industry in the Czech Republic, Germany and Slovakia

The share of employment in manufacturing industry is in general larger in new Member States than in old Member States. In all new Member States except Cyprus, Latvia and Malta, manufacturing industry employed more than 20 % of all workers in 2006. Among the old Member States, only Germany and Italy employ more than 20 % of the labour force in manufacturing. Employment in high-tech and medium-high-tech manufacturing exceeded 10 % of total employment only in the Czech Republic, Germany and Slovakia. In the case of Slovakia in particular this seems to be a consequence of foreign firms having located their manufacturing activities in Slovakia.

In contrast, employment in knowledge-intensive services (KIS) [105] is particularly well developed in the Nordic countries, the United Kingdom, the Netherlands, Iceland, Luxembourg and Switzerland, where it accounted for more than 40 % of total employment in 2006.

FIGURE I.3.14 Employment by type — % shares, 2006



Source: DG Research
Data: Eurostat

STC key figures report 2008

[105] KIS groups together a much larger number of service sectors than KIS_HT. In addition to the three service sectors of KIS_HT, KIS includes 'water transport', 'air transport', 'financial intermediation', 'insurance and pension funding', 'activities auxiliary to financial intermediation', 'real estate activities', 'renting of machinery and equipment', 'education', 'health and social work', 'recreational, cultural and sporting activities', 'other business activities'.

Chapter 4. Attractiveness of the ERA and the integration of private R&D

An important factor behind a higher degree of integration of national research systems is companies extending their research capacities outside national borders by investing in foreign research. An international company will often have research centres in several countries, with each centre fulfilling a particular role in the R&D strategy of the company [106]. Consequently, a higher degree of integration of research systems, as a result of for example the ERA, would usually result in higher levels of trans-border funding of R&D. Furthermore, the foreign funding would be expected to flow to geographical areas which have the most attractive research systems. Transnational funding of research can therefore be used as an indicator of the integration of research systems as well as an indicator of the attractiveness of a country as a location for research.

This chapter analyses the attractiveness of the ERA as a location for R&D investment and the integration of private R&D in the ERA, using data on funding and funding flows. Other indicators based on bibliometrics and patents are examined in Part II.

MAIN FINDINGS

The EU remains an attractive location for R&D investment by US firms which invested 20 times more in R&D in the EU than in R&D in China in 2005. Moreover, in the period 2003-2005 the gap between EU-15 R&D spending in the US and US R&D spending in EU-15 in the US decreased by over a half.

In a number of EU Member States, business R&D performed by foreign affiliates of parent companies from other EU Member States and EFTA countries has reached a high level. This is an indication of a relatively high level of integration of the private sector in the European Research Area.

4.1 Is the EU attracting foreign funding of research?

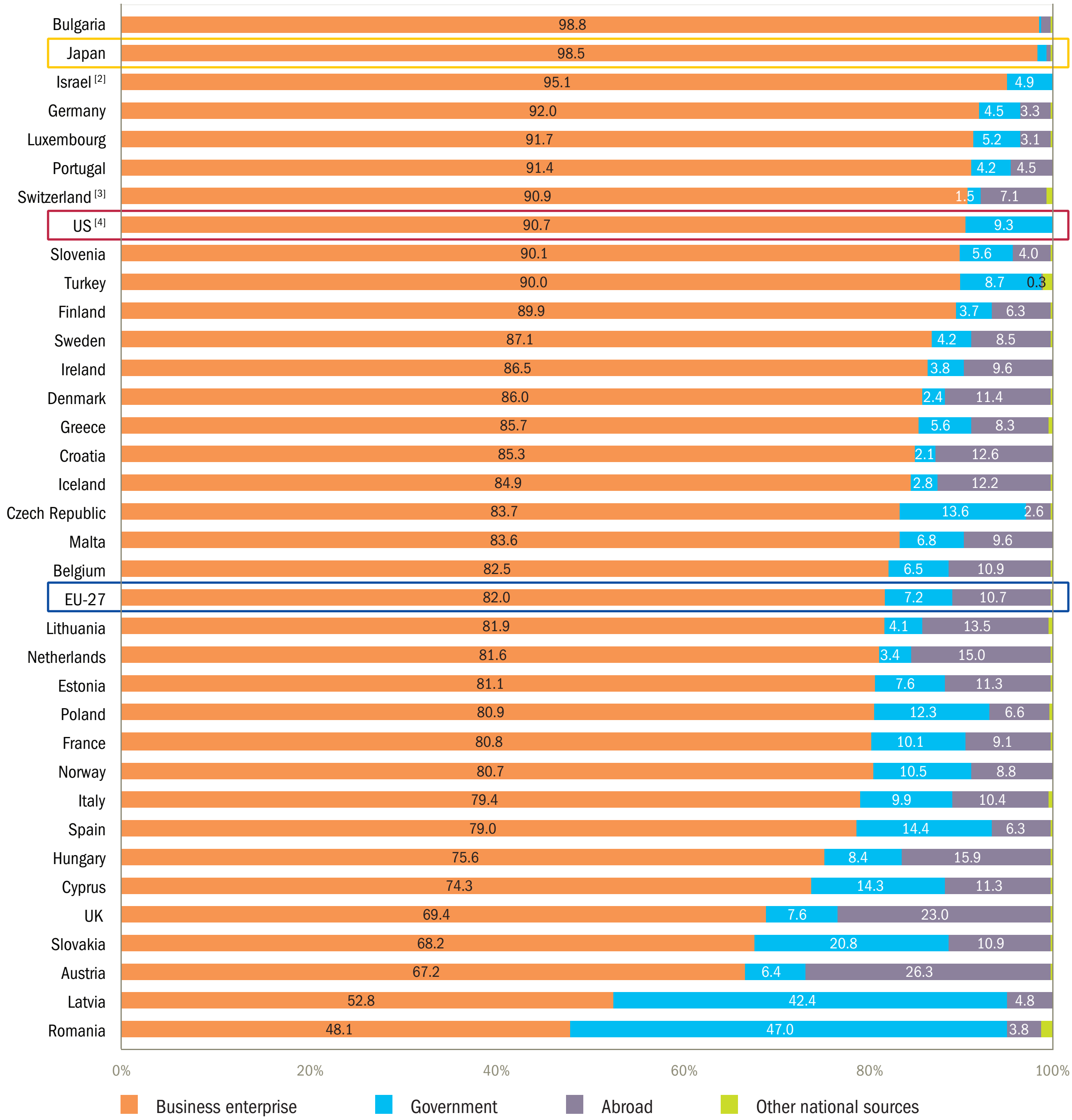
Funding from abroad is an important and growing source of funding for business R&D in the ERA

In all countries, the (domestic) business enterprise sector finances the largest part of business R&D expenditure. However, in the large majority of ERA countries, 'abroad' (private business, public institutions and international organisations) is an important and growing source of funding for business R&D [107]. The financing of business enterprise R&D from abroad primarily refers to financing by other business enterprises, notably by other multinational enterprises. In EU-27, business R&D financed from abroad represented on average almost 11 % of total business R&D in 2006 (Figure I.4.1) compared to 8.8 % in 2000. Within the EU, more than 20 % of business R&D in the United Kingdom and Austria is financed from abroad. Funding from abroad is also important in Hungary, the Netherlands, Lithuania, Denmark and Estonia. It is not possible at the moment to distinguish between funds coming from abroad outside the EU and funds coming from abroad within the EU.

[106] The decision to allocate R&D activities abroad has essentially two economic motivations: the need to adapt products and processes to host markets (also called 'asset-exploiting' strategies) and the need to acquire new knowledge assets ('asset-seeking' strategies). Aggregates related to R&D activities of foreign affiliates presented in this chapter cannot make a distinction between these two strategies. However, in both cases the new research capacity will be focused on fulfilling a particular function within a company's research capacity.

[107] In contrast to ERA countries, almost no business R&D in Japan is financed from abroad. As for the US, a distinction between the financing of R&D by foreign and domestic companies is not made, so that the 'abroad' source of funds is de facto included in the business enterprise sector. It is therefore not possible to compare the EU to the US in this regard.

FIGURE I.4.1 BERD by main sources of funds (%), 2006 [1]



Source: DG Research
Data: Eurostat, OECD
Notes: [1] NL: 2003; AT, CH: 2004; BG, DK, EL, FR, CY, LU, PT, SE, EU-27, IS, IL: 2005; IT: 2007
[2] IL: Defence is not included
[3] CH: Government refers to federal or central government expenditure only
[4] US: Most or all capital expenditure is not included; Abroad is included in business enterprise
[5] China is not included because the sum of the sectors is not equal to 100 %

STC key figures report 2008

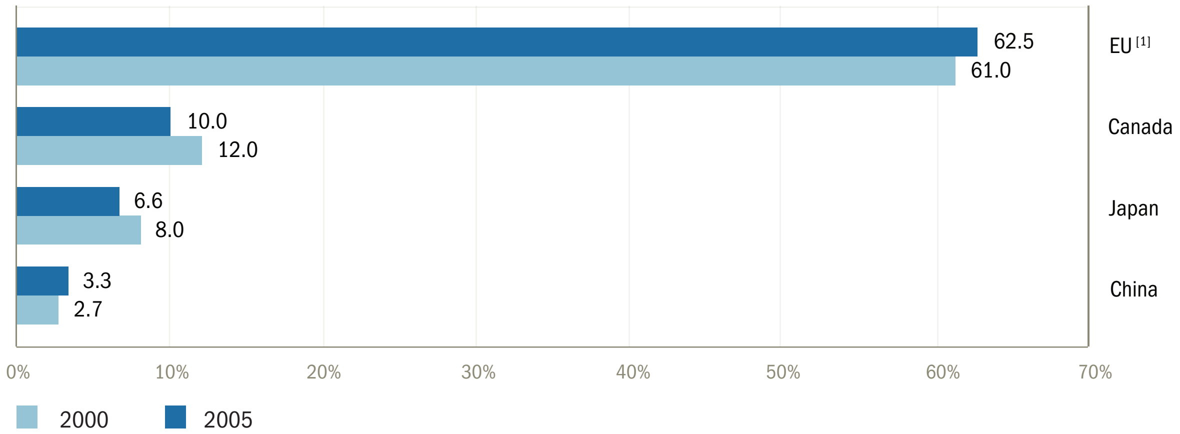
EU Member States remain highly attractive locations for R&D investment by US firms

As seen from Figure I.4.2, the EU is still by far the largest recipient of R&D investment by affiliates of US parent companies [108]. In contrast to the period 1995-2001, when the EU share of foreign US R&D investment dropped by almost 10 percentage points (from 70.4 % to 61 %) [109], the EU share remained stable between 2000 and 2005. Canada and Japan were the next largest recipients, whereas China only received 3.3 % of US investments in 2005.

[108] As noted in section 4.2 below, R&D performed by foreign affiliates may be financed from the income generated by the foreign affiliates, in which case R&D by foreign affiliates does not involve inflow of investment from abroad (the US in this particular case).

[109] OECD, The internationalisation of business R&D: evidence, impacts and implications, DSTI/STP(2007)28, October 2007.

FIGURE I.4.2 R&D expenditure of affiliates of US parent companies abroad in the four main countries or zones of destination (as % of total)

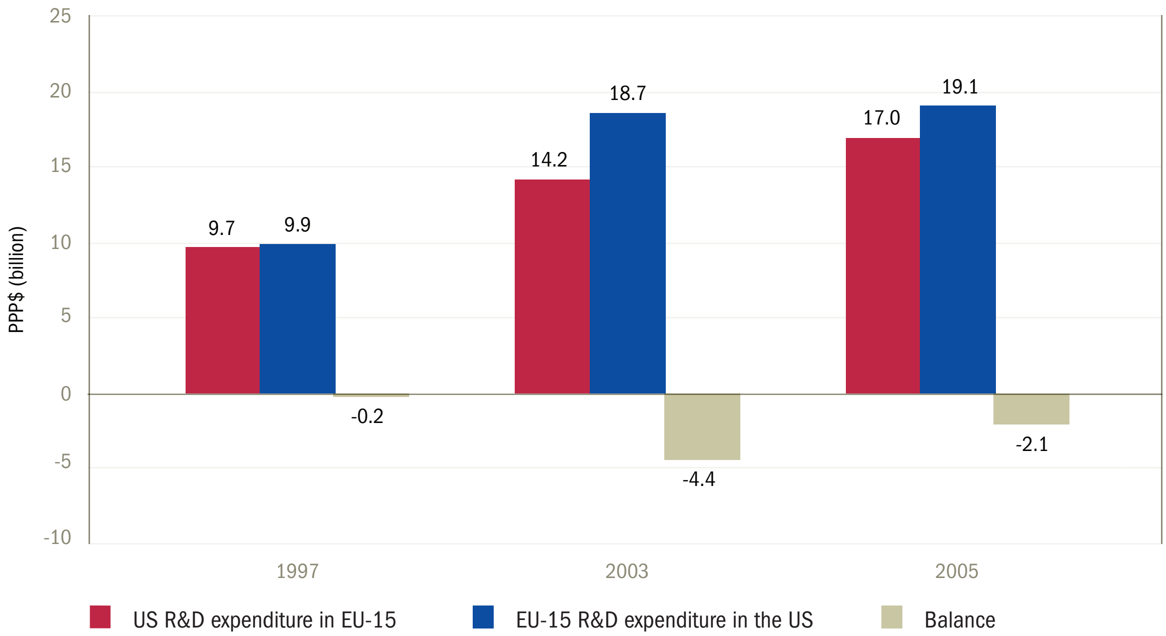


Source: DG Research
Data: OECD (Activity of Foreign Affiliates database)
Note: [1] 2000: EU-15; 2005: EU-25

STC key figures report 2008

Figure I.4.3. indicates a similar strengthening of the attractiveness of the EU Member States for R&D investment. The gap in R&D expenditure flows between EU-15 and the US decreased from PPP$ 4.4 billion in 2003 to PPP$ 2.1 billion in 2005.

FIGURE I.4.3 R&D expenditure flows between EU-15 and the US (billion PPP$), 1997, 2003 and 2005



Source: DG Research
Data: OECD (Activities of Foreign Affiliates database)

STC key figures report 2008

However, the situation could change rapidly. In a 2005 survey of multinational enterprises [110], China was considered the most attractive foreign R&D location by more than 60 % of the respondents, followed by the US (40 %), India (30 %), Japan (14 %), the United Kingdom (13 %), France (9 %), and Germany (6 %). Central-Eastern European countries did not appear as attractive locations for foreign R&D in this survey. Given their current dynamic development, it is not unlikely that China and other Asian countries will become more attractive as destinations for foreign investment in R&D in the future.

In conclusion, the EU remains an attractive location for R&D investment by US firms. However, some areas of the EU are more attractive than others in this regard. The emerging economies in other parts of the world are likely to attract more foreign R&D investment in the future.

[110] UNCTAD, World Investment Report. Transnational Corporations and the Internationalisation of R&D, 2005, UN, New-York and Geneva.

4.2 Is the private sector moving towards increased integration across ERA countries?

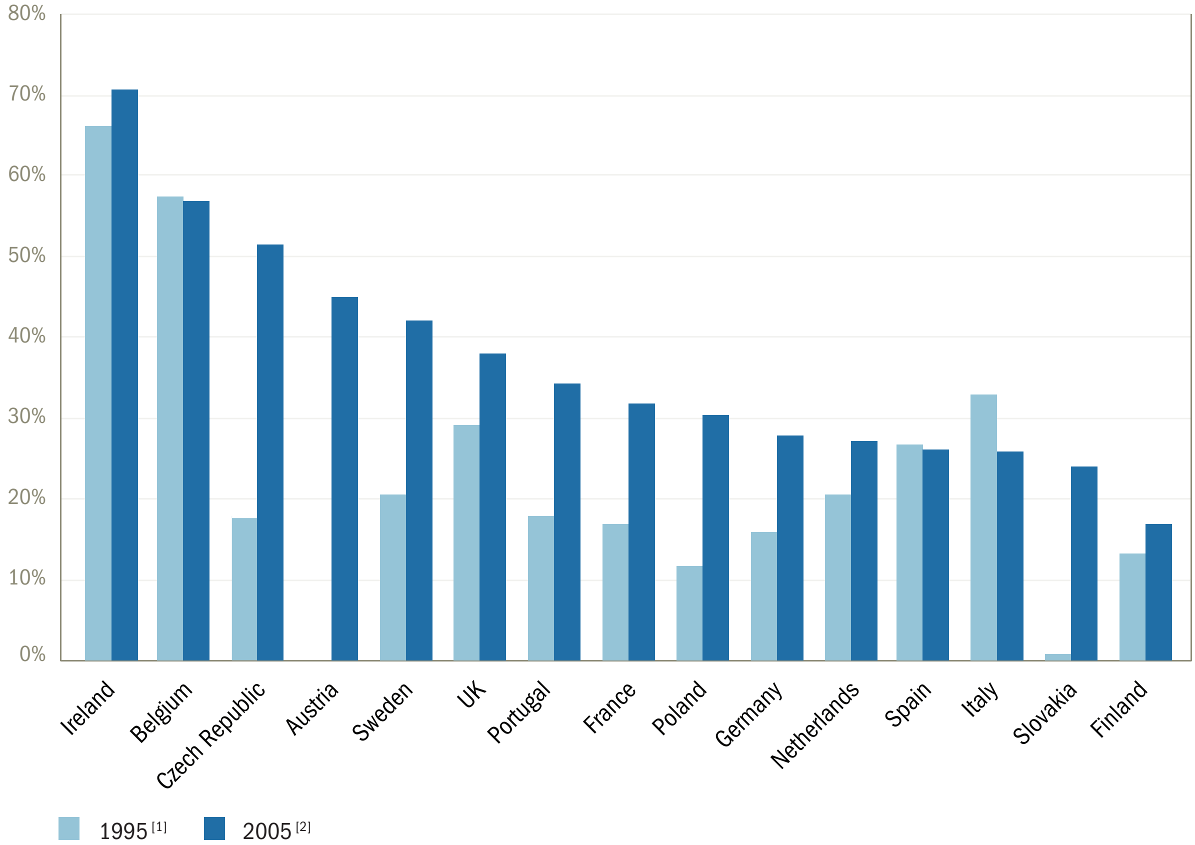
In this section the integration of business R&D across ERA countries is examined from the perspective of expenditure and funding. Co-patenting activities and cross-border ownership of patents (domestic ownership of foreign patents, foreign ownership of domestic patents) are analysed in Part II, Chapter 5, where it is shown in particular that the origin of foreign ownership of patents invented in ERA countries is largely intra-ERA, i.e. companies from ERA countries are to a large extent the owners of inventions made in other ERA countries.

Business R&D expenditure in Member States relies to a large extent on affiliates of foreign companies

The share of foreign affiliates in total business R&D expenditure is even higher than the share of business R&D funded from abroad. This is due to the fact that R&D performed by a foreign affiliate can be financed by its own funds, in which case these funds are not considered as new foreign direct investment [111].

In almost all EU Member States for which data are available, the share of affiliates under foreign control in total business sector R&D expenditure has substantially increased between 1995 and 2005 (Figure I.4.4). In Ireland this share exceeded 60 % in 2005 and was above 40 % in the Czech Republic, Belgium, Austria and Sweden. Slovakia and Finland are the only EU Member States where R&D expenditure by foreign affiliates was less than 25 % of R&D expenditure by business enterprise.

FIGURE I.4.4 R&D expenditure by foreign affiliates, 1995 and 2005 as % of R&D expenditure by business enterprise



Source: DG Research
Data: OECD (Activity of Foreign Affiliates database)
Notes: [1] CZ: 1996; NL, FI: 1997; PT: 1999; PL: 2000; IT: 2001, BE: 2003
[2] NL: 2003; IT, AT: 2004, UK: 2006

STC key figures report 2008

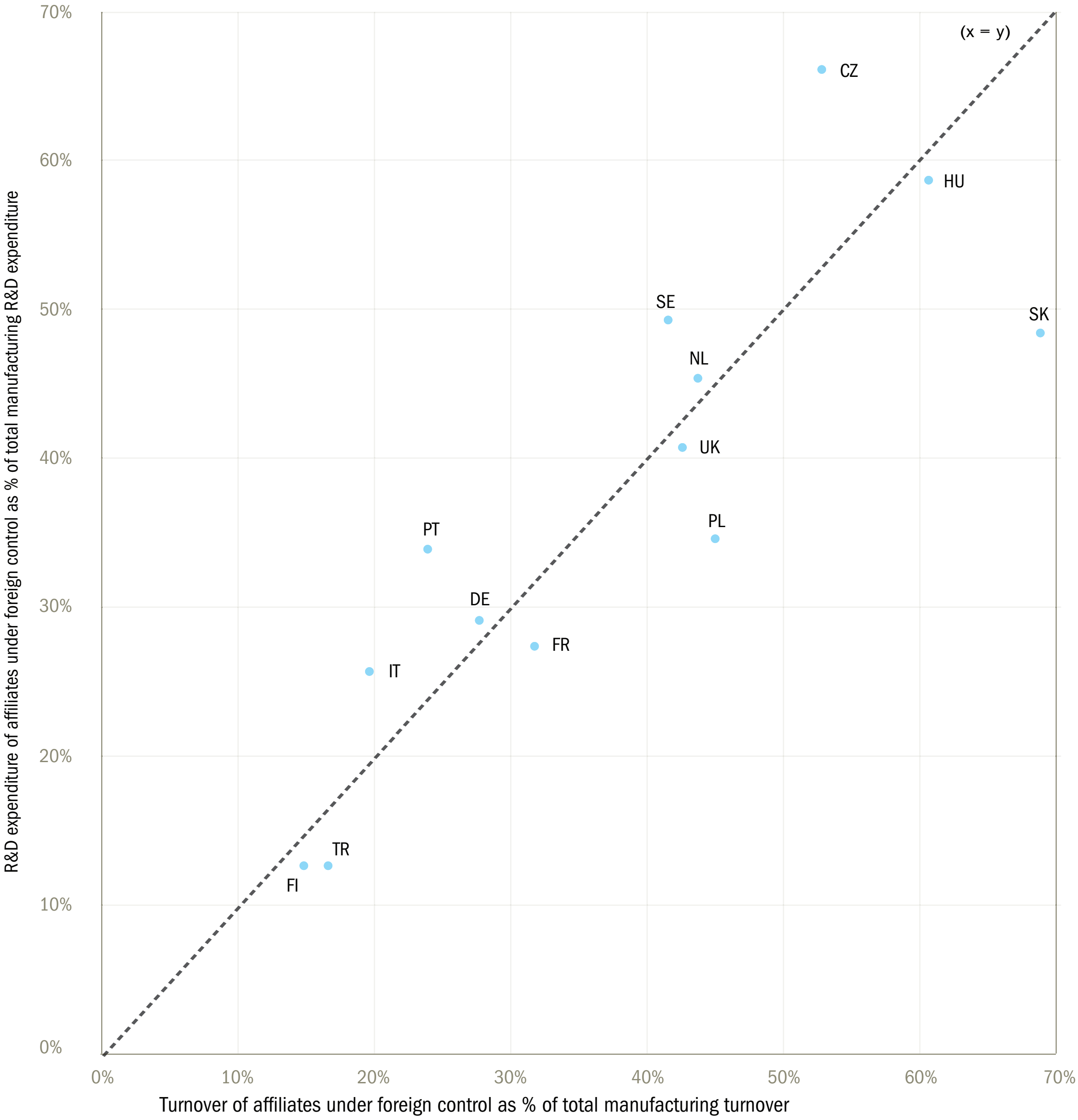
[111] Ireland and the Czech Republic are two illustrative cases in this regard since, in these two countries, 'abroad' finances less than 10 % and 3 % of business R&D respectively (see Figure I.4.1), whereas R&D expenditure by foreign affiliates represents more than 70 % and 50 % of business R&D expenditures in these countries (see Figure I.4.4).

In some EU Member States (Ireland and Belgium), foreign affiliates are the main business R&D performers. In the majority of EU Member States, 20 % to 50 % of domestic business R&D is performed by foreign affiliates.

Research intensity of foreign affiliates and domestic firms

In most Member States for which data are available, the share of R&D expenditure of foreign manufacturing companies in total manufacturing R&D mirrors the share of turnover of foreign manufacturing companies in total manufacturing turnover (Figure I.4.5). As shown in Figure I.4.5, in 2005 foreign firms contributed less to R&D than to production, particularly in Slovenia and Poland. This indicates that foreign affiliates in Slovakia and Poland are focused on manufacturing. In contrast, the Czech Republic appears to be more attractive for R&D than for production activities.

FIGURE I.4.5 Shares of turnover and R&D expenditure of affiliates under foreign control in total manufacturing turnover and total manufacturing R&D expenditure, 2005 [1]

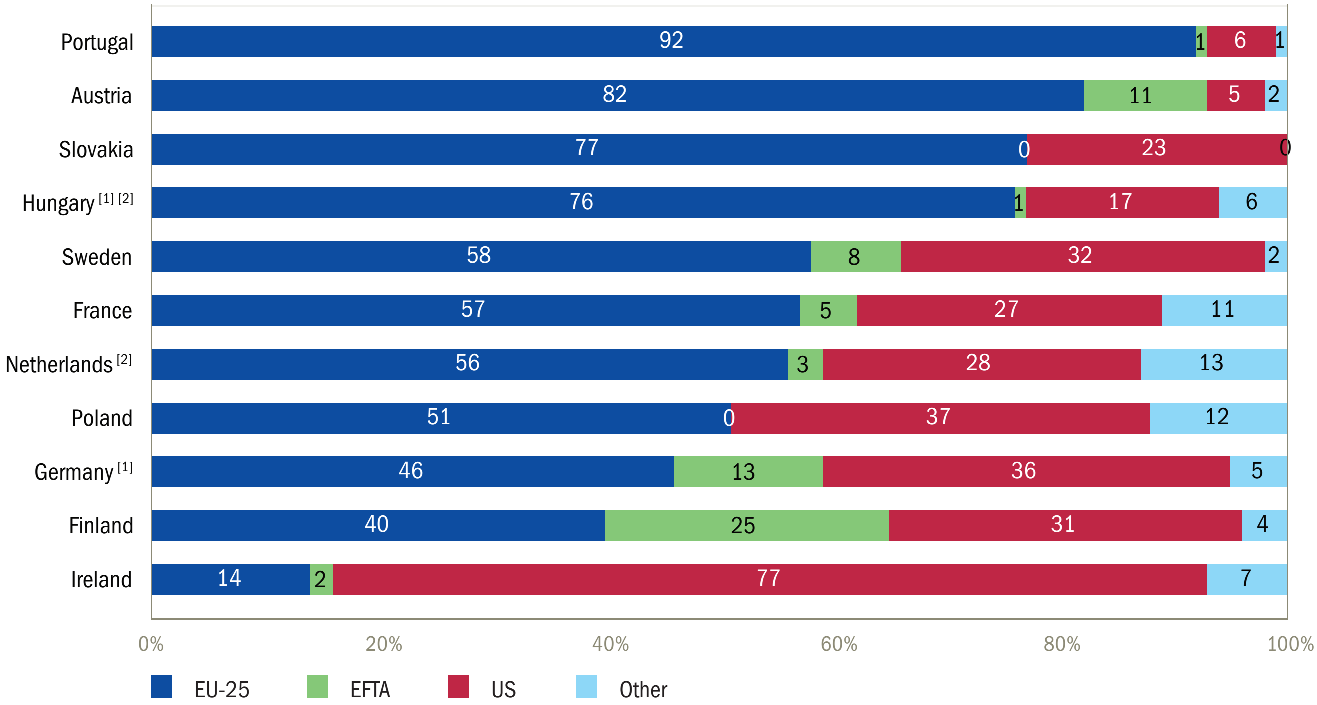


Source: DG Research
Data: OECD (Activities of Foreign Affiliates database)
Note: [1] TR: 2000; PT: 2003; FR, IT, HU, NL, SK: 2004

Intra-ERA foreign R&D investments prevail

Intra-ERA foreign expenditure contributes significantly to the high shares of foreign R&D expenditure. In all ERA countries for which data are available, with the exception of Ireland, more than 50 % of R&D expenditure by foreign affiliates in the manufacturing sector is from affiliates of an EU or EFTA parent company (Figure I.4.6). In Ireland, US firms are by far the largest foreign R&D investors.

FIGURE I.4.6 Inward R&D investment in manufacturing — % shares by investing region (EU-25, EFTA, US, Other), 2005



Source: DG Research
Data: OECD
Notes: [1] DE, HU: The values for EU refer to EU-15
[2] HU, NL: 2004

STC key figures report 2008

In conclusion, the data show that, in individual Member States, private sector R&D is to a large extent undertaken by foreign firms. This is an indication that investment in private sector R&D in EU Member States forms an integral part of the research strategies of international firms. In the EU Member States for which data are available, the main origin of foreign direct investment in R&D is intra-ERA.

BOX 6: R&D INTERNATIONALISATION IN ITALY: NEW INDICATORS BY ISTAT [112]

In 2006, a number of new indicators on the internationalisation of R&D have been proposed by the Italian Statistical Institute (ISTAT) [113]. However, the data required to build these indicators are not systematically collected in all countries as yet.

Overall Propensity

This is calculated as the rate of R&D activities owned by domestic firms abroad in total domestic business R&D activities. It therefore compares the business R&D activities in the home country to R&D activities performed abroad by firms from this country. It is equal to 1 if R&D activities are equally divided between 'abroad' and at home. An overall propensity close to zero (2.8 %) shows that Italian firms do not tend to invest much in R&D activities abroad.

Country Propensity

This is calculated as the rate of R&D activities owned by domestic firms in country X in total R&D activities owned by domestic firms abroad. It gives the geographical breakdown of R&D activities performed by domestic firms abroad. In 2003, about 20 % of R&D expenditure by Italian firms abroad was executed in Germany, 7.4 % in Switzerland, 5.2 % in the United Kingdom and 0.6 % in Belgium.

Overall Permeability

This is calculated as the rate of domestic R&D activities owned by foreign parent companies in total domestic R&D activities. It is the mirror of the overall propensity and estimates the capacity of the national R&D system to receive foreign R&D investment. In 2003, in Italy almost one third of business R&D expenditure came from foreign affiliates. This decreased to 26 % in 2005. The permeability of Italy in the chemical industry (NACE 24) is almost twice as high (58.9 %) as the overall permeability of Italy. This particular sector in Italy attracts R&D investment from abroad.

Country Penetration in Italy

This is calculated as the rate of R&D activities owned by parent companies resident in country X in total inward R&D activities. It is a mirror of the country's potential and gives the geographical breakdown of inward investment. In 2003, 10.5 % of R&D expenditure by foreign affiliates in Italy came from German firms, 8.6 % from United Kingdom firms, and 3.6 % from Belgian firms.

Bilateral Integration [114]

This estimates the level of interdependence between two national systems, with respect to the levels of all other systems investing in these two countries. It is equal to 0 if at least one of the two countries does not invest in the other; it is equal to 1 if both countries are the only foreign investor countries in the other. Italy has its highest level of integration with Germany (0.039) and, by comparison, has lower levels of integration with the United Kingdom (0.012) and Sweden (0.003).

Bilateral integration of the United Kingdom and the US is very high (0.377).

[112] Italian National Institute of Statistics.

[113] Cozza C. and Perani G., 'A proposal for developing new indicators on the internationalisation of R&D by matching micro-data from national R&D surveys', International Conference on Indicators on STI', Lugano, 16-17 November 2007.

[114] This is calculated as the rate of the reciprocal R&D activities in countries A and B, weighted by their total foreign R&D investment, in the sum of the reciprocal R&D activities in countries A and B, weighted by the sum of their total foreign R&D investment.

Part II

Integration of the European Research Area

Part II examines the state-of-the-art and progress towards the European Research Area (ERA). It presents for the first time indicators to measure transnational integration of research in its various dimensions. What is the status of the integration of research in Europe? What are the trends in terms of integration? Are we making progress since the ERA policy was launched in 2000? The findings provide a first step, which can be further developed and elaborated in coming years as means of analysing whether integration contributes to the performance and efficiency of the EU and to economic competitiveness and growth. However, the data produced in this report are necessarily limited. Additional data might shed a different light on some of the aspects tackled in the report.

The analysis follows the structure of the six axes in the ERA Green paper, launched by the European Commission in April 2007. This report examines progress on the ERA by analysing available indicators within each of these six areas. It looks first at research institutions, research programme funding and research infrastructures, and subsequently at mobility of researchers, transnational knowledge flows and internationalisation of R&D.

The indicators presented in Part II are different from the ones used in Part I. European and international statistical systems do not yet offer a full coverage of the various dimensions of integration, and in particular indicators related to flows and inter-connectivity. Therefore, the indicators presented in Part II are more experimental: some indicators are proxies rather than definite and they will be further developed in coming years. The data and indicators presented in Part II are the result of a selection from the current available indicators and data at European level.

Given the specific focus on the European Research Area, the graphs and tables cover, as far as available data allow, the 34 countries directly associated with the ERA policy agenda. However, since the statistical data collection system is not fully developed for indicators related to flows and inter-connectivity, many graphs and tables cover only countries for which comparable data are available. When data refer to the EU Member States, generally the term 'EU-27' is used; when data refer to the countries directly associated with the ERA policy agenda [115], the terms 'ERA countries' or 'Europe' are used, depending on the context. Consequently, the term 'non-EU countries' also includes some of the ERA countries, as well as countries outside Europe. When the analysis refers exclusively to countries in other continents, the text uses the term 'countries outside Europe'. One major exception concerns data referring to the Community framework programme. In this context, the term 'third countries' is used, referring to all countries that are not associated with the Community framework programme [116].

[115] The 'ERA countries' include EU-27 Member States, the EFTA countries (Switzerland, Iceland, Liechtenstein and Norway), and Candidate Countries (Croatia, the Former Yugoslav Republic of Macedonia, and Turkey). Israel is also included in all relevant graphs and tables when comparable data are available.

[116] Currently 11 countries are associated with FP7 (Albania, Croatia, the Former Yugoslav Republic of Macedonia, Montenegro, Serbia, Turkey, Iceland, Liechtenstein, Norway, Israel, and Switzerland).

Chapter 1. Strengthening universities

The European Commission communication of January 2000 'Towards a European Research Area' [117] identified the need to promote **more world-level centres of excellence in Europe**. In 2006, the European Commission presented a communication on the enhancement of the **modernisation agenda of universities in Europe** [118]. This Communication recommends that universities should be strengthened and that the funding of universities should be made more effective. One year later, the Green Paper on new perspectives on the ERA [119] reconfirmed and expanded the policy objectives for research institutions in Europe. Universities should act as fully autonomous and accountable bodies [120] able to develop research strategies based on excellence, concentration and specialisation, to diversify their sources of funding and to reinforce their links with the business sector and society at large, i.e, through public/private partnerships. This requires appropriate reforms at national level, with less state regulation, increased investment in higher education institutions, but also new appropriate research funding schemes and incentives. The policy also favours diversified institutions **embedded** in their socio-economic context and at the same time **networked and linked to other university institutions across Europe**. A 'web' of research and innovation clusters, specialised and with a critical mass, should be fostered.

This chapter will present available quantifiable evidence on progress in these policy objectives for **universities**: strengthening and linking universities. However, the ERA policy focuses not only on universities but also on **non-university research performing organisations**, under the concept of 'research institutions'. These two kinds of institutions are very different in their objectives and nature. The analysis in this edition focuses mainly on universities due to data availability limitations. The only indicator presented for which data on all research-performing organisations are available is on collaboration between participants in the EC research framework programmes (FP5 and FP6). It is expected that in the coming years comparable data will be available at European level also on non-university research-performing organisations.

The chapter is structured around two main questions: What is the situation for universities in Europe in terms of scientific output, funding and reforms? What is the configuration of transnational links between universities in Europe?

MAIN FINDINGS

Compared to the US, Europe has fewer universities that act as major research centres of large scientific size and impact. However, European countries are reforming their national research systems, increasing the share of public research expenditure allocated to higher education institutions, switching funding models of universities to more competitive and output-based funding and, in some countries, increasing institutional autonomy for the universities. At the same time, research institutions including universities are forging links between each other in transnational networks. Research institutions in most European countries form part of these networks but there is a centre and a periphery. Some indicators show that universities in Western and Northern Europe, and in particular in a limited number of regions, have the highest involvement in integrated networks.

[117] Communication of the European Commission, 'Towards a European Research Area', COM (2000) 8, 18.01.2000.
[118] Communication of the European Commission, 'Delivering on the modernisation agenda for universities: education, research and innovation', COM (2006) 208 final, 10.05.2006.
[119] European Commission Green Paper, 'Inventing our future together. The European Research Area: New Perspectives', Green Paper 04.04.2007.
[120] In 2008, an expert group advising the European Commission on how to strengthen universities in Europe identified four areas where further action is needed: funding and autonomy; governance; accountability and performance; and collaboration and partnerships.(Report of the ERA Expert Group, 'Strengthening research institutions with a focus on university-based research', 2008, EUR 23322 EN).

1.1 What is the situation for universities in Europe in terms of scientific output, funding and reforms?

This section presents data on the scientific output of Europe's most research-active universities measured by bibliometric data. The population is defined as the higher education institutions across Europe that have published more than 5,000 articles in SCI journals during 1997-2004, or on average more than 625 papers per year during this time period [121]. A total of 171 higher education institutions in Europe fulfil these criteria. This population is compared to the top US universities in terms of citation impact of their scientific publications.

The US has more universities that act as poles of scientific reference

Figure II.1.1 shows the dispersion of the citation impact of research of the most active research universities across countries normalised by sub-fields [122]. It should be borne in mind that research systems differ between the European countries and also differ with respect to the overall weight of universities in scientific production. France has the lowest percentage of scientific papers stemming from universities at 51 %; Sweden and Turkey have the highest scores at around 90 %. On average, universities in Europe produce 75 % of total scientific papers. And the set of most active European research universities analysed here accounts for 75 % of total European university scientific output.

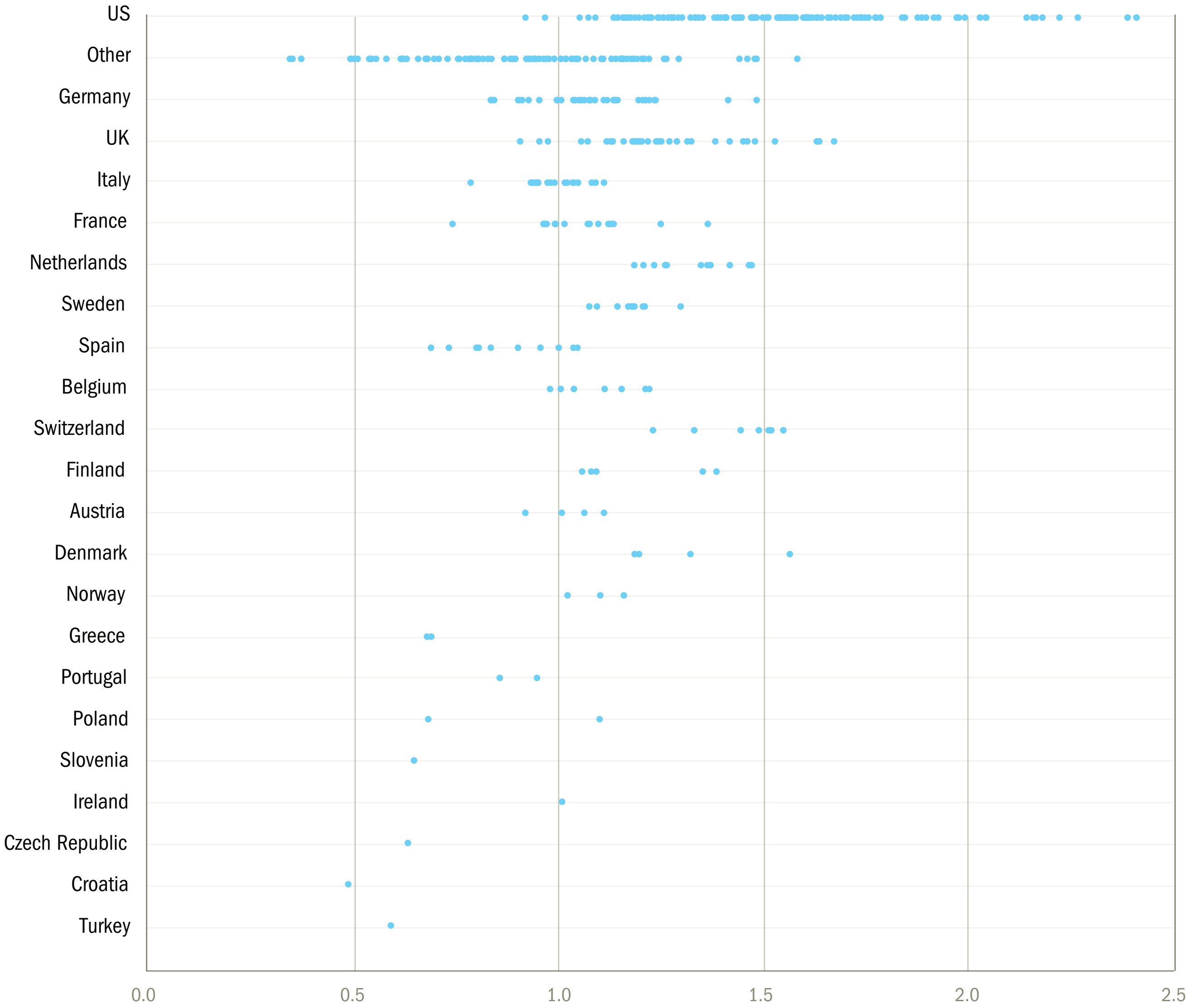
Each dot on Figure II.1.1. represents one research university. Universities in the US and in other countries (mainly from Australia, Canada, Asia and Africa) are included on the graph as a benchmark. The main finding is that, compared to all European countries taken together, the US does not have a significantly higher number of universities with a normalised citation impact above 1, but the citation impact for these US universities is much higher than for universities in Europe [123]. In other words, when compared to Europe, the US has a higher number of universities that act as poles of scientific reference.

[121] The analyses are based on data extracted from the Science Citation Index (SCI) and related Citation Indices on CD-Rom, produced by Thomson Scientific (formerly Institute for Scientific Information) and covering some 7,000 international journals in all domains of scholarship, with a good-to-excellent coverage especially in basic science. For more details on the SCI and its fields coverage, see MOED, H. F. (2005), 'Citation Analysis and Research Evaluation', (Information Science and Knowledge Management 9), Springer, Dordrecht, 2005, p. 119-136. CWTS, using the same data produced within the framework of the ASSIS project, presents data for the top 100 European Universities: a ranking by size, i.e. by number of publications (P). http://www.cwts.nl/cwts/LR_yellow_table.html, based on field-normalised average impact (CPP/FCSm). http://www.cwts.nl/cwts/LR_green_table.html. The main weakness of the scientometrics data presented in this section stems from the fact that CWTS has not performed the identification of publications in collaboration with the concerned institutions, but by using an automated procedure.

[122] Normalisation can also be based on journals (journal-normalised citation score). The probability of an author being cited depends partly on the name of the journal in which he/she is published and also on the specific sub-field in which he/she is published. The journal-related bias may influence slightly the position of the points in Figure II.1.1. but not the overall findings. Normalisation by sub-field is the most commonly used methodology at this time. The population of research universities in Figure II.1.1 is based on the number of top research universities in each country. The number of top research universities per country varies between 35 in Germany and 1 in Ireland and the Czech Republic. For further methodological specifications on field-normalised citation score, see Methodological Annex.

[123] These findings are subject to a possible bias, the co-called 'US citation bias' linked to factors of a cultural and linguistic nature.

FIGURE II.1.1 The most active research universities — normalised citation impact by country, 1997-2004



Source: DG Research
Data: Thomson Scientific/CWTS

STC key figures report 2008

Expanding the population to the 386 most active research universities in the world, we find that 45 % are located in Europe and 32 % in the US, but of the 25 most active research universities in the world, 80 % are located in the US [124]. The 2007 Shanghai University ranking, using different criteria, tells a similar story: of the top 500 universities in the world, 41 % are in Europe and 33 % in the US. Of the top 100 universities in the world, 33 are in Europe; of the top 25 only 4 are in Europe [125].

The universities in Europe with the highest citation impact are located in the United Kingdom, the Netherlands, Switzerland and Germany

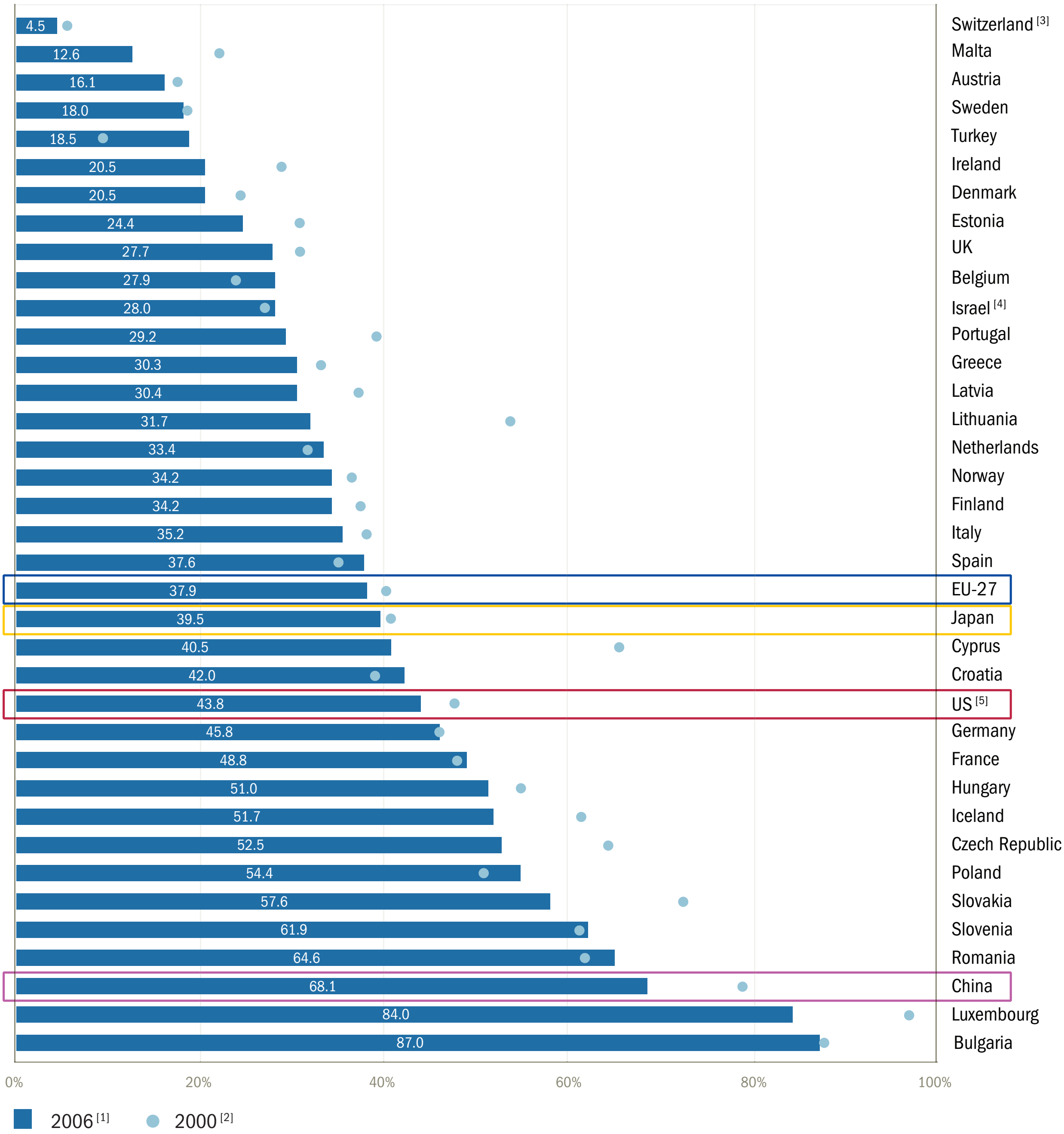
When considering the citation impact of the top universities in Europe, three groups of countries can be distinguished: countries with a relatively high number of high-impact universities (Germany, the United Kingdom, Italy, France and the Netherlands), countries with top universities above world average (France, Sweden and Norway) and countries where the best universities have a lower citation impact than the world average (mainly countries from Southern and Eastern Europe) (Figure II.1.1).

[124] CWTS/Thomson Scientific. This result is the combined effect of size of the university and the scientific productivity of its researchers. However, current data do not allow any quantification of the respective weight of these variables.
[125] The 2007 Shanghai ranking uses various indicators based on the following criteria: quality of education, quality of faculty, research output, size of institution.

The higher education sector accounts for an increasing share of public expenditure on R&D in most European countries

Figure II.1.2. shows the increased importance of the higher education sector [126]. The share of government intramural expenditure on R&D in total public R&D expenditure is lower in 2006 than in 2000 in a majority of countries, whereas the share of higher education expenditure on R&D is higher. Figure II.1.2 also illustrates the dominance of the government sector in the public research base of many Eastern European countries, while in the older EU Member States spending on public research is focused more on higher education institutions.

FIGURE II.1.2 Share of government intramural expenditure on R&D (GOVERD) in total public sector expenditure on R&D (GOVERD + HERD)



Source: DG Research
Data: Eurostat, OECD
Notes: [1] IT, CH: 2004; PT, IS: 2005; IE, FI: 2007
[2] EL, UK, NO: 2001; DK, MT, AT, HR: 2002; FR, HU: 2004; SE: 2005
[3] CH: Federal or central government expenditure only
[4] IL: Defence is not included
[5] US: Federal or central government expenditure only

STC key figures report 2008

[126] See also Part I, Chapter 1.3.

At the national level, a growing number of EU Member States are implementing changes to their higher education systems

Recent economic analysis has indicated that an increase in higher education expenditure has a higher impact on performance (measured by patents) if the universities are more autonomous. The study also indicates a positive correspondence between reforms of universities (in particular their level of autonomy as regards governance and accountability) and the research performance of the universities [127].

The position of universities in public research is changing in many European countries. A study on the reform of universities in European Member States illustrates the depth of the reforms that are reshaping the higher education system across Europe [128]. Although the process is rather uneven, five trends can be identified: most European Member States have implemented national legislation changes aimed at providing universities with more institutional autonomy; European countries have become more attentive to excellence and international recognition of their universities; Member States have made efforts to foster collaboration between universities and business enterprise; Member States have acknowledged the importance of encouraging the careers of researchers; and there is a trend towards an increase in competitive funding as opposed to block funding [129].

The funding models for university research are changing

Among the various general patterns in the higher education sector highlighted at European level, the available data show that third-party funding (outside the core public budget) of higher education institutions and their research activities is increasing [130]. However, strong differences emerge between individual institutions, with the share of external contracts ranging from more than 25 % of the total budget in some of the research universities to less than 10 % in other universities [131].

Table II.1.1 illustrates that in several countries an important part of funding is now channelled through competitive research contracts and other contract research. This is based on information collected in 2006 inside the ERAWATCH network and attempts to give a brief impression of the relative importance of the various funding types for different countries [132].

[127] P. Aghion, M. Dewatripont, C. Hoxby, A. Mas-Colell and A. Sapir, 'Why reform Europe's universities?' Bruegel policy brief 2007/04.

[128] See study by Technopolis, Policy note 1 2008, ERAWATCH, tables 'Key recent reforms concerning Universities' and 'Key Recent Reforms in Public Research Centres'.

[129] For more complete country list, see Statistical Annex (http://ec.europa.eu/research/era).

[130] See also Part II, chapter 2.1. Statistical studies have been made by Lepori B., van den Besselaar P., Dinges M., van der Meulen B., Potì B., Reale E., Slipersaeter S., Theves J.(2007), Comparing the evolution of national research policies: what pattern of change? Science and Public Policy vol. 34 no 6, July. 372-388.
Lepori B., van den Besselaar P., Dinges M., van der Meulen B., Potì B., Reale E., Slipersaeter S., Theves J., (2007a), Indicators for Comparative Analysis of Public Project Funding. Concepts, Implementation and Evaluation, Research Evaluation, 16(4), 243-256.
Benedetto Lepori, Jaan Masso, Julita Jablecka, Karel Sima, Kadri Ukrainski (2008), Comparing the organization of public research funding in Central and Eastern European Countries, presented at the 2008 PRIME indicator conference.

[131] This general trend has also been highlighted in the CHINC study which specifically focuses on the recent changes in university incomes (see the CHINC Project 'Changes in University Incomes: Their Impact on University-Based Research and Innovation', commissioned by DG JRC-IPTS at the end of 2004). This project brought together a consortium of researchers from 11 countries in an effort to collect systematic information on the changes in the European research environment and the research incomes of higher education institutions More specifically, quantitative data was collected for a sample of 117 institutions, and interviews were conducted in 97 institutions of the same group for the period 1995-2003.

[132] Table II.1.1 is indicative and based on a wide number of different data types, quantitative and semi-quantitative. 'Block grant' refers to institutional funding covering aspects of the costs of education and/or research, which in many countries are increasingly tied to past performance. 'National research contracts' refers here to project rather than institutional income, secured by individual university researchers or research groups in competition with their counterparts elsewhere in the national research system. The funds are public and derive from national grant-awarding research councils and scientific cademies. 'Fees' refers to tuition fees paid by students for undergraduate or postgraduate level studies. 'Contract research' refers to income secured by university researchers from non-governmental sources and ranges from contracts won in open competition from non-national research funds, such as the EC research framework programme, to consultancy contracts to carry out empirical research for third parties and charities and the purchase of intellectual property licences by private firms.

TABLE II.1.1 Funding models for universities, 2006

	Block grant	National research contracts	Fees (tuition)	Other contract research
Belgium	HIGH			
Bulgaria	HIGH	LOW		LOW
Czech Republic	HIGH	LOW		
Denmark	LOW	MEDIUM		
Germany	HIGH	MEDIUM	LOW	MEDIUM
Estonia	MEDIUM	MEDIUM		
Ireland	HIGH			
Greece	HIGH	LOW		
Spain	LOW	HIGH		
France	HIGH	LOW		
Italy	MEDIUM	MEDIUM		
Cyprus	MEDIUM	HIGH		
Latvia	MEDIUM	MEDIUM	HIGH	
Lithuania	HIGH			
Luxembourg	HIGH			
Hungary	HIGH			
Malta				
Netherlands	HIGH		LOW	
Austria	HIGH	MEDIUM	LOW	MEDIUM
Poland	MEDIUM	MEDIUM		
Portugal	HIGH	MEDIUM	LOW	
Romania	HIGH	LOW	LOW	LOW
Slovenia	MEDIUM	MEDIUM		
Slovakia	HIGH	MEDIUM		
Finland	MEDIUM	MEDIUM		
Sweden	HIGH	LOW		
UK	HIGH	MEDIUM	MEDIUM	

HIGH MEDIUM LOW

Source: DG Research
Data: ERAWATCH Network

STC key figures report 2008

Table II.1.1 shows that the block grant funding system still appears to be dominant within national systems. However, in all countries, an increase in the share of national research contracts is observed. Moreover, allocation mechanisms for block grant funding are evolving: in most countries block grant funding includes separate teaching and research components, calculated on the basis of different criteria (although universities are free on how they spend this money). Block grant funding for research is changing from a basic formula-based funding of universities to an output-based (quality-based) block funding.

In conclusion, when compared to the US, Europe has fewer universities that act as major reference centres of large scientific size and impact. However, the place of universities in public research is changing in Europe. European countries are directing an increasing part of total public expenditure on R&D to the higher education sector, while at the same time reforming their higher education systems towards more autonomy for universities, a larger share of competition-based funding and more output-based core funding. However, more precise data on this ongoing process are lacking.

1.2 What is the configuration of transnational links between universities in Europe?

This section refers to the term 'links' in a broad sense, but with a focus on transnational links between research institutions. Research institutions can be linked to each other with different objectives, such as research collaboration, institutional partnerships or general communication flows. Furthermore, the links can connect different institutional layers, be more or less formalised, benefit from different funding instruments, and include more or less network structure. Currently European-wide data on links and networks between European universities (or, more widely, research institutions) are not available for most forms of links. The possibilities of compiling Europe-wide data on links at institutional level within strategic partnerships or at the research level by co-publication and co-patenting data at institutional level are being explored, but such data are not yet available. As a first step, this report presents an analysis of transnational collaboration as evidenced by networking co-funded by the EC research framework programmes [133]. Data on transnational communication and research collaboration between universities in Europe, as measured by web-based hyperlinks, are also presented as background reference.

This section focuses on a networking analysis of collaboration between universities in Europe. Data are mainly based on funding from the EC research framework programmes over the period 1994-2006 [134]. The objective is to capture the relational information embedded in network structures. From a network perspective, an organisation is important if it occupies a central position. The concept of centrality is determined by both the number of projects in which a research organisation takes part and the relative position of the partner research organisations in their respective networks. Centrality is a theoretically appropriate measure to identify main actors based on the added value of relational information [135].

The most central positions in research networks co-funded by the framework programmes are located in the United Kingdom, France, Germany and Italy

Figure II.1.3 shows the distribution by country of the 100 most central institutions in FP5 and FP6. It illustrates the central positions of institutions from the United Kingdom, France, Germany and Italy in the FP networks [136].

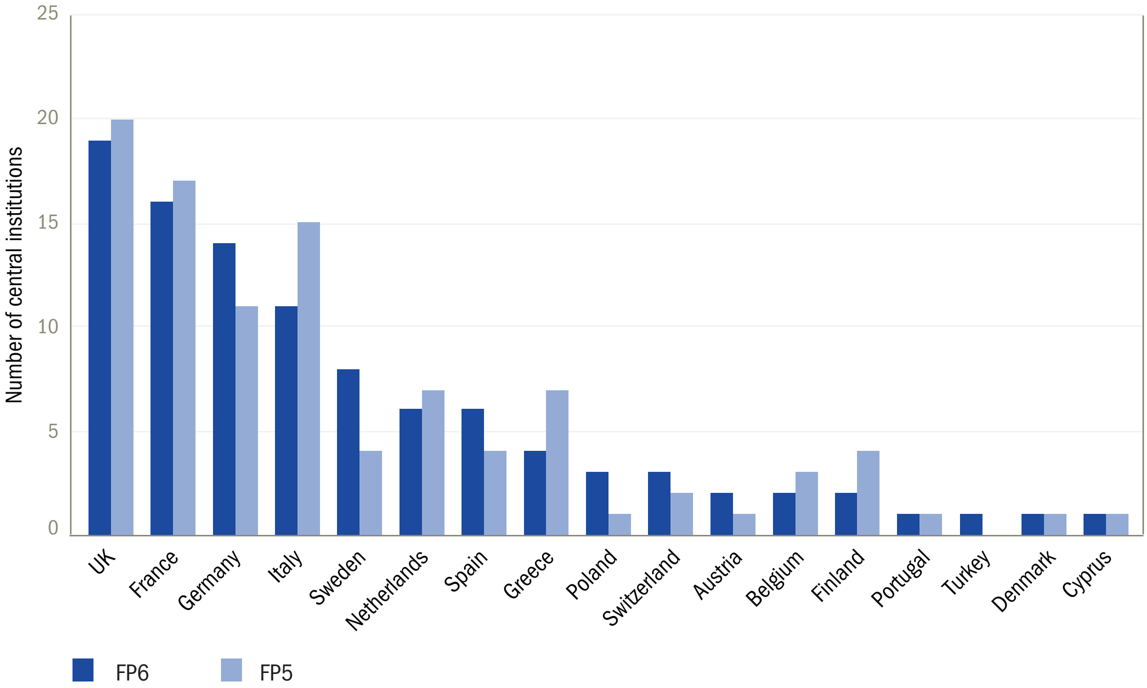
[133] This indicator provides relevant information on the structure and configuration of the research collaboration networks co-funded by the EC research framework programme. However, as the objective of the framework programme is to foster transnational collaboration, the data do not allow any conclusion on the intensity or extent of overall collaboration given that the data presented are highly influenced by the size and conditions of the framework programme as such. Moreover, this population does not cover transnational research collaboration between universities funded by national, regional or internal resources.

[134] The methodology used in this section derives from the study. 'The structure of R&D collaboration networks in the European Framework Programme' (Thomas Roediger-Schluga and Michael J. Barber (2006) UNU Merit Working Paper Series #2006-036). The results presented here have been updated to include information on FP6 projects. The Sysres EUPRO database used for this section includes all information publicly available through the CORDIS projects database (CORDIS search January 2007) and is maintained by ARC systems research (ARC sys). Apart from incoherent spellings which have been corrected, the dataset has been cleaned in order to homogenise the information. Organisational boundaries have been defined by legal control and entries have been assigned to the respective organisations. Resulting heterogeneous organisations, such as universities, large research centres, or conglomerate firms have then been broken down into sub-entities that operate in fairly coherent activity areas, such as faculties, institutes, divisions or subsidiaries. Based on the available contact information of participants, sub-entities have been identified for all entries.

[135] For more clarification of the concept of Centrality, see Methodological Annex.

[136] These data are not weighted, which gives a bias towards large countries.

FIGURE II.1.3 The countries with the most central participants in FP5 and FP6



Source: DG Research
Data: EUPRO (Austrian Research Centres)

STC key figures report 2008

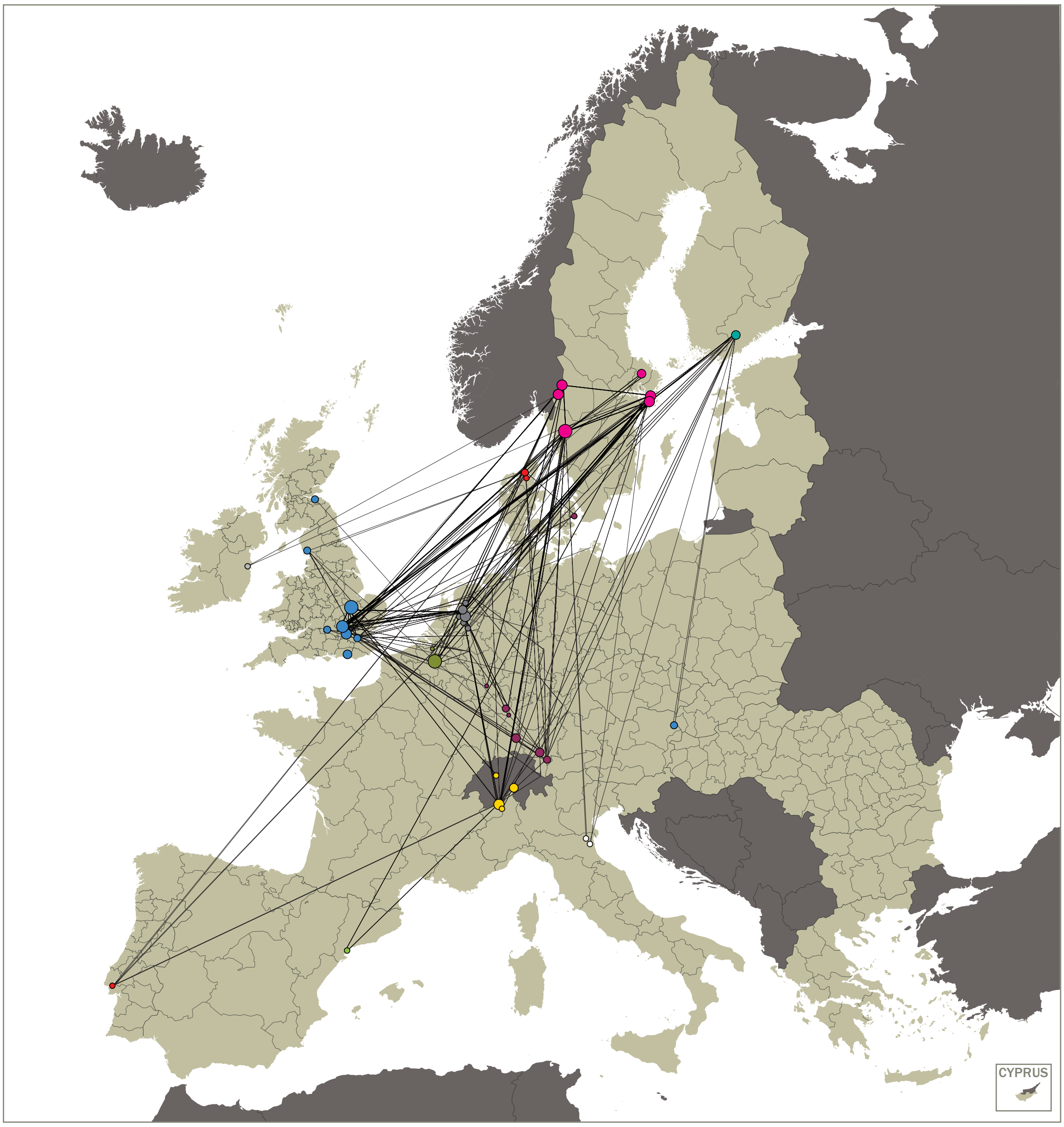
Following the principles of centrality outlined above, it is possible to rank the 20 most central organisations for FP5 and FP6. In both FPs, the most central organisations are predominantly large research centres, in particular the various sub-units of the French CNRS. Other research organisations that rank among the Top 20 include the German Aerospace Centre, the French Commissariat à l'Energie Atomique (CEA), and the Dutch TNO [137].

Networking between universities in Europe is most intensive in Western and Northern Europe

Figure II.1.4 shows the FP6 collaborations developed between universities in Europe. For sake of readability, only links above a threshold of ten collaborations are included. This spatial representation of research links between universities participating in FP6 [138] shows that extensive research networks in Europe funded by FP6 are concentrated within a 'triangle' between the United Kingdom, Sweden and Switzerland, covering the Netherlands, Germany and Denmark. Universities from other countries in Europe have a more peripheral position. However, as is evident from Figure II.1.3., when considering all public and private institutions participating in FP5 and FP6, France, Italy and Spain have more prominent positions than when only focusing on universities. This is partly linked to the fact that the research institutions with highest centrality in these countries are not the universities but the non-university research performing organisations [139].

[137] For a complete list, see Statistical Annex.
[138] The term 'R&D collaboration' refers here to the number of collaborative links between a university and its partners. It is based on the concept of degree in weighted graphs: if a university has 2 partners collaborating in 3 projects, its unweighted degree would be 2 and its weighted degree 3.
[139] This reflects different research systems. As indicated in Part II, Chapter 1.1, in France universities produce only 51 % of all scientific papers. Another reason for the difference between Figure II.1.3. and Figure II.1.4. is linked to the methodological difference between 'centrality' and 'R&D collaborations'. Centrality is a composite indicator that includes more statistical dimensions than are included in collaborative links.

FIGURE II.1.4 FP6 R&D collaborations between European universities that cooperate in more than ten research projects



- Universities with 10-500 collaborations
- Universities with 500-1000 collaborations
- Universities with more than 1000 collaborations

Source: DG Research
Data: EUPRO (Austrian Research Centres)

STC key figures report 2008

The geographical concentration of university research collaboration in Europe is confirmed but refined by a mapping of hyperlinks between webpages [140] between universities by region. Figure II.1.5 shows the geographical distribution of the incoming and outgoing hyperlinks between universities in EU-15 NUTS2 regions [141]. For the sake of readability only the very frequent links (above 2000 hyperlinks) have been represented. Counts include every link from universities located in region A that point to the universities located in region B. Most of them reflect scientific relationships between departments or research groups, but also institutional links between faculties and more general information flows [142].

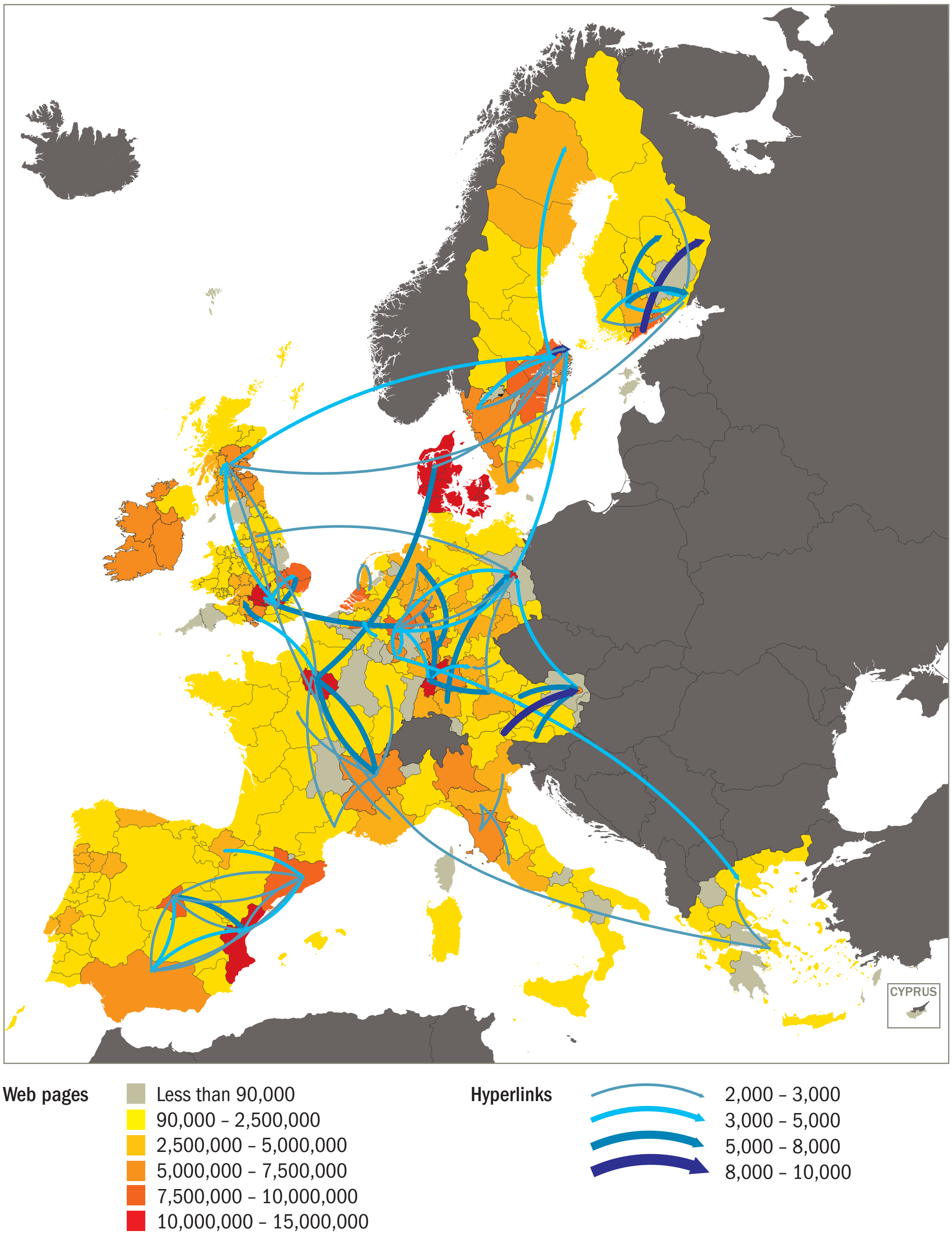
[140] Data measured in a hyperlink include electronic links/references made by an author in a scientific paper to another author as well as electronic links between website(s) at different universities. Thus, the data are an indication of both scientific and institutional cooperation.

[141] See also Ortega, JL (2007) 'Visualization of the European University Web: Quantitative link analysis through cybermetric techniques'. [PhD Thesis] Madrid: University Carlos III.

[142] This methodological approach based on hyperlinks can be complemented with an analysis of co-authoring of scientific articles at institutional level. This breakdown is available in raw data form, but not yet in an analytical form enabling network analysis covering all institutions in Europe. This will probably be available in the coming year.

The web-based hyperlinks between universities in Europe are focused around Western Europe, wit strong links to Northern Europe. Figure II.1.5 also illustrates more precise geographic configurations: close links between universities in the region of Paris and South-Eastern France, between the region of Paris and Denmark, between South-Eastern England and Western Germany, between Southern Germany and Austria and Northern Greece. Universities in Spain and Finland have more links with universities within their countries than with universities in other European regions.

FIGURE II.1.5 Web-based hyperlinks between universities in EU-15 at NUTS 2 regional level, 2008



Source: DG Research
Data: Cybermetric Lab, CSIC

STC key figures report 2008

In conclusion, universities in Europe have developed strong links between themselves. The links based on research collaboration co-funded by the EC research framework programmes are centred in a triangle covering Western and Northern Europe. Other European countries have more peripheral positions for universities, although Southern European countries are more integrated when considering all research performers. This spatial configuration of university links is by and large confirmed by an analysis based on web based hyperlinks between universities in EU-15. The most extensive links connect universities in a relatively limited number of regions.

Chapter 2. Optimising research programmes and priorities

The EC Communication of January 2000 'Towards a European Research Area' highlighted the need for **a more coherent implementation** of national and European research activities. Public funding for research and technological development was described as being compartmentalised into 15 national research systems. National research programmes were called upon to mutually **open up to each other** and to **cooperate in order to reach critical mass**. In 2007, the European Commission Green Paper on the ERA recalled the main policy objectives of **reciprocal opening up, encouraging partnerships, knowledge spill-over and fellowships**. The ERA Green Paper highlighted the need to optimise research programmes and priorities and elaborated more explicitly the objective of **joint programming to address major societal challenges**, to be built up by common foresight, evaluations and an active use of the new ERA instruments such as ERA-NETs, article 169 and Joint Technology Initiatives.

This chapter presents available statistics on progress in the areas identified for optimising research programmes and priorities. The focus is on the funding of research. Two main questions are highlighted: Have European countries increased their funding of coordinated research initiatives? Are research programmes at national level opening up to non-resident researchers?

MAIN FINDINGS

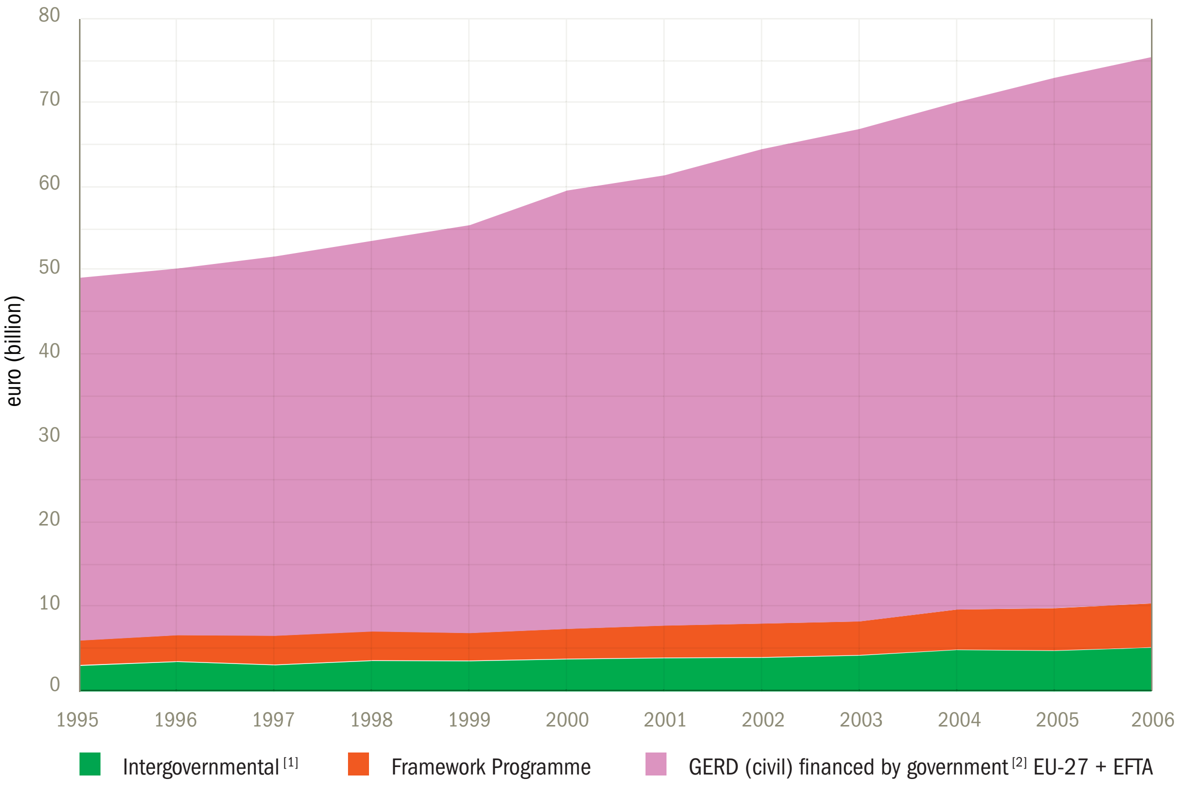
Countries in Europe are increasing their funding of coordinated research at European level in absolute terms but not in relative terms. The policy in 2000 to create a European Research Area, and the subsequent creation of new financial instruments at European level, has started to mobilise joint funding. The main effects on funding can be seen from 2005 and onwards. In parallel, national research funding programmes are opening up to transnational research in terms of possibilities for participation and funding. However, information is still lacking on the orientation and take-up of these new possibilities for transnational research.

2.1 Have European countries increased their funding of coordinated research initiatives?

The proportion of transnational to national funding has remained constant over time

Public funding for research in Europe is channelled through different funding modes at European, national and regional level. Figure II.2.1 shows the evolution of the estimated public funding expenditures on research in Europe.

FIGURE II.2.1 Structure of public funding of R&D in Europe



Source: DG Research
STC key figures report 2008
Data: DG Research, Eurostat
Notes: [1] Intergovernmental includes the budget contributions from the Member States to COST, CERN, EMBL, EMBO, ESA, ESF, ESO, ESRF, ILL and EUREKA
[2] GERD (civil) financed by government was estimated by DG Research

Figure II.2.1 [143] illustrates the dominance of national and regional research funding in the resources of research in Europe. The funding of coordinated research at European level [144] has increased over the last ten years, but so has government-funded expenditure on civil research. The overall proportion of coordinated European funding in relation to national funding has therefore by and large remained constant at a level of 12-15 % over the last ten years.

However, national and regional funding of civil research cover both competitive project funding channelled through research programmes or research councils and the institutional funding of public research organisations and universities (e.g. the payment of basic salaries of researchers and the construction and operational costs of laboratories), while funding in the Community framework programme is only competitive. A recent study covering nine European countries indicates that around one third of total national public funding of research is project funding, and that European research funding would account for between 20-30 % of the total competitive funding available per researcher in Europe [145].

[143] The graph has been elaborated as part of the Commission staff working document accompanying the communication 'Towards Joint Programming in Research', SEC(2008) 2282.

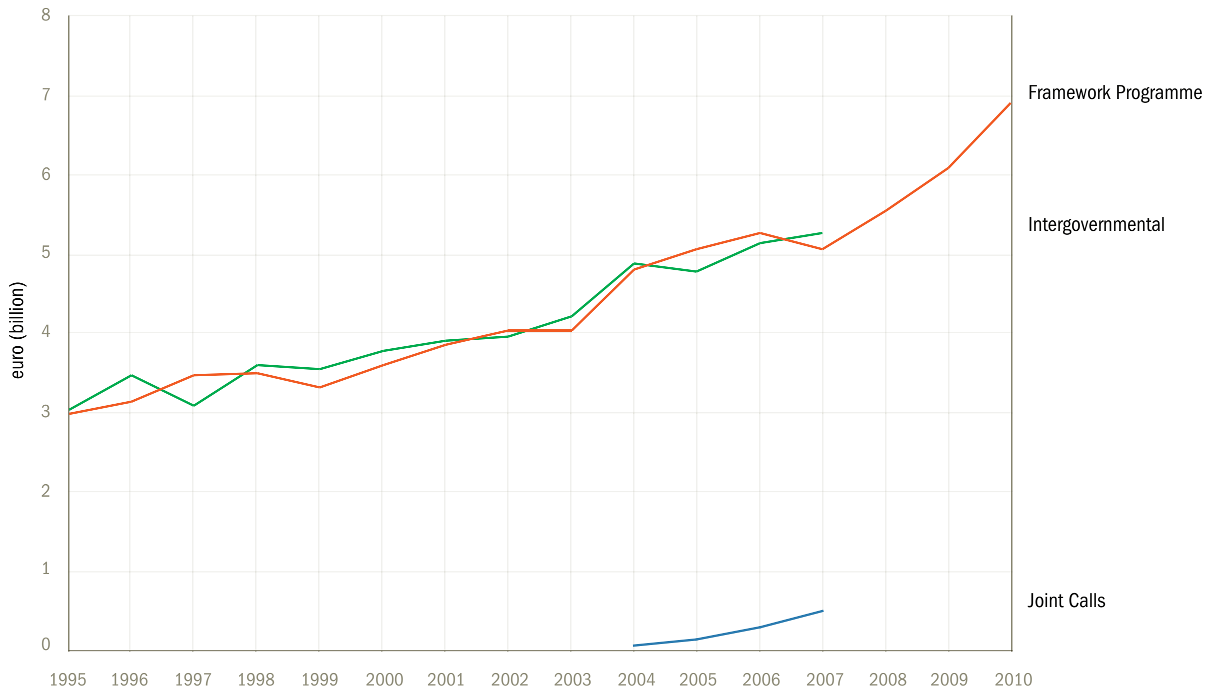
[144] These data on coordinated research funding do not take into account possible projects transnationally coordinated between national or regional research programmes inside bilateral or multilateral agreements. The reason for this is that currently no reliable, comprehensive and comparable statistics at European level exist on the funding amount mobilised in bilateral and multilateral agreements.

[145] The study referred to here found that project funding has increased in many European countries over the last five years and represents 24 % of GBAORD in Italy, between 28-33 % in Switzerland, Austria, France and the Netherlands and 42 % in Norway. In Eastern Europe, the share of project funding in total public funding for research is higher, between 33 % in Poland, 50 % in the Czech Republic and 75 % in Estonia. (Lepori B., van den Besselaar P., Dinges M., van der Meulen B., Potì B., Reale E., Slipersaeter S., Theves J., (2007), Comparing the Evolution of National Research Policies: what Patterns of Change?, Science and Public Policy Vol. 34, No. 6, pp. 372-388.) (see also http://www.enid-europe.org/funding/CEEC.html).

National funding of coordinated research between European countries is growing

The objective of increasing funding for coordinated research in Europe concerns both the Community budget and funding from national and regional budgets. Figure II.2.2 shows the growth of public funding of research implemented in transnational coordinated projects. It shows the increase of funding in intergovernmental and framework programmes as well as a third increasing dimension, 'Joint Calls' [146].

FIGURE II.2.2 Public funding for coordinated research in Europe



Source: DG Research
Data: DG Research

STC key figures report 2008

The structure of transnational funding for coordinated research is changing – with the Community budget growing in size and a new 'third pillar' emerging

Historically, coordinated funding for research at European level has been dominated by intergovernmental initiatives, in particular national funding of the large intergovernmental research infrastructures and the COST and EUREKA programmes. With the Sixth, and even more so the Seventh framework programme, Community budget funding has grown in size and will most probably exceed intergovernmental funding from 2008 onwards.

In addition, Figure II.2.2 reveals a new 'third pillar' growing in size and building on different and complementary instruments conceived in the context of policies establishing a European Research Area. The effect of these new instruments has taken some years to materialise in funding terms. The first Joint Calls were launched in 2004 and, in 2007, the funds committed in Joint Calls inside ERA-NETs and Article 169 initiatives corresponded to some 10 % of the framework programme.

This structure of transnational funding may further evolve following a new initiative of joint programming that was launched in 2008 [147]. Joint programming is the result of a process that foresees a political decision to develop common agendas for public research policies for a given area. This would then require a common analysis and vision for the agreed area, which may entail joint reviews, joint foresight and joint evaluation of existing programmes and capacities.

[146] The data on 'Joint Calls' include non-Community funding committed for joint calls for research inside ERA-NETs and Article 169. Before 2008 there were no formalised commitments to Joint Technology Initiatives (of which public funding is a part). It is to be noted that the resources counted under 'Joint Calls' in Figure II.2.2 are a subset of the total civil GERD financed by government (as presented in Figure II.2.1).

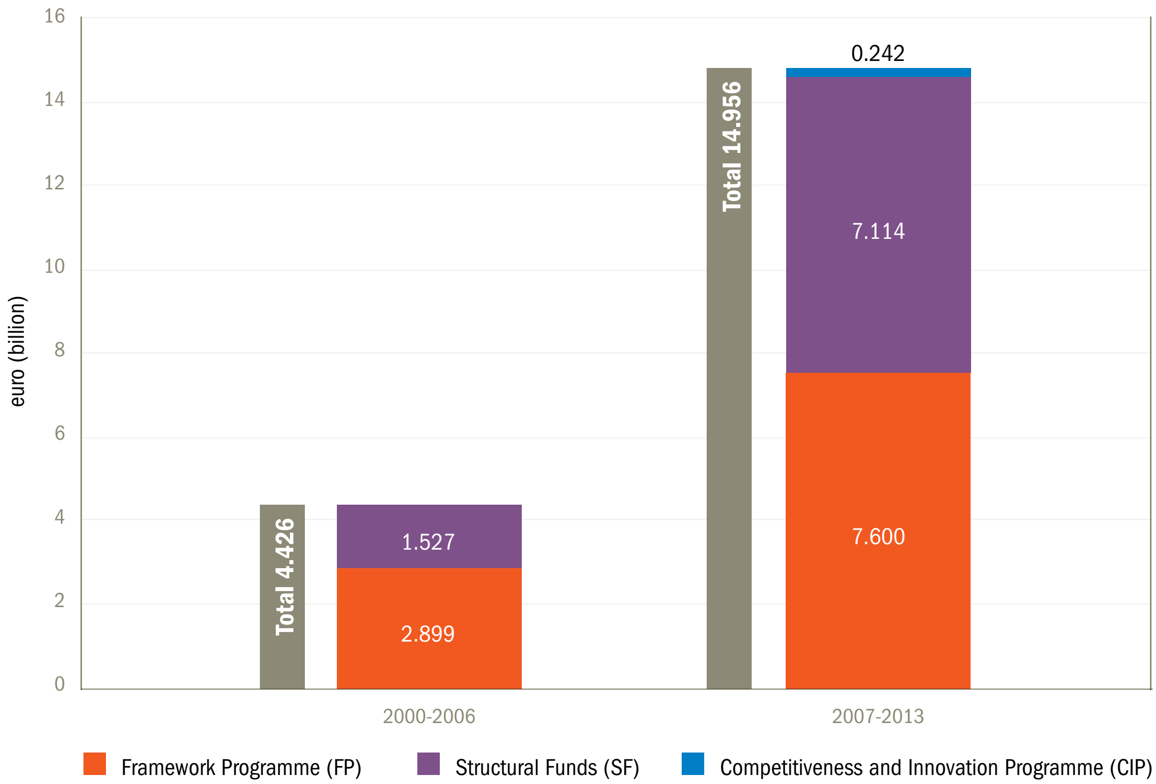
[147] See 'Communication of the European Commission, Towards Joint Programming in Research' COM(2008) 468 final, 15.07.2008.

The average annual funding of research and innovation from the European Community budget has increased more than threefold from 2007 onwards

This increase is to a large extent linked to an increase of structural funds for research and innovation, reaching a level on a par with the framework programme budget, while concentrating its funding directly on single Member States or regions, with only some 2.4 % for transnational activities.

Funding of research and innovation from the Community budget has increased substantially via the Seventh framework programme (FP7), the Competitiveness Innovation programme (CIP) and the Structural Funds (SF) [148].

FIGURE II.2.3 EC funding for research and innovation (annual average funding)



Source: DG Research
Data: DG Research, DG REGIO

STC key figures report 2008

Figure II.2.3 shows that the average annual Community funding for research and innovation will increase from slightly over € 4.4 billion to almost € 15 billion per annum.

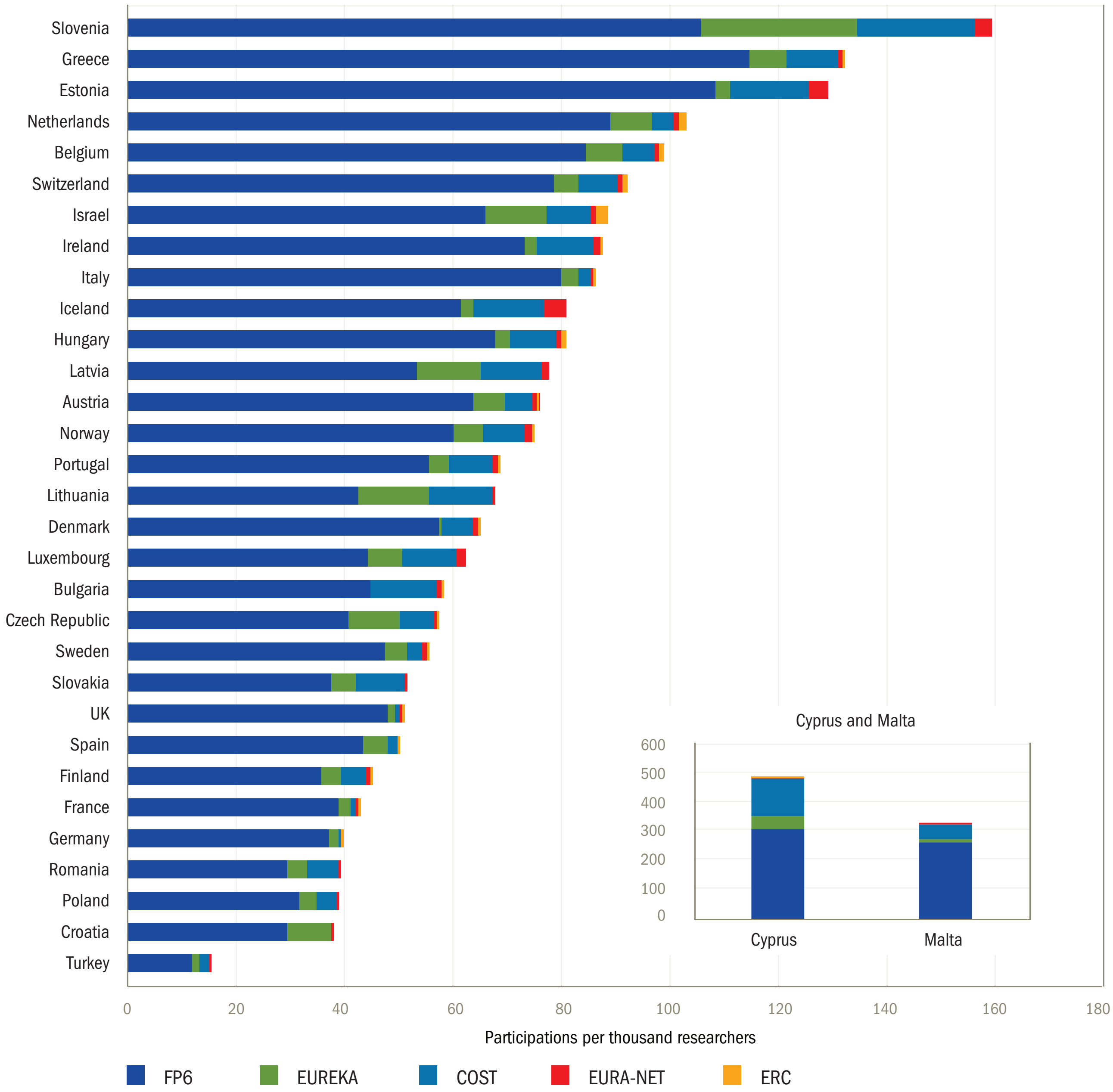
Smaller countries have a higher propensity to participate in the coordinated research instruments at European level

Figure II.2.4 shows the number of participations in European programmes (FP, EUREKA, COST and ERC) per thousand researchers for each country [149]. This gives an indication of the propensity of researchers from a given country to utilise the European funding instruments and the overall propensity of countries to participate in all major coordinated research funding in Europe.

[148] The Structural Funds for RTDI cover six fields: RTD infrastructure, development of science parks, incubators; supporting RTD activities in research centres and firms; technology transfer to SMEs; promotion of environmentally-friendly products and processes in SMEs; training of researchers, post-graduate studies, networking, etc.; and supporting the creation of regional and trans-regional clusters.(see also Part II, chapter 3.2.).

[149] The whole is multiplied by one thousand. Given the relatively small number of researchers in Malta and Cyprus, the number of participations in European programmes from these countries represents a very large share of the total number of researchers in each of these two countries.

FIGURE II.2.4 Number of participations in European programmes per thousand researchers



Source: DG Research
Data: DG Research, EUREKA, COST, ERC

STC key figures report 2008

The propensity to participate in the Sixth framework programme, as well as in other major funding instruments co-ordinated at European level, is highest in the smaller countries and in Eastern and Southern European countries. Germany, France and the United Kingdom have lower shares of their total research populations participating in the European research funding instruments, while the Netherlands, Belgium, Switzerland and Italy show a high participation rate. Finland, Sweden and Denmark are notable exceptions, with relatively low integration in the European research instruments, despite their small size and high R&D intensity.

In conclusion, the ratio of transnational coordinated funding to national funding has not increased over the last ten years. However, in absolute terms national funding of coordinated research at European level has increased steadily. This increase has accelerated after 2005, with the implementation of new ERA-oriented instruments for coordinated research. In parallel, the funding for RTDI in the Community budget has increased more than threefold for the period 2007-2013. Smaller countries have a higher propensity to participate in the framework programme as well as in intergovernmental funding programmes at European level.

2.2 Are research programmes at national level opening up to non-resident researchers?

Currently, there is no broadly agreed definition of the concept a research programme open to non-resident researchers. The concept indeed contains several dimensions: first, categories of openness to applicants, to partners, to subcontractors, or to residents for participating in transnational research; second, specific conditions that might limit the effective degree of openness. Further methodological work is therefore needed before the construction of a solid indicator in this area will be possible [150]. Therefore, this sub-chapter can only present first exploratory findings, with the objective of stimulating further policy and methodological discussions.

Since 2006, a more systematic data collection system is being built up inside the ERAWATCH inventory, allowing for a first perspective on the opening-up of national research programmes. The data collected concern the national research programmes that allow non-resident researchers inside the EU to participate as applicant or as partner, and the programmes that allow part of their funding for non-resident researchers inside the EU. These data are based on a sample of around 400 research funding programmes.

According to the ERAWATCH inventory data for 2006 and 2007, *almost 50 % of national research programmes are open to the participation of researchers or research institutions from another EU Member State as full partners* (and in some cases even as the main applicant) with or without funding. Of these programmes, *around 20 % allow non-resident researchers from another EU Member State to benefit from national funding* [151].

The opening-up of national research programmes is by definition more pronounced if a broader definition of the concept is considered [152]. For instance, when considering the possibilities for sub-contracting researchers from another EU Member State, some countries are 100 % open, while an indicator based only on the openness to direct participation would present a different image. More research programmes allow funding to be sub-contracted to non-resident researchers than allow direct funding to non-resident researchers as full partners. Specific studies on the opening-up of national research programmes indicate that in 2005 around 40 % of national research programmes allow funding via sub-contracting to researchers or research institutions located in another EU Member State. Furthermore, an estimated 40-60 % of all national research programmes involved in transnational research allow funding to resident nationals [153].

[150] See Methodological Annex.
[151] This part is not quantified. The shares are computed from the total of around 400 research funding programmes reported on in ERAWATCH in 2006-2007. No distinctions have been made on the basis of the budget for each programme, nor has any weighting been used. The data refer to the legal possibilities provided by a programme to include non-resident researchers – not the actual spending or the take-up by non-resident researchers utilising the possibilities offered by the programmes.
[152] See Methodological Annex.
[153] Study financed by the European Commission, made by Optimat and VDI/VDE/IT, 2005.

National research programmes were less open in 1998

A comparison with the situation in 1998 [154] reveals that many European countries have made real progress in opening up their programme funding to non-resident researchers. Of the 17 European countries studied in 1998, only three allowed at least one of their national research programmes to fund non-resident researchers. Among the 14 countries that had a more closed national programme funding in 1998, as many as 12 [155] had opened one or more of their research programmes to allow part of the funding to non-resident researchers in 2006.

Data on programmes open for funding to non-resident EU researchers as partners provide only a broad indication on the opening-up of national research programmes. There are countries where only one or a few research programmes are open for funding but where these programmes represent a very large share of the total research funding of the country. In addition, some of the research programmes that are open for funding have fixed an upper ceiling, a maximum share of the funding for a project that can be allocated to a non-resident researcher [156].

As a first estimation, the share of national funding (channelled through research programmes) open to non-resident researchers as partners was around 5 % in 2006. Moreover European countries that do not allow any national funding to non-resident researchers as partners may allow sub-contracting of non-resident researchers by resident researchers. Funding open to non-resident researchers seems to have grown compared to 1998. A study in 1998 estimated that projects including non-residents (mostly sub-contracting) accounted for less than 2 % of all funding of public research programmes in 1998 [157].

There are no systematic Europe-wide data on the take-up of national funding by non-resident researchers

There are currently no systematic data available either on actual spending on non-resident researchers by European countries, or on the take-up of non-resident researchers by nationality.

In conclusion, national research programmes are increasingly open to non-resident researchers. Half of the programmes allow non-resident researchers to participate and 20 % allow these researchers to be funded as partners. If the possibilities of subcontracting non-resident researchers or funding national researchers for participation in transnational projects are also taken into account, even more national programmes can be considered as partly open. More statistical refinements are being developed to distinguish between these different categories and to provide data on actual funding and take-up rates.

[154] Strict statistical time series are lacking. Before 2006, the European Commission issued two specific studies focusing on this challenge of opening-up (one in 2005 and one in 1998-1999). However, since the data collection before and after 2006 is slightly different in methodology and geographical scope, the analysis of progress over time is only possible for some countries and with an estimated approach including both quantitative and semi-quantitative data.

[155] Portugal, Ireland, Austria, Finland, the Netherlands, France, Greece, Sweden, Germany, Spain, Luxembourg and the United Kingdom. (Comparing data from study financed by the European Commission in 1999, made by Technopolis, VDI/VDE-IT, IKEI with data from ERAWATCH inventory in 2007). The study of 1998-1999 derived the data from a literature study of all relevant official documents and rules, and a questionnaire survey of national programmes sent out in Spring 1998 to more than 500 programme managers, with a 40 % response rate.

[156] For instance in 2006, in Austria, some open programmes had a funding ceiling of 25 %, in Cyprus the funding ceiling was 30 % for an open programme and, in Iceland, the funding to non-resident researchers could not exceed 50 % of the total funding of the project.

[157] Study financed by the European Commission in 1999, made by Technopolis, VDI/VDE-IT, IKEI and Logotech. 'Cross-Border Cooperation within National RTD Programmes', Volume 1, page 1.

Chapter 3. Research infrastructures

The EC Communication of January 2000 'Towards a European Research Area' identified the need to develop strategic and large-scale research infrastructures in Europe. The Communication advocated a **common method to finance large research infrastructures in Europe**, leading to the **creation of new installations at European level**. A second objective was to **network and link existing centres of excellence across European countries**. The EC Sixth framework programme and the Structural Funds for the period 2000-2006 were highlighted as a means to respond to the need for the development of research infrastructures in the ERA. In April 2007, the ERA Green Paper took this policy one step further, calling for **joint European ventures for the construction and exploitation of major European research infrastructures** building on the roadmap established by the European Strategic Forum on Research Infrastructures (ESFRI). The Green Paper also emphasised that research infrastructures in Europe should be **integrated** (on the basis of coherent planning), **networked and accessible** to research teams from across Europe and the world.

This chapter presents the available statistical evidence on the progress in these two areas, formulated into two key questions: Has there been any progress in the creation of new large-scale research infrastructures at European level? Are existing research infrastructures in Europe networked and accessible to research teams across Europe and the world? The chapter also presents the scale of Structural Funds support to capital expenditures on research and innovation.

MAIN FINDINGS

There has been progress in the creation of new large-scale research infrastructures at European level. 35 large-scale research infrastructures have been identified for development, out of which 32 have entered the preparatory phase. The substantially increased Structural Funds for Research, Technology, Development and Innovation Infrastructures will provide a strong impetus for the development of research infrastructures in Europe at all levels. At the same time, existing research infrastructures in EU Member States are open to users from other Member States and outside the EU, with one third of research infrastructures having more than 50 % foreign users.

A recent study on research infrastructures estimates that the number of research infrastructures of significant size (medium and large-scale) currently in operation in Europe is between 250 and 400 [158]. The study concludes that these research infrastructures represent an initial investment (construction cost) of about € 21.4 to 33.1 billion [159] and annual operating costs of € 7.9 to 9.4 billion in 2006, including the European Space Agency (ESA). The yearly operational budget of the latter is about € 3.45 billion.

[158] *European Research Infrastructures Development Watch (ERID-Watch) project, 2007-2009. In order to understand the economic impact of European research infrastructures in the scientific domains identified by ESFRI (social sciences & humanities, environmental sciences, energy, biomedical and life sciences, material sciences, astronomy, astrophysics, nuclear and particle physics, computer and data processing), this study has surveyed a sample of 45 research infrastructures, 175 companies (suppliers, R&D collaborators and users of research infrastructures), and more than 30 representatives of institutional bodies in 17 Member States.*

[159] *This estimation of the total construction cost does not include research infrastructures under construction which are not yet operational and research infrastructures for which the estimation of construction costs has not been possible (Collections of Museums or European Space Agency – ESA – infrastructures).*

Another survey conducted in 2006-2007 by the European Commission, the European Science Foundation (ESF) and EUROHORCS [160] provides information on the geographical location of research infrastructures in Europe [161]. According to this study, 47% of the surveyed research infrastructures have their owner institutions in one of the four largest countries in terms of population and research effort: Germany, France, Italy and the United Kingdom [162]. 72% of the research infrastructures with very high construction costs (greater than €250 million) belong to institutions of these four countries [163]. This survey also shows that there are regional concentrations of research infrastructures in certain scientific domains, e.g. environmental, marine and earth sciences research infrastructures in Scandinavian countries and social sciences research infrastructures in Scandinavian countries, the United Kingdom and the Netherlands [164].

Among the large-scale research infrastructures in Europe, there are seven major intergovernmental European research organisations operating large-scale infrastructures (CERN, EFDA, EMBL, ESA, ESO, ESRF and ILL), which collaborate and combine resources and expertise in the EIRO-forum partnership [165]. Their respective legal statutes are based on international agreements and on the national legislation of their country of location. The total annual budget for the operation of these seven intergovernmental research infrastructures amounts to €4.4 billion [166], which corresponds to about 23% of total annual capital expenditure on R&D in EU-27 [167].

3.1 Has there been any progress in the creation of new large-scale research infrastructures at European level?

In 2002, the European Strategic Forum on Research Infrastructures (ESFRI) was established with the objective of agreeing on the common planning of new large-scale research infrastructures at European level. In October 2006, ESFRI published the first ever European 'roadmap' for building new and upgraded pan-European research infrastructures. This roadmap provides an overview of the needs for research infrastructures of pan-European interest for the next 10 to 20 years. It contains a description of 35 large-scale, world-class research infrastructures in nine scientific domains.

32 of the 35 European research infrastructures identified in the EFSRI Roadmap have proceeded into the preparatory phase

Table II.3.1 [168] gives an overview of the projected main characteristics of these 32 research infrastructures. In addition to its contribution to the preparatory phases of these infrastructures, the EC is funding part of the preparatory phases of two new research infrastructures under the European Strategy for Particle Physics, as approved by the CERN Council (marked in brown on Table II.3.1).

[160] European Heads of Research Councils.
[161] 2006-2007 Survey of European Research infrastructures, by the European Commission, European Science Foundation and European Heads of Research Councils. For more details, the report of this survey is available at: http://ec.europa.eu/research/infrastructures/landscape_en.html.
[162] It must be noted that the country of the institution owning a research infrastructure is not necessarily the country hosting the same research infrastructure.
[163] The share of these four countries correspond to their share in EU-27 total R&D expenditure (about 69% in 2005) and in EU-27 total GDP (about 65% in 2005).
[164] For more details, the report of this survey is available at: http://ec.europa.eu/research/infrastructures/landscape_en.html.
[165] In addition to the seven EIRO-members, there are other intergovernmental research infrastructures in Europe, such as ITER, EUMETSAT, ICES, among others.
[166] European Research infrastructures Development Watch (ERID-Watch) project, 2007-2009.
[167] About €19 billion in 2005.
[168] In this Table, figures and dates are only indicative. At the time of writing the ESFRI Roadmap is being revised.

TABLE II.3.1 Projects funded as preparatory phases for the construction (or major upgrade) of research infrastructures (ESFRI roadmap), (May 2008) [1]

Projects (in alphabetical order per domain)	Full name of project	Estimated construction cost [5] (million euro)	Indicative operational cost per year [5] (million euro)	Countries participating in the preparatory phase [3]
Social Sciences and Humanities				
CESSDA	Council of European Social Science Data Archives	*30*	*6*	CZ, DK, DE, EL, ES, FR, IT, HU, NL, AT, RO, SI, FI, SE, UK, NO, CH
CLARIN	Common Language Resources and technology Initiative	165	*10*	BG, CZ, DK, DE, EE, EL, ES, FR, HU, MT, NL, AT, PL, PT, RO, FI, SE, UK, HR, NO
DARIAH	DigitAl Research Infrastructure for the Arts and Humanities	40	10	DK, DE, IE, EL, FR, CY, NL, SI, UK, HR
ESS	The European Social Survey	*9*	9	BE, BG, DE, ES, FR, NL, SI, SE, UK, IS, NO, CH, ESF (INO) [4]
SHARE	Survey of Health, Ageing and Retirement in Europe	51	< 1	BE, CZ, DK, DE, IE, EL, ES, FR, IT, NL, AT, PL, SI, SE, UK, CH, IL
Environmental Sciences				
AURORA BOREALIS	European Polar Research Icebreaker	635	32.5	BE, BG, DE, FR, IT, NL, RO, FI, NO, RU, ESF (INO)
EMSO	European Multidisciplinary Seafloor Observation	100	32	DE, IE, EL, ES, FR, IT, NL, PT, SE, UK, TR, NO
EUFAR	European Fleet of Airborne Research	~ 50	~ 2	DE, EL, ES, FR, IT, PL, PT, FI, UK
EURO ARGO	Global Ocean Observing in Infrastructure	73	6.3	BG, DE, IE, EL, ES, FR, IT, NL, PL, PT, UK, NO
IAGOS-ERI	In-service Aircraft for a Global Observing System – European Research Infrastructure	15	5-10	DE, FR, UK, WMO (INO)
ICOS	Integrated Carbon Observation System	96	14	BE, CZ, DK, DE, ES, FR, IT, NL, FI, SE, UK
LIFE WATCH	Research Infrastructures Network for Research in Biodiversity	370	71	BE, DK, DE, ES, FR, IT, NL, PL, RO, SI, SK, FI, SE, UK, NO
Biomedical and Life Sciences				
EATRIS	European Advanced Translational Research Infrastructure for medicine	250	50	DK, DE, FR, IT, NL, FI, SE, UK, NO
BBMRI	European Biobanking and Molecular Resources	170	15	DE, EE, IE, ES, FR, IT, HU, MT, NL, AT, RO, FI, SE, UK, IS, NO
INFRAFRONTIER	Infrastructure for Phenomefrontier and Archivefrontier	270	36	DK, DE, EL, ES, FR, IT, PT, FI, SE, UK
ECRIN	Infrastructures for Clinical Trials and Biotherapy	50	5	BE, DK, DE, IE, ES, FR, IT, HU, AT, SI, FI, SE, UK, CH
INSTRUCT	Integrated Structural Biology Infrastructure	250	25	DE, FR, IT, UK, IL, EMBL (EIRO)
ELIXIR	Upgrade of European Bioinformatics Infrastructure	550*	7	DK, DE, ES, FR, IT, HU, NL, FI, SE, UK, IS, CH, IL, EMBL (EIRO)

Projects (in alphabetical order per domain)	Full name of project	Estimated construction cost [5] (million euro)	Indicative operational cost per year [5] (million euro)	Countries participating in the preparatory phase [3]
Energy				
HIPER	High Power Experimental Research Facility	800	*80*	CZ, DE, EL, ES, FR, IT, PL, PT, UK, RU
Material Sciences				
ELI	Extreme Light Infrastructure	400	30	BG, CZ, DE, EL, ES, FR, IT, LT, HU, PL, PT, RO, UK
ESRF Upgrade	European Synchroton Radiation Facility	287	na	ESRF (EIRO) [4]
Neutron Source ESS	European Spallation Source for Producing Neutrons	1050-1500	80-100	DE, ES, FR, IT, LV, HU, SE, GB, CH
European XFEL	X-ray Free Electron Laser	1200	84	DK, DE, ES, FR, IT, HU, PL, SK, SE, UK, CH, RU
ILL 20/20 Upgrade	Institute Laue Langevin	160	na	ILL (EIRO)
IRUV X-FEL	Infrared to Ultraviolet and soft X-rays Free Electron Lasers	1300-1800	130-180	DE, IT, SE, UK
PRINS	Paneuropean Research Infrastructures for Nano-Structures	1150-1750	250	BE, DE, FR, NL
Astronomy, Astrophysics, Nuclear and Particle Physics				
E-ELT	European Extremely Large Telescope	600-800	40	ESO (EIRO)
FAIR	Facility for Antioproton and Ion Research	1000	135	DE, ES, FR, IT, AT, PL, RO, FI, SE, UK, RU, IN
KM 3NeT	Cubic Kilometre Neutrino Telescope	~ 200	na	DE, IE, EL, ES, FR, IT, CY, NL, RO, UK
SKA	Square Kilometre Array	1500	100-150	DE, ES, FR, IT, NL, UK, US, AU, CA, ZA
SPIRAL2	Système de Production d'Ions RAdioactifs en Ligne	170	6.6	BE, BG, CZ, DE, ES, FR, IT, HU, NL, PL, RO, UK, IL
ILC-HiGrade [2]	e+e – International Linear Collider	4400	na	DE, FR, IT, UK, CERN (EIRO)
SLHC [2]	Large Hadron Collider upgrade	1000	na	CZ, DE, ES, FR, IT, NL, PL, UK, CH, CERN (EIRO)
Computer and Data Treatment				
HPC (PRACE)	European High-Performance Computing Service	200-400	30-50	DE, EL, ES, FR, IT, NL, AT, PT, PL, FI, SE, UK, NO, CH

Source: DG Research
Data: DG Research
Notes: [1] Estimated construction cost and Indicative operational cost as known in May 2008
[2] Projects of the European Strategy for Particle Physics (CERN Council)
[3] Countries can withdraw and/or other countries can join at a later stage
[4] EIRO: EIROforum, partnership of the seven largest intergovernmental research organisations
INO: International organisation
[5] Values in italics are estimates which were published in 2006
na = not available

STC key figures report 2008

Table II.3.1 shows that a large number of European countries are involved in the preparatory phase of each of the 32 ESFRI research infrastructures. A few of these projects are major upgrades of existing research infrastructures which are already in operation.

The total construction costs of the research infrastructures in the ESFRI Roadmap represent 70 % of EU-27 capital expenditure on R&D in one year

Table II.3.2 compares the key expenditure data on research infrastructures in Europe to the total estimated cost of the 32 research infrastructures of the ESFRI Roadmap. It shows that the total estimated construction cost of the research infrastructures of the ESFRI Roadmap is in the order of 70 % of EU-27 capital expenditure on R&D [169] in one year or about three years of coordinated spending on intergovernmental research infrastructures.

TABLE II.3.2 Expenditure on research infrastructures (RIs) in Europe (billion euro)

Capital expenditure on R&D EU-27 [1] 2005	ESFRI Roadmap RIs estimated global construction cost	Structural Funds for RIs 2000-2006 [2]	Structural Funds earmarked for RIs 2007-2013 [3]	EIROforum 7 RIs annual budget
19.1	13.2	3.1	9.8	4.4

Source: DG Research STC key figures report 2008
Data: Eurostat, DG Research, DG REGIO
Notes: [1] EU-27: Capital expenditure on R&D for MT, AT and UK was estimated by DG Research
[2] This represents around 29 % of the total Structural Funds for core RTDI (10.7 billion euro) over the period 2000-2006
[3] This represents around 19 % of the total Structural Funds earmarked for core RTDI (49.9 billion euro) over the period 2007-2013

In conclusion, there has been progress in the creation of new large-scale research infrastructures at European level. 35 large-scale research infrastructures have been identified for development, out of which 32 have entered the preparatory phase.

[169] 'Capital expenditure on R&D' includes expenditure on fixed assets used in R&D activities such as land and buildings and also expenditure on equipment, research instruments and computer software. The other category of R&D expenditure 'current costs' includes labour costs and the non-capital purchase of materials and supplies (Frascati Manual).

3.2 What is the scale of Structural Funds support for capital expenditure on research, development and innovation?

The structural funds will give a strong impetus to the development of infrastructures for research, development and innovation in the new Member States

The new large-scale research infrastructures are only one part of the European countries' investment in research infrastructures. The broad category of expenditure on research infrastructures covers all physical capital for research activities, i.e. land, buildings, instruments, equipment in laboratories, etc. In this context, the 2007-2013 Structural Funds allocated for RTDI [170] will have an impact on investment in research infrastructures in the EU. The Structural Funds will provide substantial support for research infrastructures that have national or regional dimensions.

Over the period 2000-2006, Structural Funds support for RTDI amounted to € 10.7 billion. For the current 2007-2013 cycle the amount of Structural Funds allocated for RTDI in EU-27 Member States is € 49.8 billion, i.e. more than € 7 billion per annum. The Structural Funds RTDI category not only covers R&D capital investment [171]: among the € 10.7 billion for RTDI in 2000-2006, € 3.1 billion was allocated specifically for RTDI infrastructures, i.e. about € 0.4 billion per annum on average. Of the € 49.8 billion designated for RTDI in 2007-2013, € 9.8 billion is allocated for 'RTD infrastructures and centres of competence', i.e. about € 1.4 billion per annum. Every year from 2007 to 2013, Structural Funds for R&D capital investment will account for a substantial share (7-8 %) of total capital expenditure on R&D by the 27 Member States. This shows the high level of impetus that the Structural Funds will contribute to the development of research infrastructures (R&D capital) in Europe.

TABLE II.3.3 Comparison between capital expenditure on R&D in 2005 and the average annual funding for research infrastructures (RIs) under the Structural Funds (million euro)

	EU-27 [1]	New Member States
Capital expenditure on R&D, 2005	19000	761
Structural Funds for RIs — average annual, 2000-2006 [2]	440	80
Structural Funds for RIs — average annual, 2007-2013	1400	685

Source: DG Research
Data: Eurostat, DG REGIO
Notes: [1] EU-27: Capital expenditure on R&D for MT, AT and UK was estimated by DG Research
[2] Structural Funds for RIs, 2000-2006: Data for the new Member States refer to 2004-2006 and do not include BG and RO

STC key figures report 2008

For the 12 new Member States, the Structural Funds will be particularly important for the funding of research infrastructures. In the period 2007-2013, Structural Funds allocated for RDTI in these countries amount to € 20.6 billion, of which € 4.8 billion is for RTD infrastructures. That is about € 685 million per annum. To put this in perspective, in 2005 the total capital expenditure on R&D of the 12 new Member States [172] amounted to € 761 million. National co-financing will range between 15-25 % or some € 140 million euro per annum. It seems likely, therefore, that the development of research infrastructures in these countries will to a large extent be funded by the Structural Funds in the coming years.

In conclusion, the substantial increase in the Structural Funds allocated for research infrastructures will give a major impetus to the development of research infrastructures not only at European level but also at national and regional levels, in particular in the new Member States.

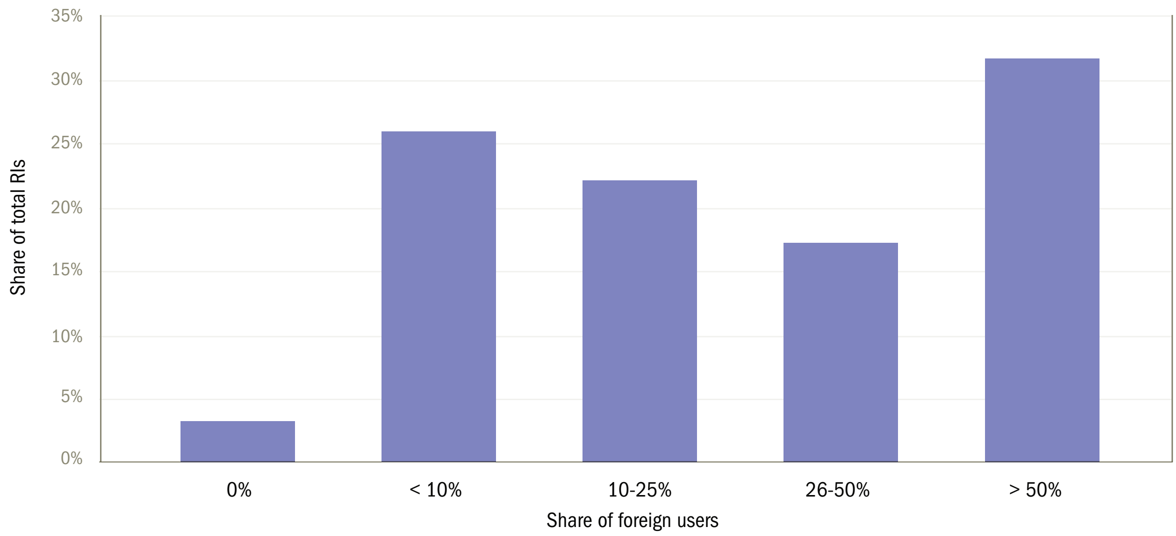
[170] RTDI: Research, Technology, Development and Innovation.
[171] The innovation-related activities in Structural Funds programmes that are grouped into the RTDI category of spending are mainly: RTD activities in research centres, RTD infrastructure and centres of competence, technology transfer and improvement of cooperation networks, assistance to RTD (particularly in SMEs), investment in firms directly linked to research and innovation, developing human potential in the field of research and innovation.
[172] Not including Malta in respect of which data are not available.

3.3 Are existing research infrastructures in Europe networked and accessible to research teams across Europe and the world?

One third of surveyed research infrastructures in Europe report having over 50 % foreign users [173]

Most users of the surveyed research infrastructures in Europe are national users, i.e. users whose nationality is that of the country hosting the facility. However, about 32 % of all research infrastructures report having more than 50 % foreign users, which indicates that research infrastructures in Europe are open to researchers from abroad (see Figure II.3.1). About 70 % of the surveyed research infrastructures report more than 10 % users from abroad.

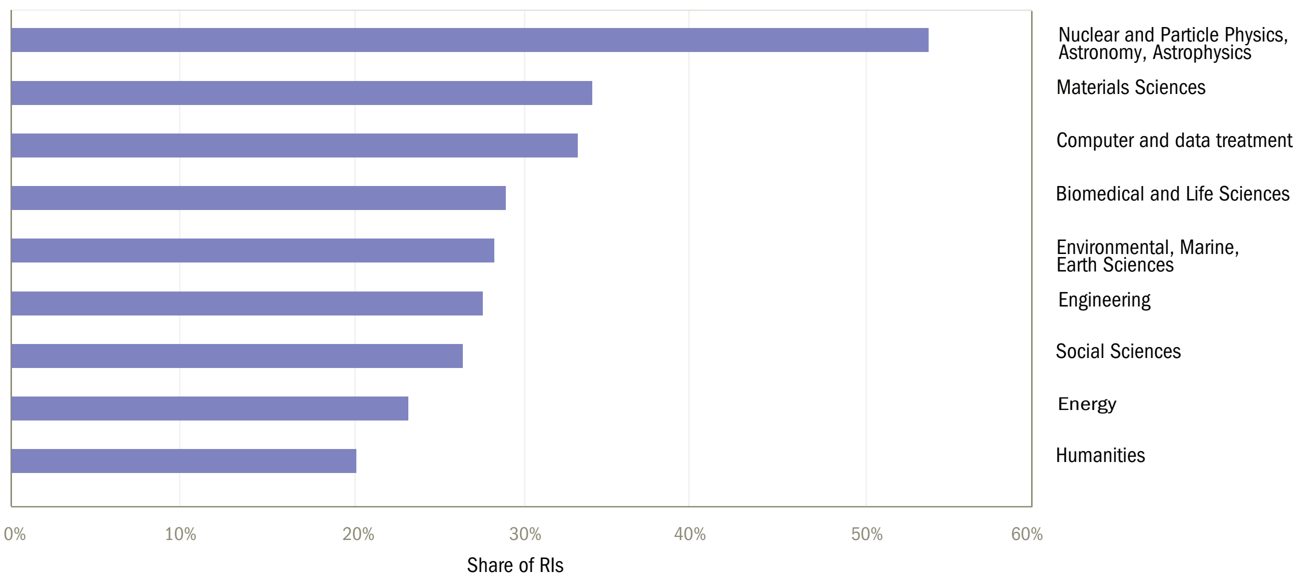
FIGURE II.3.1 Foreign users of research infrastructures (RIs)



Source: DG Research
Data: DG Research

STC key figures report 2008

FIGURE II.3.2 Shares (%) of research infrastructures (RIs) by domain with more than 50 % foreign users



Source: DG Research
Data: DG Research

STC key figures report 2008

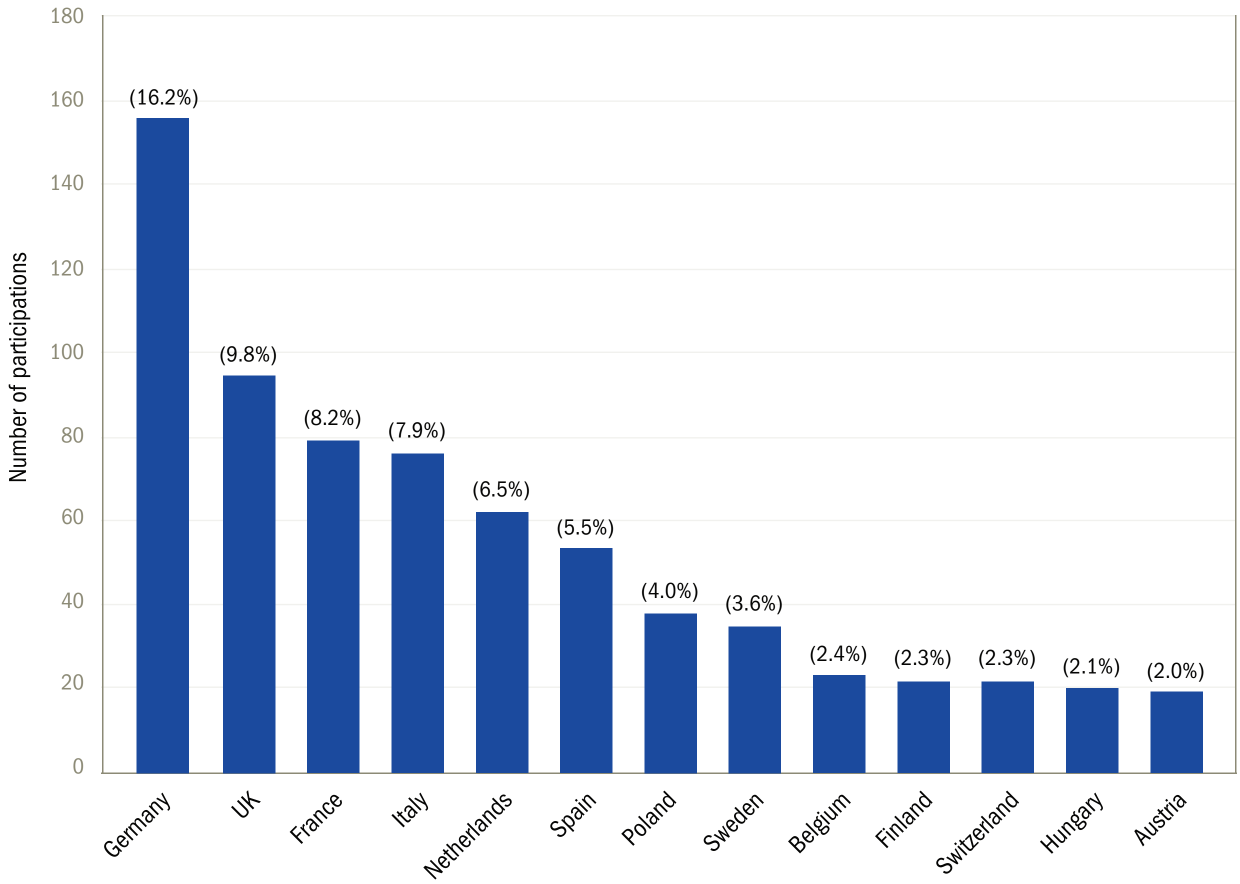
[173] *The whole section is based on the* 2006-2007 Survey of European Research infrastructures, *by the European Commission, European Science Foundation and European Heads of Research Councils. For more details, see the report of this survey available at: http://ec.europa.eu/research/infrastructures/landscape_en.html*

Two domains stand out: nuclear and particle physics, astronomy, astrophysics (NPPAA) research infrastructures are the most international, and humanities research infrastructures the least (Figure II.3.2): 54 % of NPPAA research infrastructures have more than 50 % foreign users, which means that foreign users clearly dominate in this field, whereas foreign researchers represent only 20 % of users in the humanities [174] . The high share of foreign users in NPPAA has to be seen in the context of the high levels of international funding for this domain. The shares of European research infrastructures reporting a majority of foreign users range from 23 % to 34 % in other domains. Very few research infrastructures (3 %) report 0 % foreign users, whereas more than 71 % have more than 10 % foreign users. The research infrastructures in this survey, therefore, demonstrate a clear international dimension.

Large networks of research infrastructures have been formed under FP6 in all scientific domains

Research infrastructures will be employed to best effect if they offer their services to a wide research community. In order to provide a wider and more efficient access to, and use of, research infrastructures, FP6 and FP7 support joint research and networking through Integrated Activities and Transnational Access projects. 959 institutional partners have participated in FP6 Integrating Activities and Transnational Access projects, with 295 research infrastructures offering access to foreign researchers.

FIGURE II.3.3 Number of institutional participations by country [1] in research infrastructure projects funded by FP6 (I3 and TA) [2]; in brackets: % share of the total number of participations (959)



Source: DG Research
Data: DG Research
Notes: [1] Countries which account for less than 2 % of the total number of participations are not represented
[2] I3: Integrated Infrastructures Initiatives; TA: Transnational Access

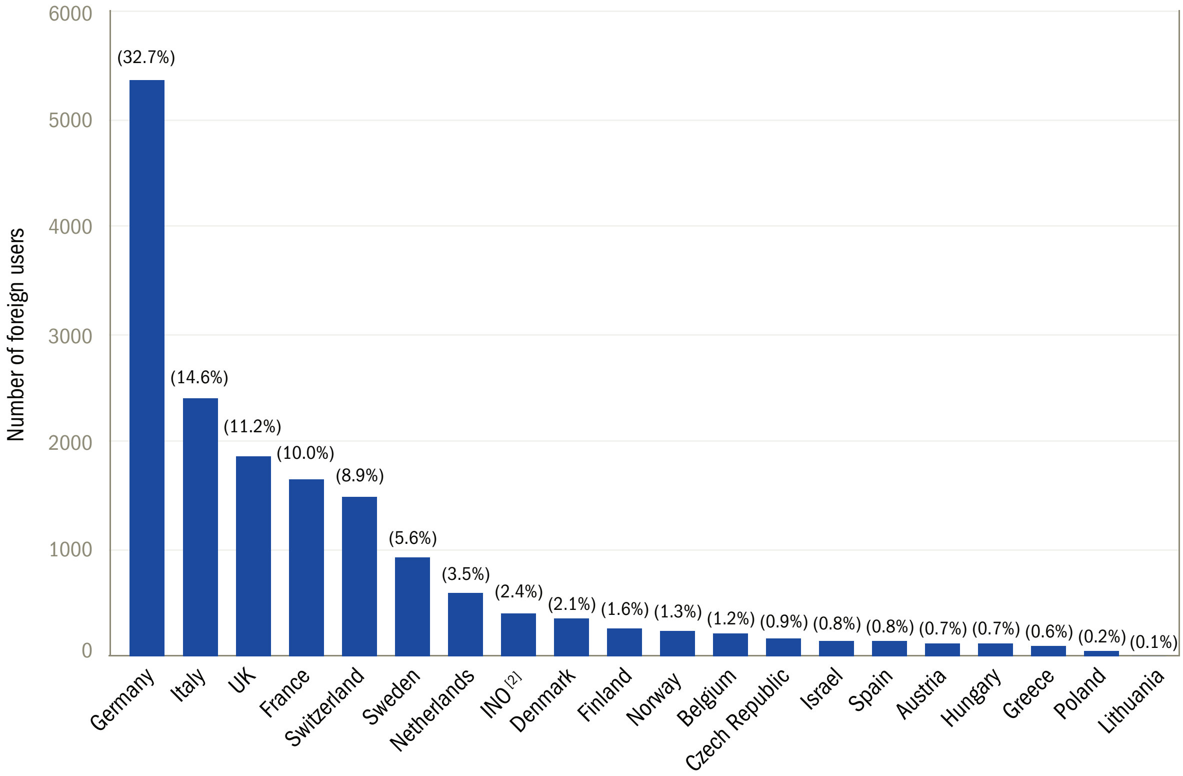
STC key figures report 2008

[174] The lower share of foreign users in the humanities research infrastructures is linked to the fact that there are strong national research traditions in the humanities where much research is produced in national languages. There is also less international funding for humanities research infrastructures.

Ongoing FP activities give more than 14,000 researchers [175] direct access to existing facilities not located in their own countries

Under FP6 in every scientific domain, including social sciences and humanities, research infrastructures have formed large networks consisting of 5 to 48 institutions. Ongoing FP activities have so far given more than 14,000 researchers access to existing facilities not located in their own countries. FP6 contracts [176] cover the travel costs of the researcher from the country of his/her host institution, as well as the user fees of the research infrastructures, i.e. the scientific, technical and logistic supports that are related to the use of the research infrastructures.

FIGURE II.3.4 Number of foreign users by operator country in research infrastructure projects funded by FP6 (I3 and TA) [1]; in brackets: % share of the total number of foreign users (16412)



Source: DG Research — STC key figures report 2008
Data: DG Research
Notes: [1] Integrated Infrastructures Initiatives (I3) and Transnational Access (TA) contracts under FP6
Data include users of an RI who came to this RI up until January 2008, through an FP6 I3 or TA contract from a country other than the country operating this RI
[2] INO: International Organisation e.g. CERN, EMBL

Countries which are not represented on Figure II.3.4 have not hosted any foreign user through an FP6 contract. Figure II.3.4 shows that German research infrastructures have hosted almost one third of all FP6 foreign users so far. Research infrastructures operated by Italy, the United Kingdom and France have hosted two to three times less foreign users through FP6 than research infrastructures operated by Germany [177]. The 10 smaller EU-15 Member States [178] have hosted about 15 % of all FP6 foreign users. The 12 new Member States are mostly absent from Figure II.3.4, as they have hosted only around 1-2 % of all FP6 foreign users.

[175] *As of January 2008 : as some of the FP6 contracts will run until 2010, they will involve further users in the years to come. The final number of individual transnational accesses provided by FP6 contracts will therefore be higher than the 14,327 users counted up to January 2008.*
[176] *Integrated Infrastructures Initiatives (I3) and Transnational Access (TA) contracts.*
[177] *It should be noted that among all the FP6 contracts taken into consideration for Figure II.3.4, one single contract involves 6,096 foreign users. Therefore, this contract alone heavily influences the overall breakdown of foreign users by host countries. In this contract, German research infrastructures host 43 % and Swiss research infrastructures 18 % of the foreign users, hence their high overall shares. When this contract is excluded, the shares of Germany, Switzerland and Sweden fall to 25.5 %, 5.4 % and 5.2 % respectively, while the shares of Italy, the United Kingdom and France go up to 14.3 %, 13.7 % and 13 % respectively. The shares of international organisations (INO) and the Czech Republic also go up to 3.5 % and 1.5 % respectively.*
[178] *EU-15 minus Germany, France, the United Kingdom, Italy and Spain: these 10 countries comprise about 82 million inhabitants, comparable to the population of Germany.*

Germany, Italy, the United Kingdom, France, Switzerland and Sweden are net providers of research infrastructures that offer transnational access

A comparison between Figure II.3.3 and Figure II.3.4 provides a picture of the countries that are 'net providers of research infrastructures', i.e. countries that have higher shares of foreign users than participating institutions. This is the case for Germany, Italy, the United Kingdom, France, Switzerland and Sweden.

Table II.3.4 shows that flows of researchers converge between Germany, Italy, the United Kingdom, France and Switzerland. Most of these researchers come from these countries as well, indicating that, in absolute terms, the circulation of researchers within these five countries accounts for much of the transnational use of research infrastructures in Europe. However, if we normalise the figures taking into account the total number of national researchers, it appears that new Member States and other smaller countries benefit most from FP6 transnational access.

TABLE II.3.4 The ten biggest transnational flows of research infrastructure (RI) users in FP6 [1]

ORIGIN	DESTINATION	Number of RI users
Country of home institution	Operator country	
UK	Germany	614
Germany	Switzerland	605
France	Germany	539
Italy	Germany	528
Germany	Italy	528
Belgium	Germany	514
France	Italy	438
Poland	Germany	436
Germany	Germany [2]	398
Italy	France	336

Source: DG Research STC key figures report 2008
Data: DG Research
Notes: [1] Data include users of an RI who came to this RI up until January 2008 through an FP6 I3 or TA contract
[2] The transnational character of the access is assured by the nationality of the users in these cases (non-German users)

There are also flows of research infrastructure users from countries with smaller shares of users than institutional partners to the five countries with higher shares of users than institutional partners [179]: for instance, the flows from Belgium and Poland to Germany are among the ten highest flows of FP6 research infrastructure users.

Information and Communication Technology (ICT) based research infrastructures – e-Infrastructures – enabled new forms of collaboration and integration across Europe

Key underlying communication infrastructures reaching world leadership (such as GÉANT in the area of communication network or EGEE in the area of scientific resource sharing) has contributed to the attractiveness of Europe for research [180]. GÉANT now serves the research and education communities in 40 countries across Europe. At the same time, vital communication links have been established with science groups world-wide. These infrastructures enabled a move towards computationally intensive science carried out in highly distributed network environments – e-Science [181].

In conclusion, research infrastructures in Europe are accessible to foreign users with one third of the research infrastructures having a majority of foreign users. Germany, Italy, the United Kingdom, France, Switzerland and Sweden are net providers of research infrastructures that offer transnational access funded by FP6. There are currently no comprehensive European pre-defined indicators on other networking activities between research infrastructures.

[179] This does not mean that flows in the opposite direction do not exist.
[180] See also Aho Report, 'Information Society Research and Innovation: Delivering results with sustained impact', May 2008. For GÉANT, see http://www.geant.net/and for EGEE (Enabling Grids for E-sciencE), see http://www.eu.egee.org.
[181] Source DG Information Society.

Chapter 4. Mobility of researchers and human resources in S&T

The EC Communication of January 2000 'Towards a European Research Area' identified **increasing the number of mobile researchers in Europe** as a central objective of constructing the ERA. The Communication also advocated the **introduction of a European dimension to scientific careers**. In April 2007, the European Commission Green Paper on the European Research Area reconfirmed these two areas of action as important for the realisation of a European Research Area: a **high level of mobility of researchers between countries and institutions** and a **full opening of academic research positions across Europe**. In 2008, the EC Communication on mobility and careers [182] proposed the development of a partnership with Member States to ensure that researchers **across Europe could benefit from attractive careers** and from the removal of barriers to their mobility (including the introduction of systematic open recruitment of European researchers).

This chapter will present the available statistical evidence on progress in some of these policy areas, in particular two key questions: Has the mobility of human resources in S&T increased in Europe since 2000? Are countries in Europe attracting foreign researchers?

MAIN FINDINGS

The mobility of professionals in S&T has increased rapidly over the period 2000-2006. However, precise data regarding the mobility of researchers is lacking at geographical and sectoral level. The United Kingdom, Austria, Belgium, Denmark and the Netherlands have the highest shares of foreign researchers. In absolute numbers, the largest intra-EU flows of mobile researchers go between the five largest EU Member States, and in particular to the United Kingdom. However, Switzerland, Canada and the US have higher shares of foreign doctorate holders than Germany.

4.1 Has the mobility of human resources in S&T increased in Europe since 2000?

There is limited availability of statistical information on researchers at European level [183]. Calculating *trends* on mobility is currently only possible for the population 'Human Resources in Science and Technology Core' (HRSTC) [184], often used as a proxy population for researchers. HRSTC consists of 'professionals' and 'technicians and associated professionals' with a tertiary-level education (here also referred to as S&T professionals). This population is considerably larger than that of researchers [185] and there are no data on how large a part of this population is conducting research. Statistical data on HRSTC over the period 2000-2006 are available for nine EU Member States on the basis of nationality and ten EU Member States on the basis of country of birth.

Taking into account these limitations, the available data for the period 2000-2006 indicate that the number and proportion of non-national human resources in science and technology core have increased.

[182] Communication of the European Commission, 'Better careers and more mobility: a European partnership for researchers', COM (2008) 317 final, 23.05.2008.

[183] See Methodological Annex. As defined by the Frascati manual in OECD 2002. The standard classification used internationally in surveys, the International Standard Classification of Occupations (ISC°, does not recognise 'researcher' as a profession, only 'research and development manager'. (see http://www.ilo.org/public/english/bureau/stat/isco/docs/draft08.pdf).

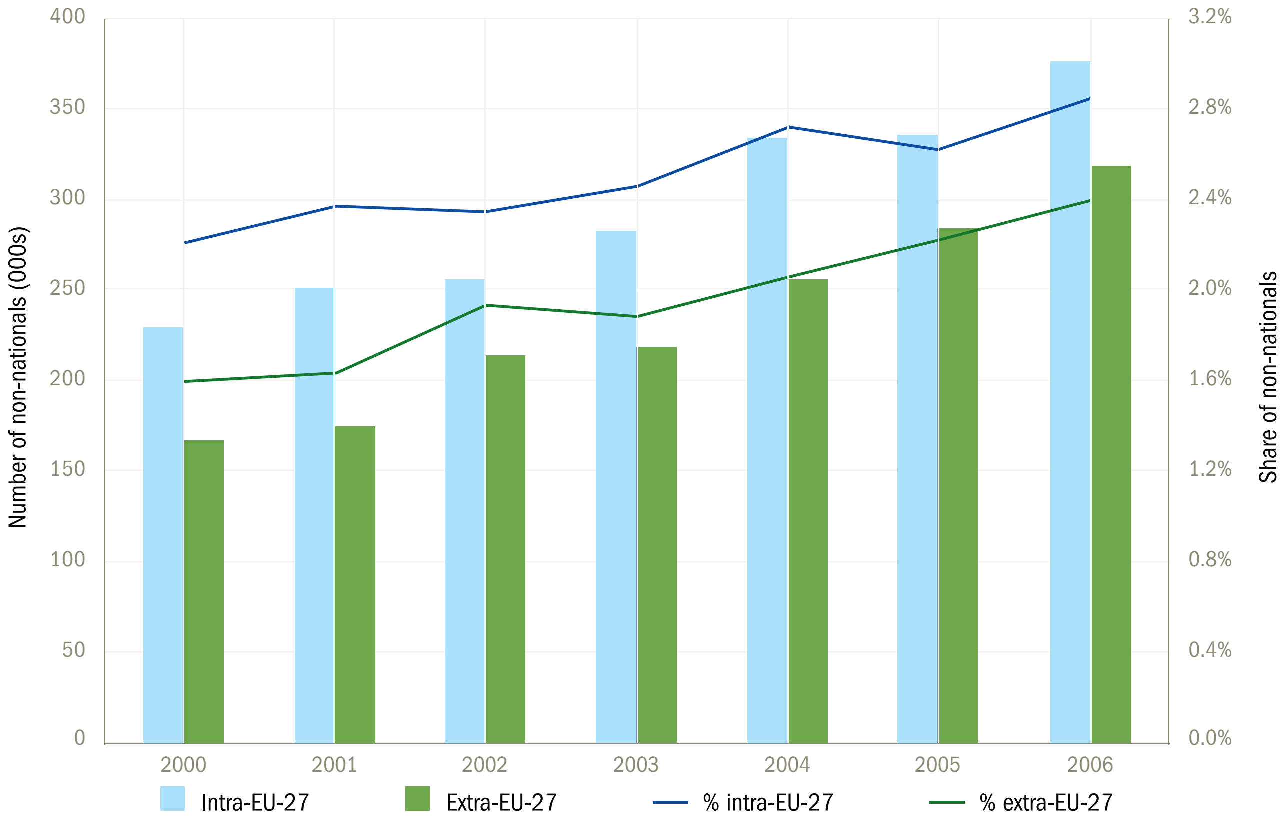
[184] Defined in the Canberra manual, OECD 1995.

[185] In 2006, total HRSTC in EU-27 amounted to 34.5 million compared to 1.9 million researchers in Head Count and 1.3 million researchers in Full-Time Equivalent.(see also Part I, Chapter 2.1., Figure I.2.1).

The mobility of professionals in science and technology has increased over the period 2000-2006

Total non-national HRSTC having EU-27 citizenship increased from 229,000 in 2000 to 376,000 in 2006. This implies an annual growth rate of 8.6 %. Their share in the HRSTC total increased from 2.2 % in 2000 to 2.9 % in 2006. In Spain and in the United Kingdom, there were increases from 26,000 to 94,000 and from 80,000 to 110,000 respectively.

FIGURE II.4.1 Non-national human resources in science and technology core (HRSTC) in nine EU Member States [1]: numbers (thousands) and shares (%), 2000-2006



Source: DG Research
Data: Eurostat
Note: [1] The nine Member States are: BE, EL, ES, CY, LU, NL, AT, SE, UK

STC key figures report 2008

Data on *foreign-born* HRSTC show a similar picture. The number of EU-27 foreign-born HRSTC increased from 345,000 in 2000 to 496,000 in 2006 (an increase of 6.2 % per annum) in the 10 EU Member States for which data are available. Their share in the total increased from 3.2 % to 3.6 % over the same period (see Statistical Annex).

The intra-EU mobility of S&T professionals has increased. However, the stock of S&T professionals from countries outside the EU has increased at a higher rate

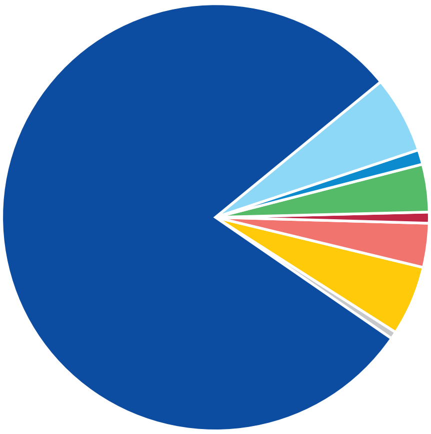
The growth in the mobility of S&T professionals is not a strictly European dynamic, as could be expected of closer European integration. In fact, the number of non-nationals having citizenship from outside EU-27 increased over the period 2000-2006, from 167,000 in 2000 to 318,000 in 2006 in the nine Member States under consideration. This implies a 11.3 % annual growth rate. The same trend exists for foreign-born HRSTC: the increase of mobility is higher for extra-EU HRSTC than for intra-EU HRSTC. Total HRSTC born in a country outside EU-27 increased from 524,000 to 854,000 (an increase of 8.5 % per annum) [186].

Doctoral candidates are more mobile than S&T professionals

Within EU-27, 4.4 % of non-national science and technology professionals come from another EU country [187] and 5.8 % of doctoral students have the nationality of another EU Member State (6.9 % when other European countries are included).

In the EU (data are available for 21 Member States) [188], 79 % of the 487,000 doctoral candidates in 2005 were citizens of the country in which they worked, 6.9 % had the nationality of another ERA country (about 28,000 in total) and 14 % came from countries outside the ERA.

FIGURE II.4.2 Number and % share of doctoral candidates in EU-27 [1] by country of citizenship, 2005



Own country	387000 (79.5%)
Other EU country	28400 (5.8%)
Other European country	5300 (1.1%)
Africa	17900 (3.7%)
North America	4400 (0.9%)
South America	15300 (3.1%)
Asia, Middle East, Oceania	26000 (5.3%)
Unknown	2600 (0.5%)

Source: DG Research
Data: Eurostat
Note: [1] EU-27 does not include: DE, IE, EL, LV, LU, NL

STC key figures report 2008

In conclusion, there has been an increase in the mobility of S&T professionals inside the EU since 2000, but this trend is partly an effect of the overall globalisation of research rather than of European integration as such, since the mobility growth of non-EU professionals in S&T has exceeded the intra-EU mobility growth. The same conclusion can be drawn from the stock of doctoral candidates. In 2005, 6.9 % of the doctoral candidates in EU-27 had the nationality of another ERA country, while 14.1 % had the nationality of a country outside the ERA.

[186] See Statistical Annex.
[187] Data on the share of non-nationals in Human Resources in Science and Technology Core (HRSTC) are available from EUROSTAT for 14 EU countries, as well as for Norway and Switzerland.
[188] The six missing countries are Germany, Ireland, Greece, Latvia, Luxembourg and the Netherlands.

4.2 Are countries in Europe attracting foreign researchers?

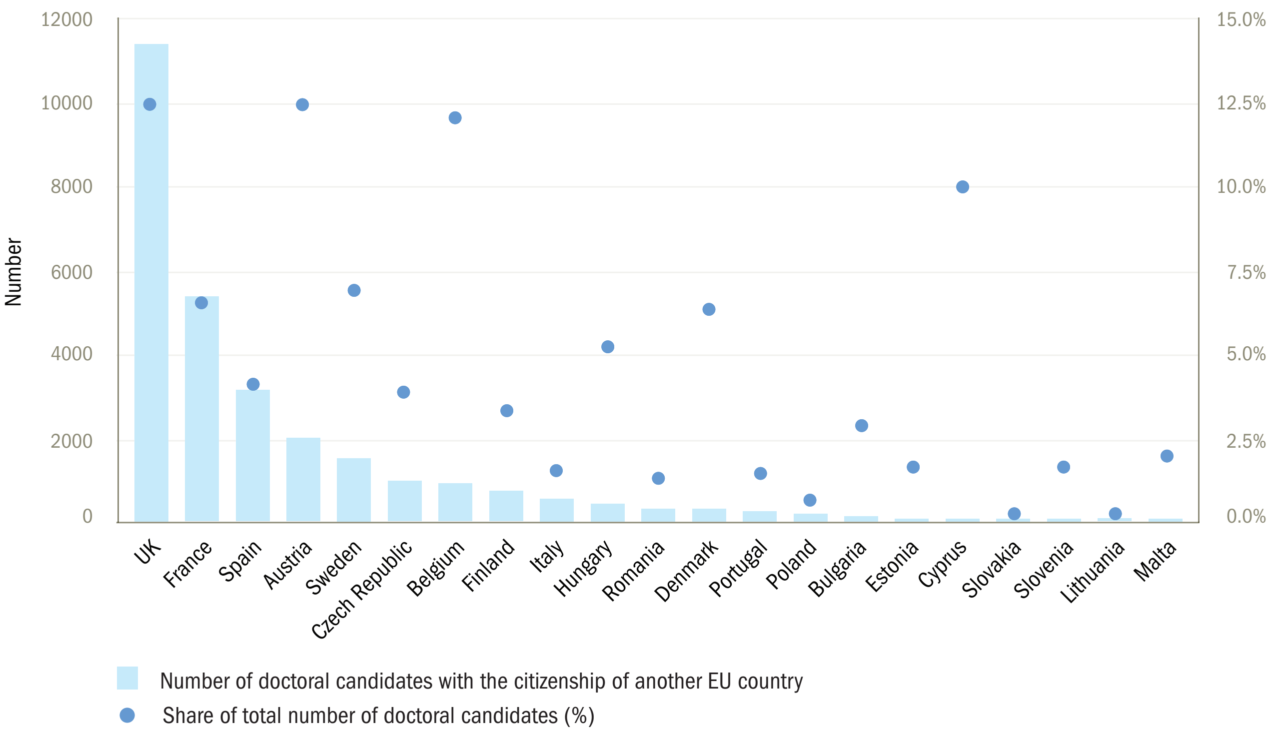
Current statistics provide some information by country on non-national researchers and on the balance of outgoing and incoming researchers. Data at European level are partly available for doctoral candidates, doctorate holders and mobility funded by European instruments such as Marie Curie and, indirectly, the European Research Council. This information can be considered as a very rough proxy for the level of openness and attractiveness of national research institutions.

However, no data are available at European level on the academic research positions these researchers hold in the research system of the host institutions, nor on the place the mobility period has in their scientific careers. Some exploratory studies on the relationship between mobility periods and researchers' academic careers are being made, based on the CVs of researchers [189]. However, a full understanding of this dynamic would require comparable data from research-performing institutions at European level.

The United Kingdom, Austria and Belgium have the highest shares of non-national doctoral candidates

Figure II.4.3 shows that the United Kingdom, Austria and Belgium had the highest shares of doctoral candidates with citizenship of another EU country, with shares of 12.5 %, 12.5 % and 12.1 % respectively. The countries with the next highest shares were Cyprus, Sweden, France, Denmark and Hungary, with shares of between 5 % and 10 %. In the remaining 13 countries (out of 21), foreign EU doctoral candidates accounted for less than 5 % of enrolments at doctoral level.

FIGURE II.4.3 EU-27 [1] – number and % share of doctoral candidates with the citizenship of another Member State in the reporting country, 2005



Source: DG Research
Data: Eurostat
Note: [1] EU-27 does not include: DE, IE, EL, LV, LU, NL

STC key figures report 2008

Doctoral candidates are mainly moving to the larger EU Member States and in particular to the United Kingdom

The three countries which are the main destinations for doctoral candidates in terms of absolute numbers are the United Kingdom, France and Spain. These are followed by Austria and Sweden. Of the new Member States, the Czech Republic is the most popular destination for doctoral candidates.

[189] *C. Cañibano, J. Otamendi, and I. Andújar (2008) Measuring and assessing researcher's mobility from CV analysis: the case of the Ramon y Cajal programme in Spain, Research Evaluation 17 (1), 17-31.*

That the larger EU Member States, and in particular the United Kingdom, are the focus of mobility is also evident from the Marie Curie statistics. The United Kingdom, France, Germany and Spain were the main destinations for Marie Curie Intra-European fellows over the period 2003-2006. The United Kingdom alone receives 35 % of the Marie Curie fellows, followed by France (15 %) and Germany (10 %). Spain had more than twice as many outgoing as incoming Marie Curie fellows, while the United Kingdom had more than three times as many incoming as outgoing Marie Curie fellows [190].

The same conclusion is drawn in a recent survey on the mobility and career development of academic researchers. Most of the mobility of this limited sample of researchers [191] occurred within the five largest EU Member States (the United Kingdom, France, Germany, Italy and Spain). 47 % of the surveyed researchers from one of these five countries moved to one of the other four countries. At the same time, 35 % of the surveyed researchers from the Nordic countries and 35 % of the surveyed researchers from the remaining EU-27 countries moved to one of the five above-mentioned countries [192].

The United States, Canada, Australia and Switzerland have a higher share of foreign doctorate holders than Germany

Table II.4.1 shows that almost one out of every three doctorate holders in Switzerland is foreign. Australia, Canada and the US have shares of foreign doctorate holders above 10 % [193]. Germany is at a lower level with 7.4 % in 2004. However, the German level of foreign doctorate holders increased by 10 % from 2003 to 2004, which could be an indication of a changing trend.

It is also notable that there is a higher proportion of non-nationals among women foreign doctorate holders than among men for all surveyed countries except the US. In Germany, in 2004, 9.6 % of women doctorate holders had foreign citizenship whereas the corresponding share for men was only 6.4 %.

TABLE II.4.1 Doctorate holders by sex and country of origin

	TOTAL		MEN		WOMEN	
	Citizens of reporting country (%)	Foreign citizens (%)	Citizens of reporting country (%)	Foreign citizens (%)	Citizens of reporting country (%)	Foreign citizens (%)
Germany (2003)	93.2	6.8	94.4	5.6	90.6	9.4
Germany (2004)	92.6	7.4	93.6	6.4	90.4	9.6
Switzerland (2003)	70.0	30.0	:	:	:	:
Switzerland (2004)	69.9	30.1	:	:	:	:
US (1993)	90.7	9.3	90.2	9.8	92.4	7.6
US (2003)	88.3	11.7	87.2	12.8	90.2	9.8
Canada (1996)	83.2	16.8	83.4	16.6	82.3	17.7
Canada (2001)	82.0	18.0	82.0	18.0	81.8	18.2
Australia (2001)	86.0	14.0	86.6	13.4	84.4	15.6
Argentina (2005)	99.8	0.2	99.6	0.4	100.0	0.0

Source: DG Research
Data: Eurostat, OECD, UNESCO

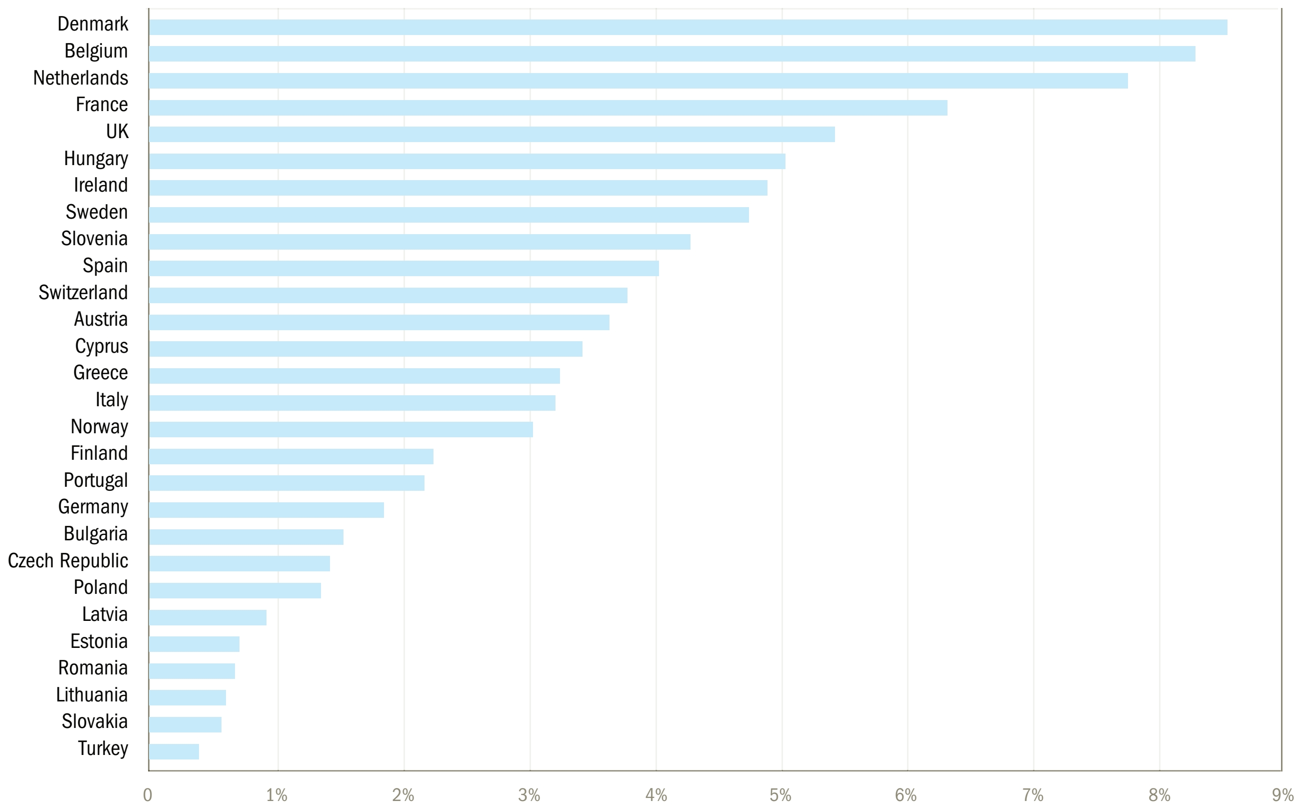
STC key figures report 2008

[190] *See Statistical Annex.*
[191] *The survey included researchers from higher education institutions and from public research institutes, including both early-stage researchers and experienced researchers. The mobile population at the time of the survey amounted to a total of 804 researchers from various EU-27 Member States and beyond.*
[192] *A study by Rindicate commissioned by DG Research, 'Evidence on the main factors inhibiting mobility and career development of researchers', Final report 2008.*
[193] *The US has a very open research education system. In 2005, one third of the S&E doctorates awarded by US universities (14,400 out of 43,400) were to non-US citizens. (National Science Board, Science and engineering indicators 2008, volume 1).*

Denmark, Belgium and the Netherlands are the most open countries for the international mobility of Marie Curie fellows [194]

A statistical analysis of the main destinations for Marie Curie Intra-European fellows, as referred to previously in this chapter, provides an indication of the attractiveness of a country for foreign researchers. However, combining the incoming and outgoing mobility flows of Marie Curie fellows as a percentage of the stock of doctoral graduates in a country provides a proxy indicator for the degree of openness of a national research system to mobile doctorate holders. According to this indicator, Denmark, Belgium and the Netherlands are the most open countries in terms of flows of Marie Curie fellows. It is noticeable that many new Member States (with the exceptions of Hungary and Slovenia) have very low levels of international mobility of Marie Curie fellows.

FIGURE II.4.4 Marie Curie Fellowships – Flows (incoming plus outgoing) [1] as % of total PhD/Doctoral graduates, 2006 [2]



Source: DG Research
Data: DG Research
Notes: [1] Outgoing applications for intra-European fellowships are included on the basis of country of residence rather than nationality of the applicant
[2] Total PhD/Doctoral graduates refers to 2006 for all countries except Italy (2004)

STC key figures report 2008

The ten highest single mobility flows of Marie Curie fellows between European countries were: France to the United Kingdom (111), Spain to the United Kingdom (85), Germany to the United Kingdom (70), Italy to the United Kingdom (51), Italy to France (46), Spain to France (45), the Netherlands to the United Kingdom (35), Germany to France (33), Poland to the United Kingdom (28) and France to the Netherlands (28) [195].

Finally, the openness of national systems to the mobility of researchers can also be measured by the implementation of the different EU initiatives to promote a European-wide career. In 2008, around 200 research organisations (representing more than 800 institutions, such as universities, research institutes, international organisations, etc.) from 23 countries had signed the EC Recommendation on the European Charter for Researchers and on the Code of Conduct for the Recruitment of Researchers. While these figures are positive, the overall take-up of the voluntary Charter and Code has been relatively limited and several Member States have still not implemented the Visa Directive.

[194] For a more detailed description of the Marie Curie action in the EC framework programme, see Methodological Annex.
[195] Source: DG Research.

In 2004, the Researchers' Mobility Portal [196] was launched to provide information on fellowships/grants, research job vacancies and practical information when moving. More than 4,800 jobs were posted on the Portal in 2007. Most jobs were posted in the Netherlands, Norway and Bulgaria.

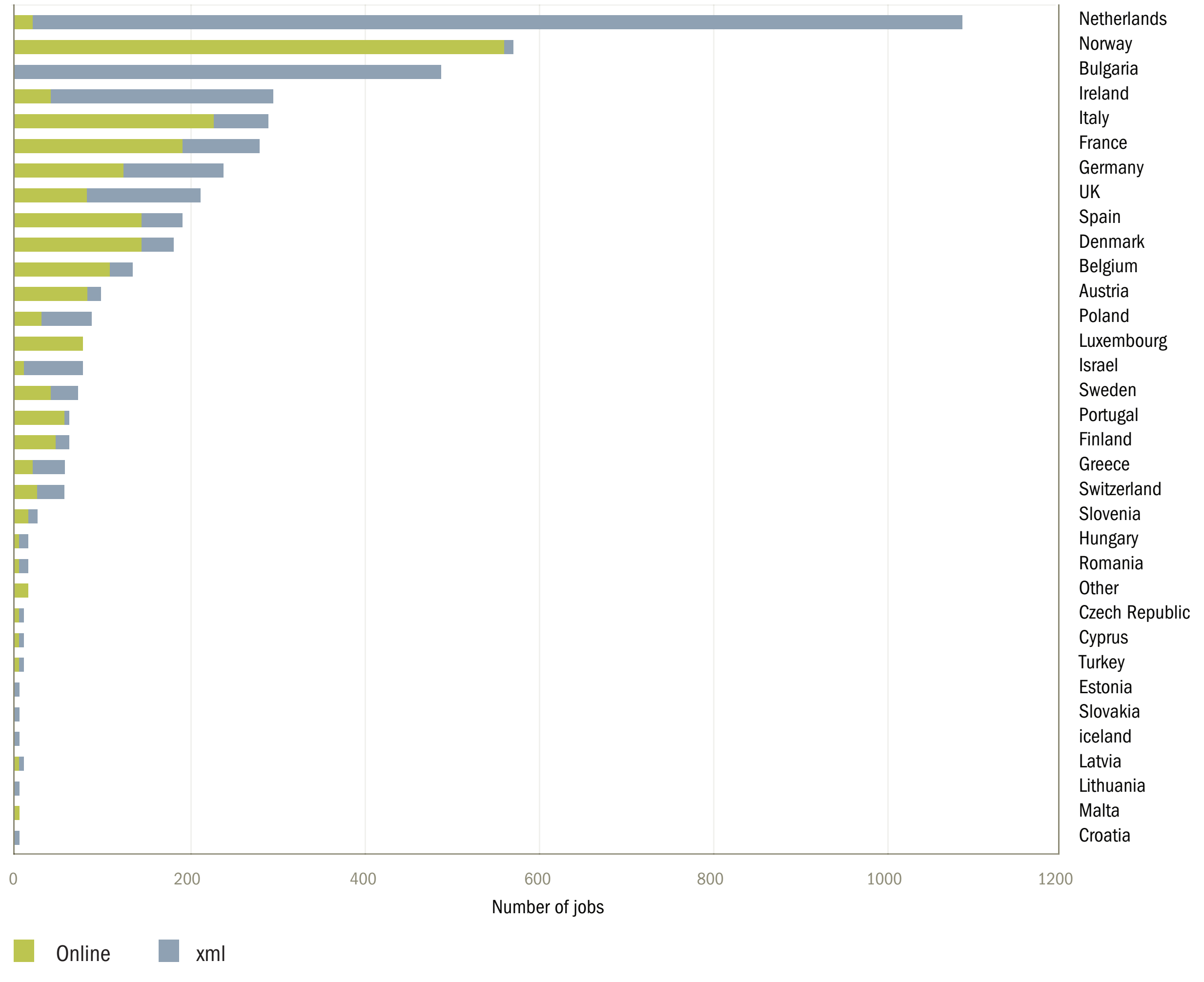
TABLE II.4.2 Number of jobs posted on the Researchers' Mobility Portal

	Online	XML	Total
2005	799	589	1388
2006	1749	3074	4823
2007	2176	2626	4802

Source: DG Research
Data: Researchers Mobility Portal

STC key figures report 2008

FIGURE II.4.5 Number of jobs posted on the Researchers Mobility Portal by country



Source: DG Research
Data: Researchers Mobility Portal

STC key figures report 2008

In conclusion, some EU Member States have come further than others in opening up their academic research systems to attract foreign researchers. This is particularly the case of the United Kingdom, Austria, Belgium, Denmark and the Netherlands. In absolute numbers, the largest intra-EU flows of mobile researchers seem to occur between the five largest EU Member States, with the United Kingdom being the main country of destination for mobile researchers. However, the United States, Canada, Australia and Switzerland have considerably higher shares of foreign doctorate holders than Germany.

[196] http://ec.europa.eu/eracareers/index_en.cfm. Now the EURAXESS Network with the former ERA-MORE network.

Chapter 5. Knowledge flows

The EC Communication of January 2000 'Towards a European Research Area' stressed the need for a **free circulation of knowledge across Europe and beyond**, a circulation of knowledge without barriers. In 2007, the Green Paper on ERA and the public consultation reconfirmed the importance of free **circulation of knowledge** across Europe, in the sense of **collaboration in the production of science and technology and open access** to scientific products, effective **knowledge transfer** between public research and industry as well as with the public at large and, finally, **exploiting knowledge produced outside Europe** [197].

This chapter presents the available statistical evidence on progress in these three areas, formulated into three questions: Are the levels of scientific and technological cooperation and the sharing of knowledge increasing in Europe? Is knowledge transfer between public research and society improving? Are European scientists and firms exploiting knowledge produced in other parts of the world?

MAIN FINDINGS

Knowledge production in the EU is more than ever generated within transnational scientific and technological cooperation. Researchers in Europe are increasingly involved in transnational S&T cooperation, and a large share of transnational co-publications and co-patenting include partners from non-EU countries. Transfer of knowledge from publications to patenting is stronger in the US, partly due to a smaller level of scientific publishing activity by European firms. Furthermore, major research-intensive countries in the world are mobilising their capacity to absorb knowledge produced outside their national borders. EU co-publication and co-patenting activity with partners from outside the EU is increasing. However, firms in the EU are lagging behind US firms in the exploitation of inventions produced abroad.

5.1 Are the levels of scientific and technological cooperation and the sharing of knowledge increasing in Europe?

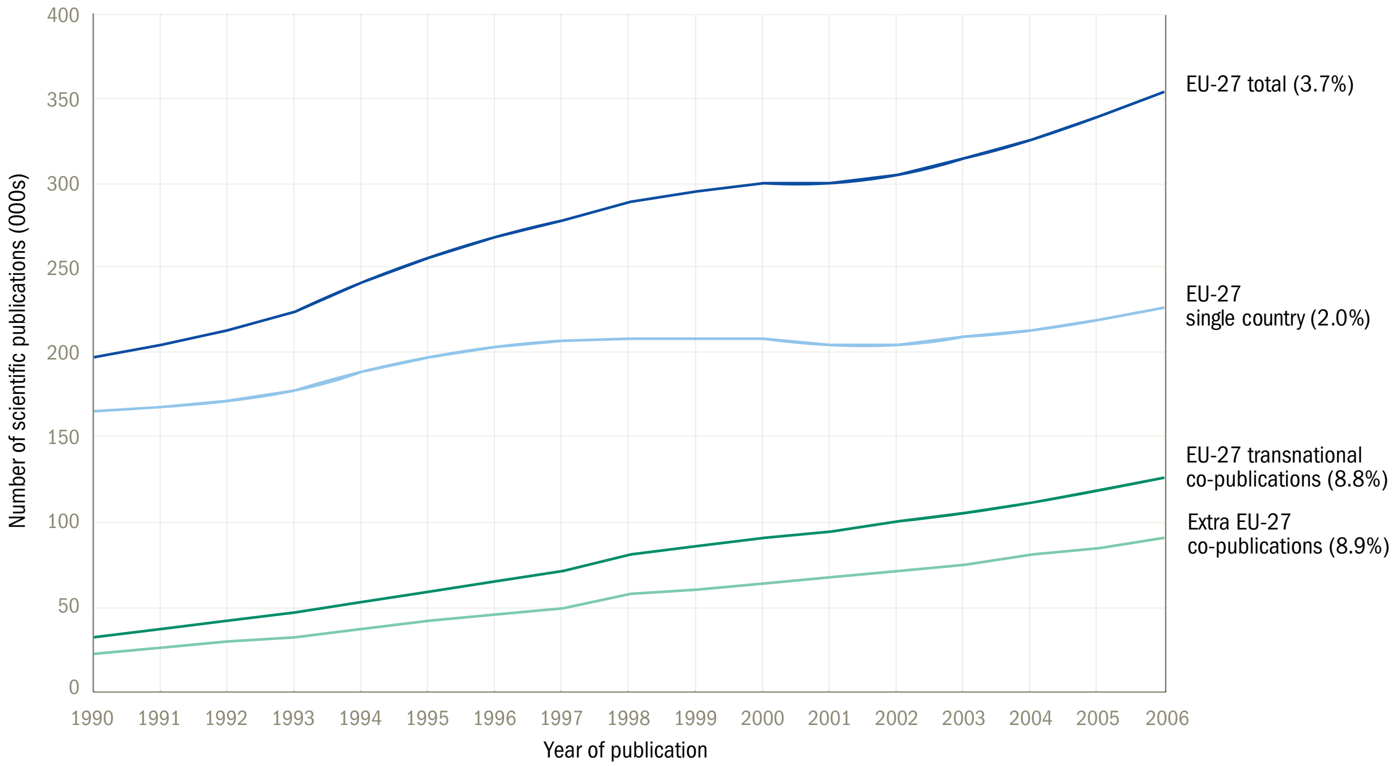
There are three main statistical sources available at European and world level that provide information on cooperation and sharing of knowledge in science and technology: co-publications, co-patenting and data on Open Access to scientific publications and journals. Relevant statistical studies may also include webometrics and in particular work on identifying scientific communities and pre-publishing knowledge-sharing in the scientific and technological fields. However, validated and comprehensive data at European level on pre-publishing knowledge-sharing are not yet available.

[197] Report on the public consultation on the ERA Green Paper, 2008.

There is a trend towards increased transnational scientific collaboration within the EU and between the EU and the rest of the world

Figure II.5.1 shows the total number of EU-27 scientific publications, the number of single country scientific publications, the number of transnational scientific co-publications involving at least one EU-27 Member State and, as a subset of the latter, the number of transnational scientific co-publications where at least one author is from a country outside Europe [198], for the period 1990-2006.

FIGURE II.5.1 EU-27 — Evolution of scientific publications and co-publications, 1990-2006 in brackets: average annual growth (%), 1990-2006



Source: DG Research
Data: Thomson Scientific/Rindicate Consortium

STC key figures report 2008

The graph illustrates that researchers from EU-27 are increasingly involved in transnational scientific collaboration. This is reflected by a higher growth of transnational joint research publications as against single country publications over the period 1990-2006. Whereas transnational co-publications had an average annual growth rate of 8.8 %, the single country publications recorded a rather modest increase of 2.0 % per annum.

Furthermore, a large and growing number of co-publications are produced in collaboration with at least one author from a country outside the EU. Of the total number of transnational co-publications in which researchers from EU-27 were involved in 2006, 71.2 % included also a partner from a non-EU country. This shows an increasing openness of European research towards the rest of the world.

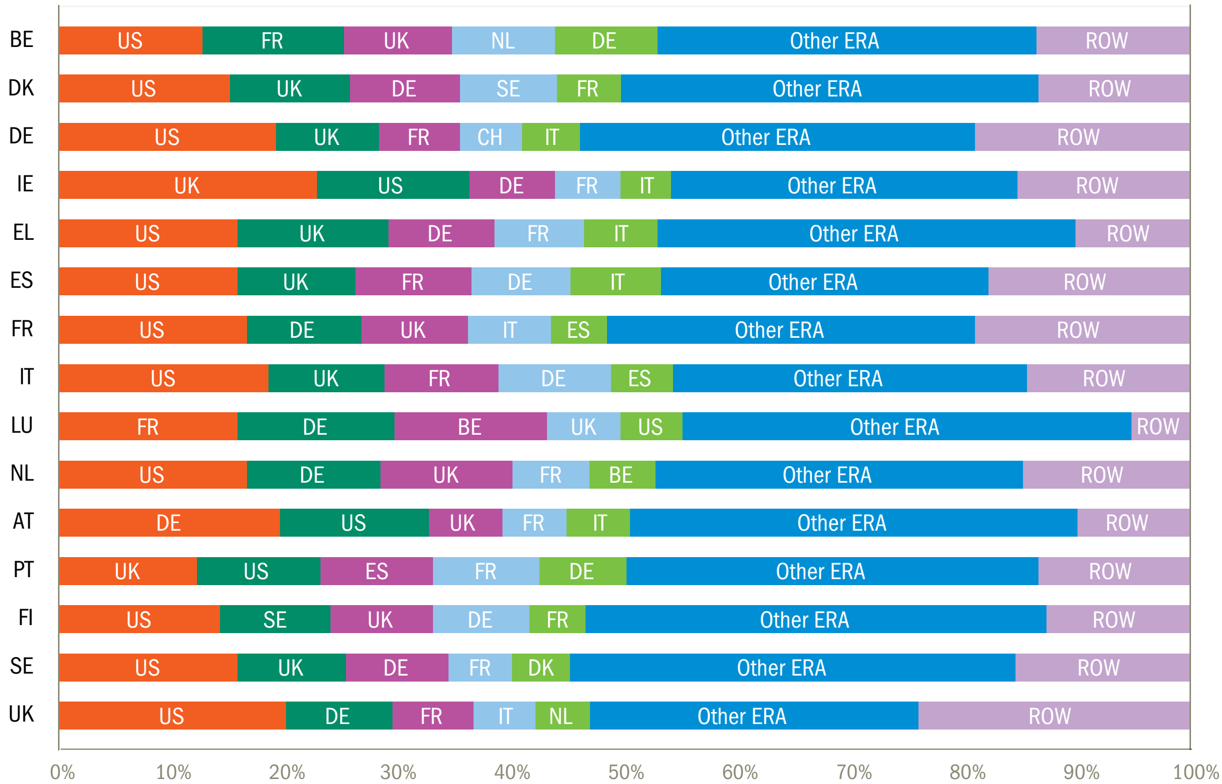
[198] In general, data presented on the co-publications refer to the EU-27 countries. The exception is Figure II.5.9, which regroups the countries associated with the European Research Area (the ERA countries). It should also be noted that co-publications – as well as co-patenting – are not complete indicators of scientific and technological cooperation. Complementary indicators (such as webometrics) are under development to measure informal cooperation or scientific cooperation not necessarily leading up to publication. For more details on the definitions used for co-publication, see Methodological Annex.

Researchers from European countries cooperate most frequently with colleagues from the US, Germany, the United Kingdom, France and Italy, as well as countries in geographical proximity

Although EU Member States collaborate most with other ERA countries [131], the single most important partner for most Member States is the US.

EU-15 Member States collaborate most with US partners, followed by the United Kingdom, Germany and France. Italy is also among the top five partners for seven Member States. Other main partners are often in geographical proximity, such as Sweden for Finland and Denmark, and Belgium for Luxembourg and the Netherlands.

FIGURE II.5.2 The five main co-publication partners of each EU-15 Member State (%), 2000-2006



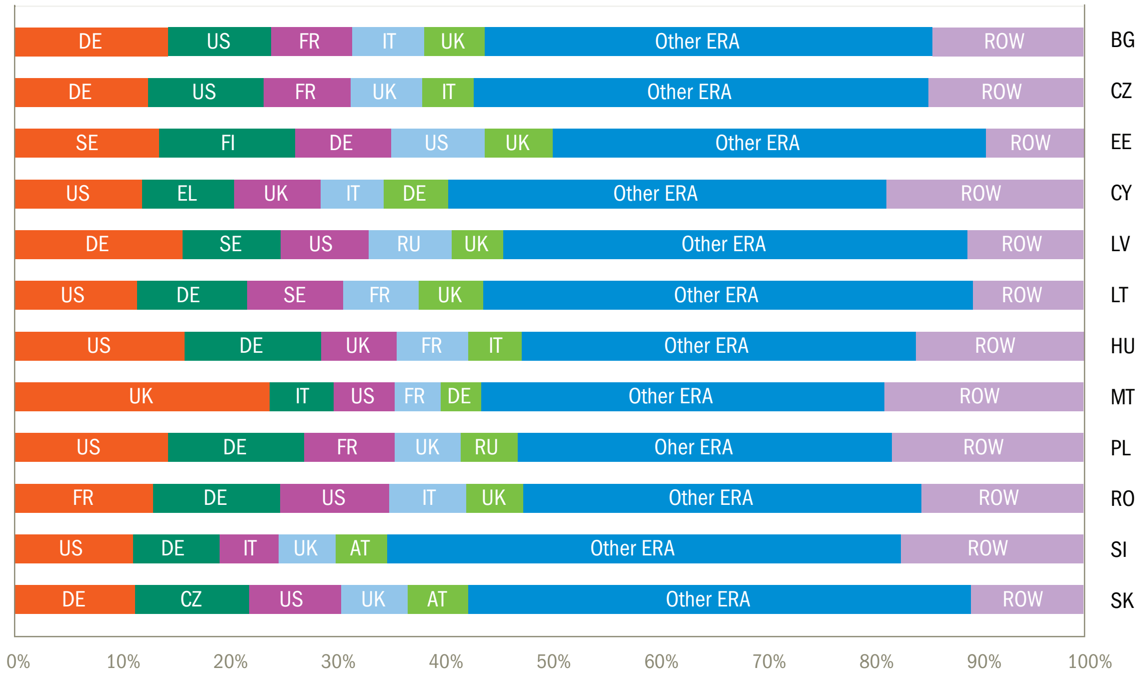
Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University

STC key figures report 2008

The collaboration patterns for the 12 new Member States (EU-12) differ from those of the older Member States (EU-15)

The US and Germany are the main co-publication partners for most of the new Member States, followed by the United Kingdom, France and Italy. Geographical proximity also plays a role. Sweden is a main partner of Lithuania, Latvia and Estonia, and Austria is a significant partner for Slovakia and Slovenia.

FIGURE II.5.3 The five main co-publication partners of each of the 12 new Member States (%), 2000-2006



Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University

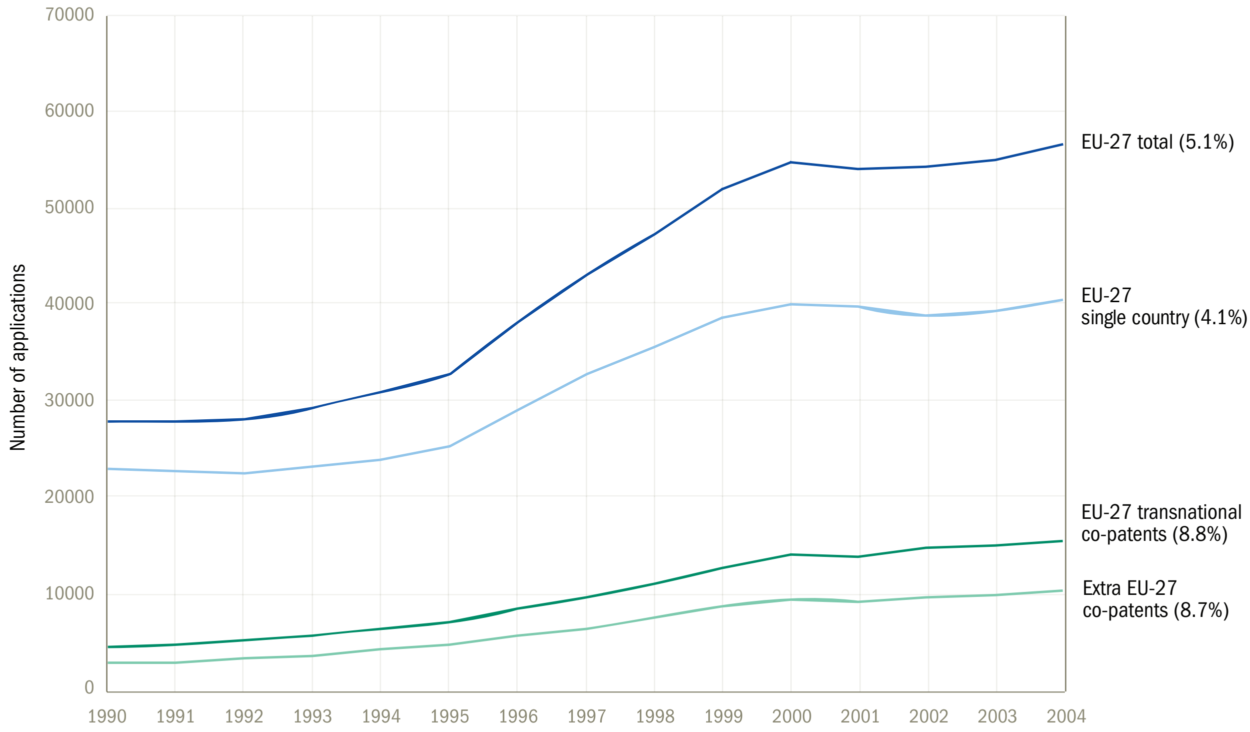
STC key figures report 2008

Transnational cooperation in technology production has more than tripled since 1990

Circulation of knowledge can be measured not only in terms of scientific co-production but also in terms of co-patenting activity. Co-patenting is an indication of cooperation in technological development. Patents are fairly good indicators of the inventiveness of countries or regions, and can provide evidence on technological changes and trends. They also play an important role in the dissemination of knowledge, as well as the role they play in the protection of intellectual assets. The incidence of co-patenting is determined by a number of factors such as the environment of the researcher/inventor, the composition of his or her research team, the contractual context in which the research is being performed, the degree of internationalisation of the research institution, the region and country as well as the technological field.

Figure II.5.4 shows that in the period 1990-2004 the total number of transnational co-patents in which EU-27 applicants were involved increased annually by 8.8 %, which is more than the increase of total patents (5.1 %). The total number of EU-27 transnational co-patents has increased from 4,920 in 1990 to 16,019 in 2004. However, many new EU Member States (Slovenia, Hungary, Czech Republic and Poland), and also some old Member States such as Italy and Spain, show higher growth rates of domestic patents than of transnational co-patents.

FIGURE II.5.4 **EU-27 — Evolution of patent and co-patent applications, 1990-2004 in brackets: average annual growth (%), 1990-2004**



Source: DG Research
Data: Rindicate Consortium

STC key figures report 2008

EU-27 opens up co-patenting in collaboration with applicants from non-EU countries

Figure II.5.4 also shows that co-patenting with partners from non-EU countries has grown at a rate of 8.7 % per annum over the period 1990-2004. The increase in EU-27 co-patenting with partners from outside the EU has followed the same trend as overall EU transnational co-patenting. In 2004, 67.9 % of total transnational co-patents involving EU-27 applicants also included a co-applicant from a country outside the EU. Germany, France and the United Kingdom involve non-EU country partners in most co-patenting activities. The three Nordic countries also show a higher co-patenting collaboration with applicants from outside the EU than with applicants from other EU Member States [199]. On the other hand, 20 EU Member States show a high degree of co-patenting with partners from other EU Member States [200].

In conclusion, in the EU, knowledge is increasingly generated in transnational cooperation. Researchers in the EU are more involved in scientific and technological collaboration as measured by transnational co-publications and co-patents, both with an average annual growth rate of almost 9 %. At the same time, EU knowledge cooperation is opening up to non-EU countries. The transnational scientific cooperation takes place mainly with a partner from a large country (the US, the United Kingdom, France, Germany and Italy) as well as with neighbouring countries. As regards transnational technological cooperation, larger Member States and the Nordic countries are more likely to form co-patenting partnerships with countries outside Europe, whereas the other Member States predominantly co-patent with partners from other EU countries.

[199] Finnish and Danish co-patenting activity, including at least one partner from a country outside Europe, has grown by average annual rates of over 10 % and 11 % respectively between 2000 and 2004 compared to growth rates of -1.7 % and 0.1 % respectively for domestic patents and -9 % and 1 % respectively for co-patenting with other EU countries. Sweden shows a similar pattern, with an average annual growth rate of 4.7 % for Swedish co-patents with third countries, compared to negative growth rates both for single country patents and for intra-EU co-patents of -3 % and -1.6 % respectively.

[200] See Statistical Annex.

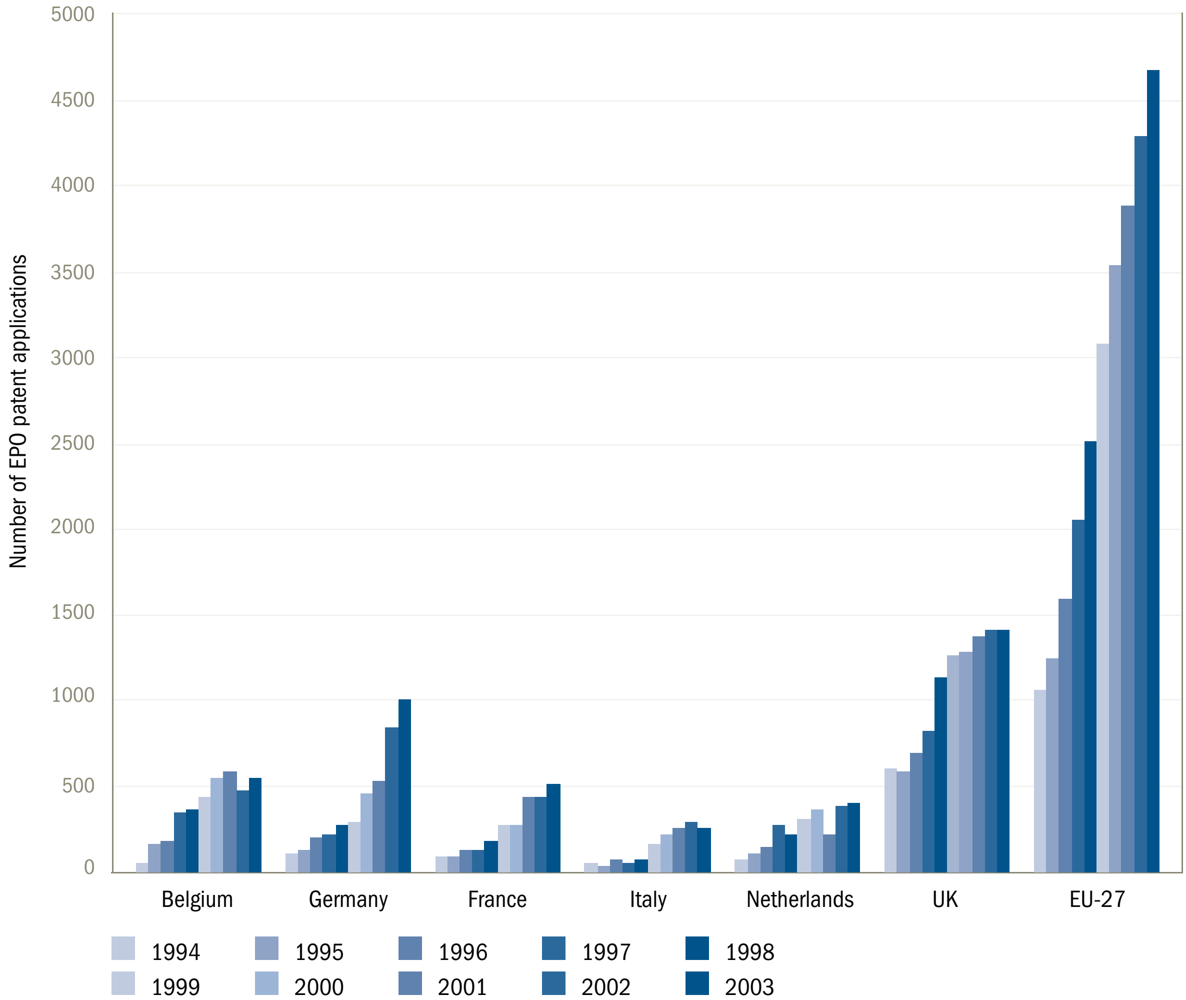
5.2 Is knowledge transfer between public research and society improving?

Where knowledge is transferred from the public sector to the business sector, it broadens the links between science and the economy and brings the benefits to society as a whole. An increasing number of public institutions are actively promoting the transfer of their R&D results to industry, with a view to promoting their exploitation and providing justification for an increase in expenditure on public research. To facilitate the conversion of new knowledge produced in their laboratories into patent-protected public knowledge that can potentially be licensed by others or form the basis for a start-up firm, more and more universities have established technology management or technology transfer offices.

European higher education institutions have increased their patenting activity over the last 10 years

Patents are one of the most common indicators used to measure the technological output of R&D. The number of patents applied for by higher education institutions (HEIs) in the most active countries over the period 1992-2003 [201] is shown in Figure II.5.5.

FIGURE II.5.5 Number of EPO patent applications by higher education institutions (HEIs) in selected countries, 1994-2003



Source: DG Research
Data: Eurostat

STC key figures report 2008

[201] *These data concern patent applications to the European Patent Office (EPO). Therefore they do not reflect exactly the inventive activity developed within higher education institutions. Firstly, because, the data concern only patents applied for by the higher education sector. Patents applied for by external Technological Transfer Offices are not all included in these data. Secondly, in a stricter sense, the research institution technological output should be monitored through the inventors of the patents. This is not feasible given the data currently available to the Commission services.*

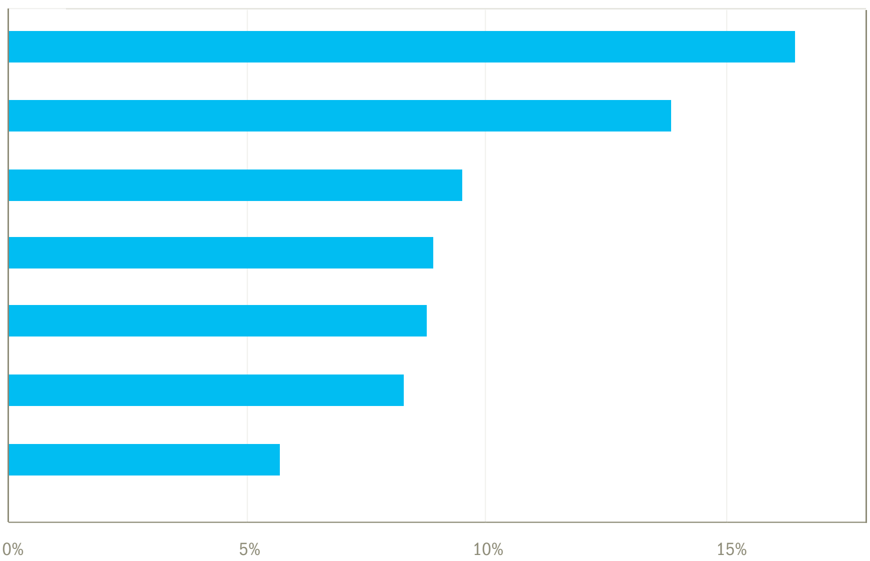
However, the number of EPO patents applied for by EU-27 higher education institutions represents less than 10 % of the total number of EPO patents applied for by EU-27 applicants [202]. Nevertheless, this figure represents a growth rate of 28.2 % for the same period.

Considering a five-year period (1999-2003), the institutions in the United Kingdom alone represent more than one third of the total number of patents applied for by higher education institutions in EU-27 (34.6 %). And the six most active countries over the same period (in decreasing order: the United Kingdom, Germany, Belgium, France, the Netherlands and Italy) contribute to almost 90 % of the total (88.8 %) number of patents applied for by higher education institutions. However, other EU Member States are increasing their shares – Denmark, Spain and Ireland have close to or more than one hundred patents per year.

Universities and higher education institutions are not the main cooperation partners for innovative firms in the EU

The public sector is not the preferred partner in the development of projects for innovative firms in the EU (Figure II.5.6). Suppliers of equipment, clients or customers, other enterprises within the company group and consultants are the more frequently selected cooperative partners. Suppliers of equipment and clients are more involved in cooperative activities with innovative firms than enterprises within the same group of firms. Universities also have an important role and are at the same level as consultants and commercial laboratories and slightly ahead of competitors or firms of the same sector.

FIGURE II.5.6 EU-27 — Main cooperation partners of innovative enterprises as % of innovative enterprises, 2002-2004



Source: DG Research
Data: Eurostat

STC key figures report 2008

The situations differ at country level. In Finland, universities and other higher education institutions are one of the chosen partners for one in three innovative companies, and public research institutes are selected as a partner by one out of four innovative companies. Moreover, Finnish companies are estimated to have on average five different cooperation partners in their innovation activities, which is above the average value for the EU. Innovative companies in Lithuania cooperate the most: this is due to a high degree of cooperation with suppliers of equipment, materials components and software. Innovative companies in Poland, Sweden and Denmark have very high levels of all types of cooperation. On the other hand, in Austria the preferred cooperation partners for innovative firms are universities and other higher education institutions [203].

[202] For example, for the year 2003, a total of 4,661 patents was applied for by HEIs compared to an overall total of 51,010 patent applications in the EU-27.
[203] Source: Eurostat.

The citation of scientific publications in patents is generally lower in the EU than in the US

Another indicator for knowledge transfer between research and industry measures scientific publications cited in patents. This indicator shows that knowledge flows from science to technology have increased in recent years. A comparison between the EU and the US reveals, however, an ongoing relative weakness in the EU in the process of knowledge transfer from science to technology [204]. This analysis covers five of the most science-intensive technological fields: transmission of digital information, speech analysis, semiconductors, lasers and biotechnology. High-quality scientific publications are usually heavily cited in patents, showing that high-quality publications find their way into the technological realm.

TABLE II.5.1 Shares of the EU and the US in the total number of scientific publications cited in patents for five science-intensive technological fields, 1990-2003

	Transmission	Speech analysis	Semiconductors	Laser	Biotechnology
	EPO PATENTS				
All cited publications					
EU-27 [1]	26.9	32.1	19.6	23.9	29.8
US	45.9	39.7	46.1	45.5	53.4
Highly-cited publications					
EU-27 [1]	28.3	55.7	10.1	11.4	24.9
US	52.1	26.4	49.6	61.3	63.6
	USPTO PATENTS				
All cited publications					
EU-27 [1]	15.8	19.9	12.7	20.7	22.3
US	60.1	61.2	60.7	53.6	64.2
Highly-cited publications					
EU-27 [1]	11.0	18.7	9.7	14.7	19.7
US	76.9	68.3	64.5	55.7	68.9

Source: DG Research
Data: DG Research
Note: [1] EU-27: EU-27 does not include BG and RO

STC key figures report 2008

EPO data show that the shares of total scientific publications cited in patents are higher for the US than the EU in most fields (e.g. the field of transmission of digital information 45.9 % against 26.9 % for all cited publications, and 52.1 % against 28.3 % for highly-cited publications respectively). The exception is the field of speech analysis, where although the EU share is lower than that of the US for all cited publications (32.1 % against 39.7 %), it is higher in the case of highly-cited publications (55.7 % compared to 26.4 %). As expected, the USPTO data show that the shares of the US are higher, both for all cited and for highly-cited publications. This seems to indicate that high-quality European scientific publications do not find their way into the technological realm to the same extent as US publications.

[204] *The analysis is based on a study conducted on behalf of the European Commission and based on data for the period 1990-2003: Breschi, S.e.a.,* Highly cited publications and research networks, *(Research contract carried out by CESPRI-University Bocconi on behalf of the European Commission (research contract PP-CT-M2-2004-005), 2006.*

The higher level of scientific publications cited in patents in the US is partly linked to a larger proportion of scientific publications produced by the private sector

Scientific publications produced by public research institutions feature in the patent citations of EU organisations to a comparable and often higher extent than they feature in the patent citations of US organisations. However, scientific publications produced by the private sector feature to a considerably lower extent in the patent citations of EU organisations. Taking the field of transmission of digital information as an example, US private companies account for 66 % and 75 % respectively of all highly-cited scientific publications in patent applications by US organisations to the European Patent Office (EPO) and in patents granted by the United States Patent Office (USPTO). The corresponding figures for European private companies are, respectively, 39 % and 64 %. On the other hand, for the same field, US public research institutions account for 32 % and 23 % of all highly-cited scientific publications in patents, compared to 50 % and 36 % for European public research institutions.

As private companies account for a quite large share of highly-cited publications in patents for all technology fields, the low degree of involvement of private companies in Europe in the conduct of research leading to the citation of scientific publications in patents is an indication of a weakness in the way knowledge is transferred from science to technology [205].

The R&D personnel working in companies are big producers of scientific and technological papers all over the world, and EU companies are no exception to this rule. Over the period 2000 to 2005, the top 25 research-intensive companies and private research organisations authored 73,707 publications [206]. All of these companies and institutions are also among the world's top R&D investors, although not in the same order of ranking as for scientific production. Of these top 25 publishing companies, 11 are EU companies, 8 US, 5 Japanese and 1 company is from South Korea.

Europe is taking the lead in sharing scientific knowledge in open access repositories

Knowledge transfer takes place not only between public research and industry but also more broadly between research and society. In the last five years Open Access has become a major tool for the transfer of knowledge from public research to society. Open Access is defined as free access to the reader, over the Internet, of scientific peer reviewed published articles resulting from publicly funded research. Open access repositories contain collections of publications (books, journals) which are available online free of charge to readers [207].

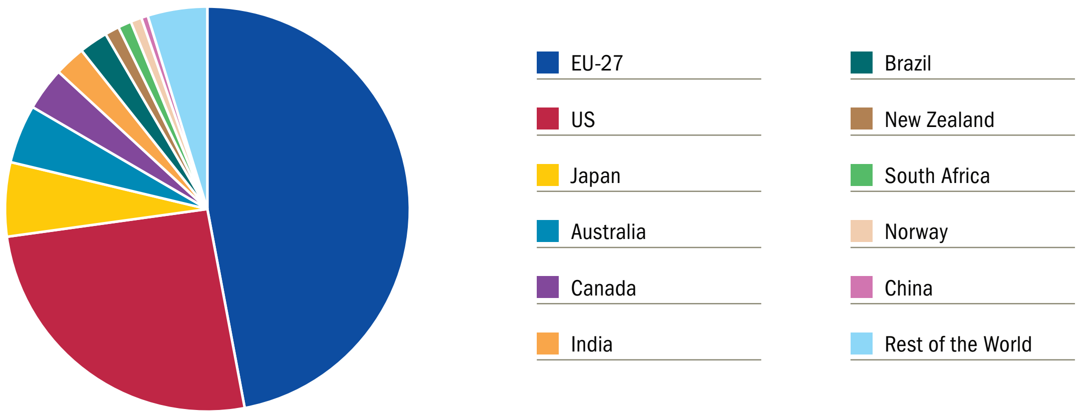
According to the directory of academic Open Access repositories, in June 2008 the worldwide total number of repositories was 1,152, with almost half (561) of these attributed to Europe. Of these, EU-27 accounts for 533 repositories.

[205] The same conclusion can be found in a study commissioned by the European Commission in 2002: A. Verbeek, 'Linking science to technology – bibliographic references in patents'.

[206] This total double counts the publications that are authored by two of these companies. The sector the most represented by far, in accordance with the ICB (Industrial Classification Benchmark) is pharmaceuticals. Some of the 25 top publishing companies are in other sectors, like software & computer services and technology hardware & equipment. Other factors that should be taken in consideration when comparing scientific publication output are size and internal policies. A common characteristic of these top scientific publishers is that they are also amongst the list of companies with the highest expenditures on R&D.

[207] They can be hosted by various research institutions around the world, as well as libraries, archives, etc. A repository may contain the host institution's research outputs, the publications of a number of research institutions, or publications related to a certain scientific/academic field.

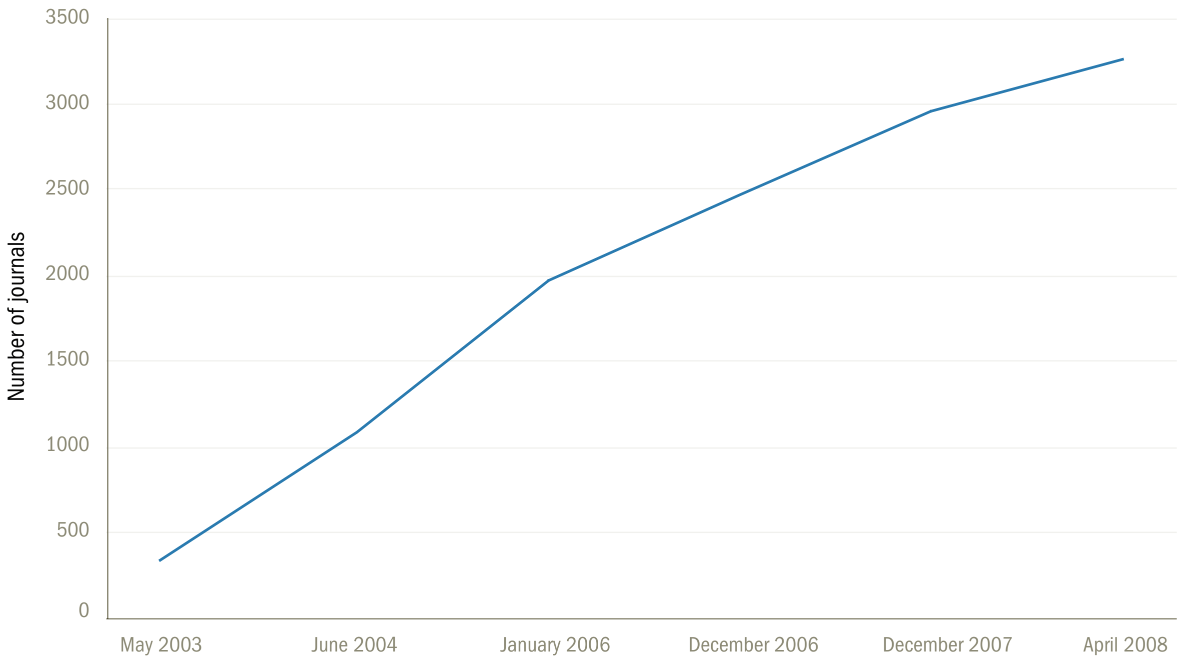
FIGURE II.5.7 Worldwide Open Access repositories



Source: DG Research
Data: Directory of Academic Open Access repositories

STC key figures report 2008

FIGURE II.5.8 Open Access journals



Source: DG Research
Data: Directory of Open Access journals

STC key figures report 2008

In EU-27, the countries with the most Open Access repositories are Germany and the United Kingdom with 125 repositories each, followed by the Netherlands with 45 and France and Italy, both with 39. Figure II.5.7 shows that US repositories represent more than one-quarter of the total. Of the emerging countries, India has 28, Brazil 26 and China 6.

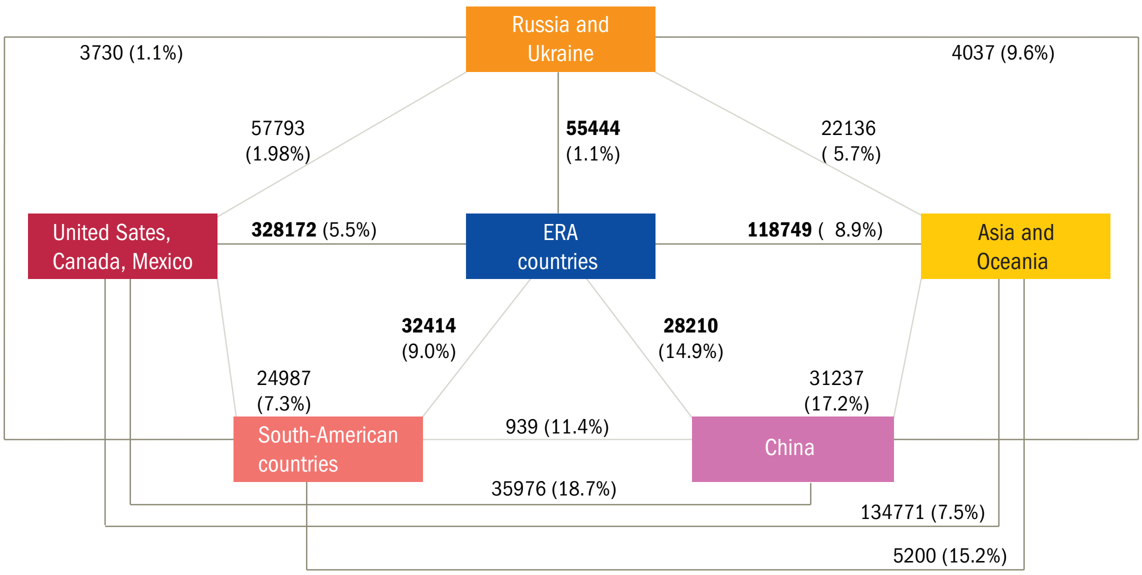
In conclusion, although higher education institutions in Europe have increased their patenting activity and created new technology transfer offices, the link between patents and publications is still weaker in the EU than in the US. There is less scientific publishing activity in European firms. Moreover, universities and public research institutes do not appear as the main cooperation partners for innovative firms in Europe. On the other hand, knowledge transfer from public research to society has increased over the last five years with the EU having the largest share of open access repositories in the world.

5.3 Are European scientists and firms exploiting knowledge produced in other parts of the world?

Countries in Northern America and countries in the European Research Area are reinforcing their international scientific collaboration, in particular with Asia.

Transnational research cooperation is becoming a key indicator of the ability of economic zones to develop links between themselves. Europe, the US and Japan are competing to increase their links with major emerging research regions. Figure II.5.9 illustrates the cooperation between the countries within the ERA and different world regions. The figure shows the level of transnational scientific co-publication for each pair of world regions, between 2000 and 2006.

FIGURE II.5.9 Number of transnational scientific co-publication partners for each pair of world regions, 2000-2006 in brackets: average annual growth rates (%), 2000-2006



Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University

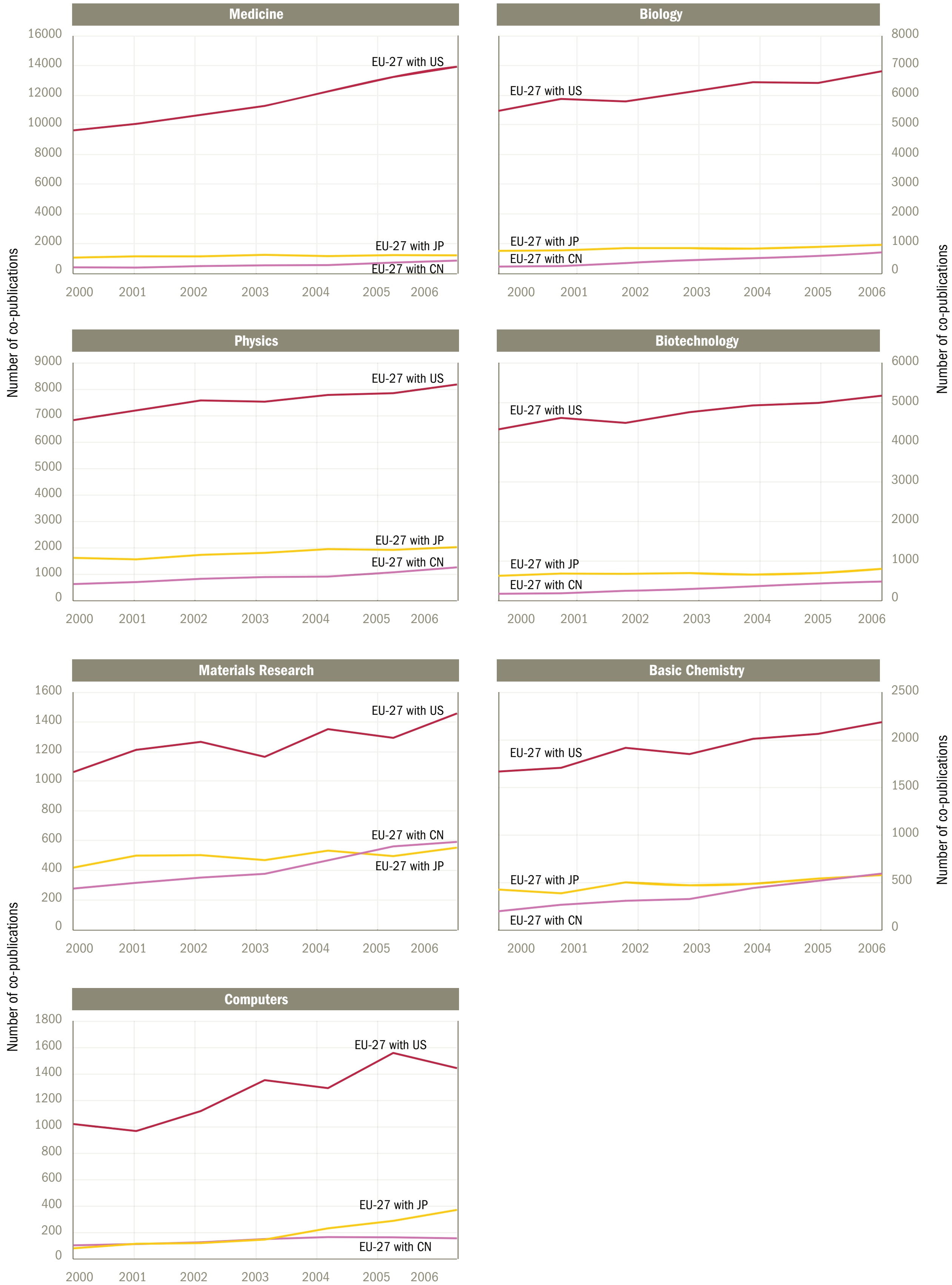
STC key figures report 2008

Figure II.5.9. shows that transnational scientific co-publication is increasing between all world regions. The highest level of cooperation takes place between authors from European and Northern American countries. There are more than 320,000 co-publications between these two blocks of science producers (which is significantly more than double the number of co-publications between North America and Asia, including China). However, the largest growth in scientific cooperation over the period 2000-2006 has been with researchers from Asia, and in particular from China. Figure II.5.9 also shows that the Northern American countries (and in particular the US) are reinforcing their scientific collaboration with China to a somewhat larger extent than the ERA countries. However, the ERA countries have consolidated their position as important scientific collaboration partners with the rest of Asia, Oceania and South America. This conclusion is confirmed when considering the growth rates of co-publications between 2005 and 2006 (the latest years available). Between 2005 and 2006 the US has increased co-publication with China by 15.3 %, compared to 9.9 % for the ERA countries. On the other hand, ERA researchers have increased co-publication with researchers from Asia (excluding China) and Oceania by 3.1 % compared to 1.6 % for the US.

The fields where European researchers cooperate more frequently with Japanese researchers are medicine, physics, biology, biotechnology and computers. However, cooperation with Chinese researchers is most frequent in materials research and basic chemistry.

US researchers continue to be the main collaborative partners for researchers from EU-27. However, an interesting trend can be observed regarding Japan, in relation to the emergence of China. Whereas in a number of fields (medicine, physics, biology and biotechnology) EU-27 researchers have a propensity to publish at a higher rate with Japanese partners than with Chinese partners, the trend is currently reversing in other fields. Between 2000 and 2006 China approached progressively towards the level of Japan as a preferred co-publication partner of EU-27 in the field of materials research and basic chemistry.

FIGURE II.5.10 Total number of EU-27 co-publications with world regions for selected scientific fields, 2000-2006

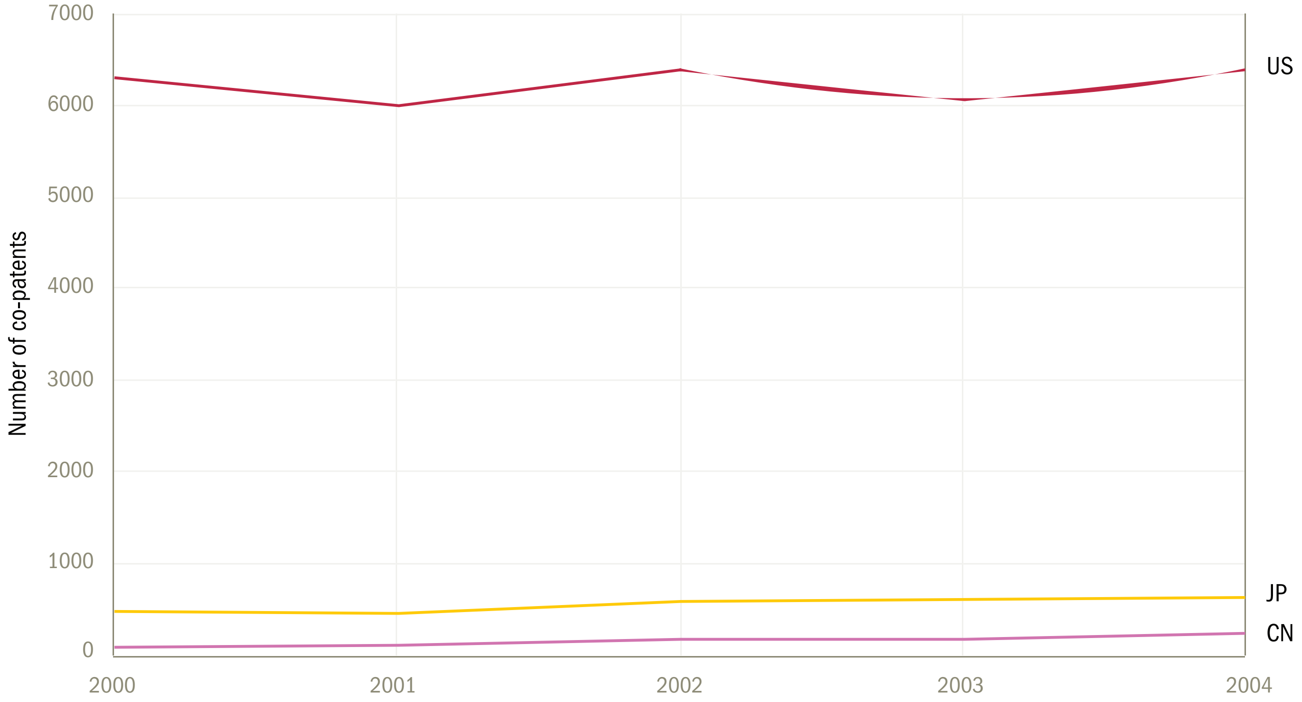


Source: DG Research
Data: Thomson Scientific/Rindicate Consortium

The US is also the main collaborative partner of EU-27 in co-patenting

As can be seen in Figure II.5.11, EU-27 Member States use co-patenting with the US as a collaboration tool in a very significant way, with between 6,000 and 7,000 co-patents per year. The number of EU-27 co-patents with Japan and China is much less important, with values of 200-300 for Japan and about 100 for China.

FIGURE II.5.11 EU-27 co-patents with US, Japan and China, 2000-2004



Source: DG Research
Data: Rindicate Consortium

STC key figures report 2008

Cross-border ownership of patents is increasing and, in the case of the EU, is mainly oriented towards inventions made in other EU Member States

Patent documents specify the inventor(s) and the applicant(s) – the owner of the patent at the time of application – along with their country (or respective countries) of residence. In most cases, the applicant is an institution (generally a firm, university or public laboratory), but can sometimes be an individual. The following analysis concerns patent applications to the EPO.

An increasing share of patent applications is owned or co-owned by applicants whose country of residence is different from the country of residence of the inventor(s) [208]. On average, 17.2 % of all inventions filed at the EPO were owned or co-owned by a foreign resident in 2003, a steady increase from 15.3 % in 1998 and 10 % in 1990.

The origin of foreign ownership in European countries is largely intra-European: companies from European countries owning inventions in other European countries. This is particularly true for small European countries. For inventions made in Germany and France, ownership by US residents is more frequent and, in the case of the United Kingdom, equals ownership by EU-27 residents. The US dominates foreign ownership of domestic inventions in Israel, Luxembourg and Turkey.

[208] Cross-border ownership is mainly the result of activities of multinationals: the applicant is a conglomerate and the inventors are employees of a foreign subsidiary. Patent data thus make it possible to track the international flow of knowledge from 'inventor' countries to 'applicant' countries.

EU ownership of inventions made outside the EU remains limited

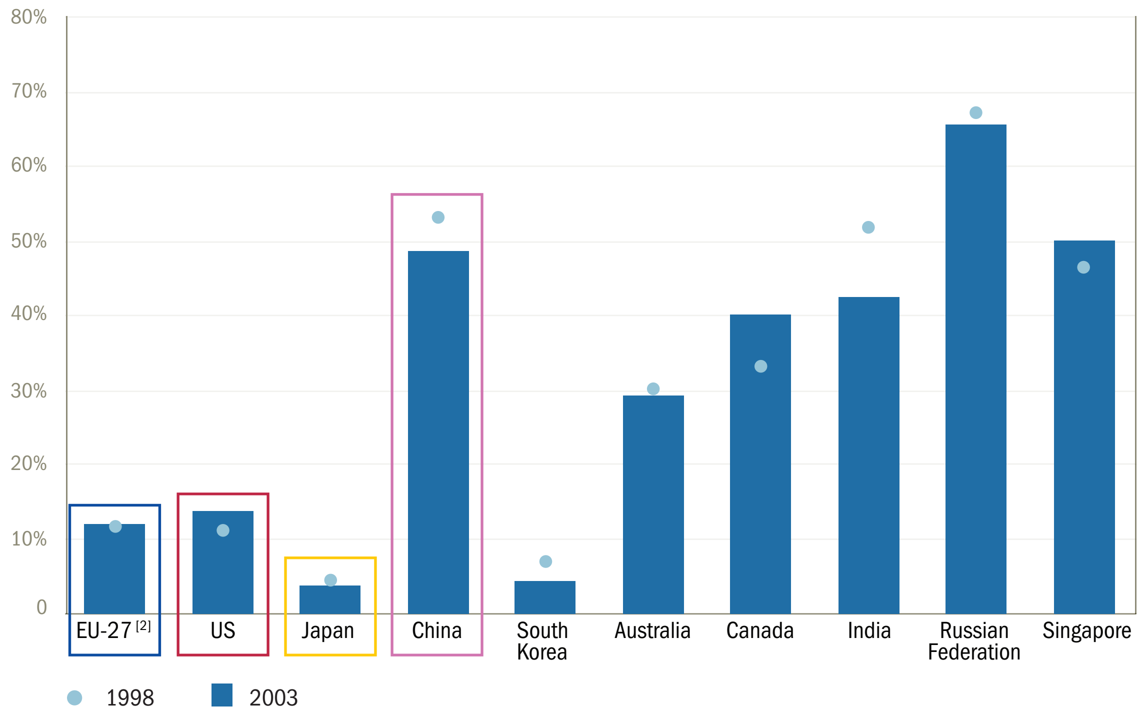
Domestic ownership of inventions made abroad can be used to assess the extent to which domestic firms control inventions made by residents of other countries. Because the share of patents invented in the EU has been decreasing over the years, it becomes more and more important for EU companies to be able to absorb inventions made abroad.

A comparison between Figure II.5.12 and Figure II.5.14 reveals that the share of patents owned outside EU-27 in all patents invented in EU-27 is slightly higher than the share of patents invented outside EU-27 in all patents owned in EU-27. In other words, EU ownership of non-EU inventions is less frequent than EU inventions owned by non-EU residents. This also holds for Australia, Canada, the Russian Federation, China and India[209]. The opposite is true for the US and Singapore, which indicates that these countries are more likely to acquire ownership of inventions made abroad. Foreign inventions have a greater share in US-owned patents than in EU-27-owned patents (Figure II.5.14). In contrast, Japanese and South Korean residents rarely own foreign inventions.

Domestic ownership of inventions made abroad is particularly high in small economies: 81.3 % of EPO patent applications by Luxembourg residents in 2003 were invented abroad (Figure II.5.15), compared to 52.3 % and 48.4 % in the cases of Switzerland and Ireland respectively. Domestic ownership reached a peak in China in 1997-1999 (about 48 % in 1998, see Figure II.5.14) after a constant rise in the 90s, but has since then declined towards its mid-nineties value of 19 %.

In conclusion, the EU is improving its absorption capacity of knowledge from other world regions, in particular from the US but also from other countries, by increasingly opening up its co-publication and co-patenting activities to non-EU country partners. However, regarding the patents produced outside the EU, relatively few of the inventions are owned by firms in the EU when compared to the higher absorption capacity of US firms.

FIGURE II.5.12 Foreign ownership (%) of domestic inventions [1], 2003

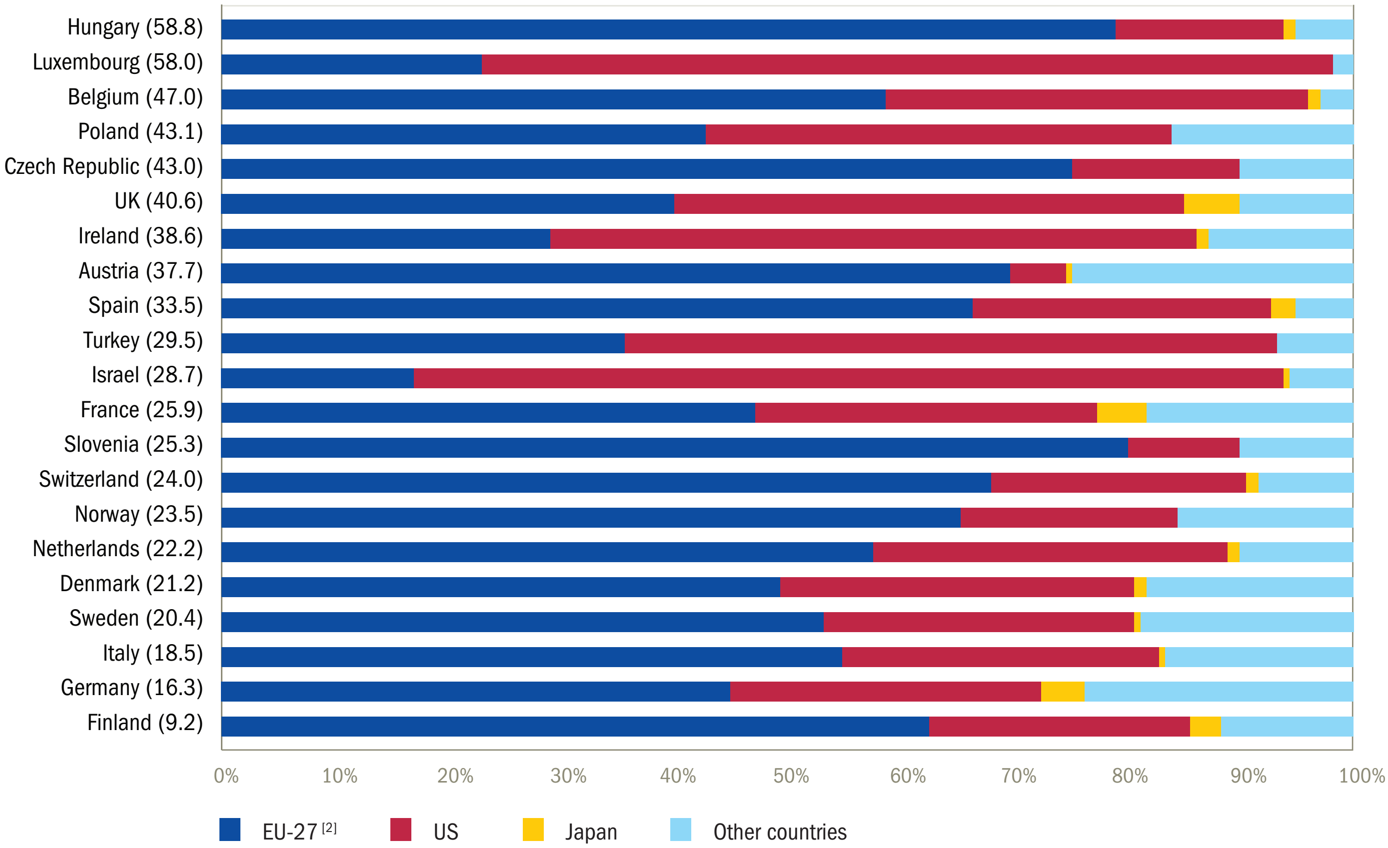


Source: DG Research
Data: OECD
Notes: [1] The share of domestic EPO patent applications owned by foreign residents
The patents count is based on the priority date and the inventor's country of residence
[2] EU-27 is treated as one entity

STC key figures report 2008

[209] *Foreign ownership of Chinese, the Russian Federation, Indian and also Canadian, Australian and Singaporean inventions is much higher than those of the EU and the US. In the case of China and India, it has slightly declined between 1998 and 2003, indicating that a growing share of their domestic inventions remains under control of domestic residents. Foreign ownership of inventions made in Japan and South Korea remains very limited.*

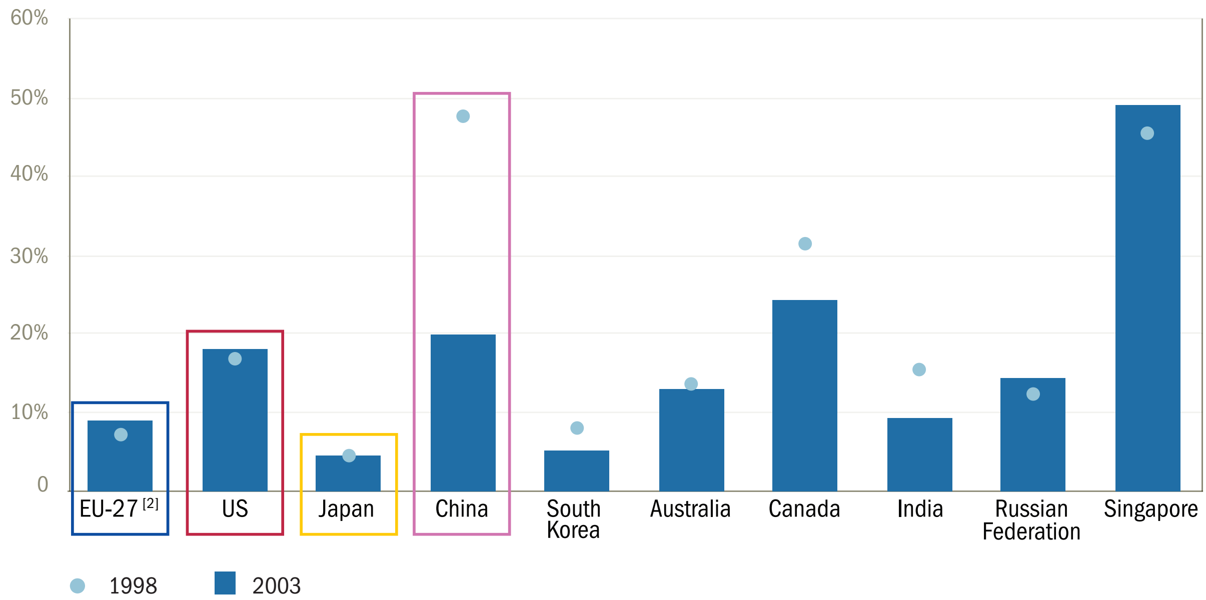
FIGURE II.5.13 Foreign ownership of domestic inventions [1], 2003; in brackets: the share (%) of domestic EPO patent applications owned by foreign residents



Source: DG Research
Data: OECD
Notes: [1] The share of domestic EPO patent applications owned by foreign residents
The patents count is based on the priority date and the inventor's country of residence
[2] In the cases of EU-27 Member States, EU-27 refers to all Member States except the Member State under consideration

STC key figures report 2008

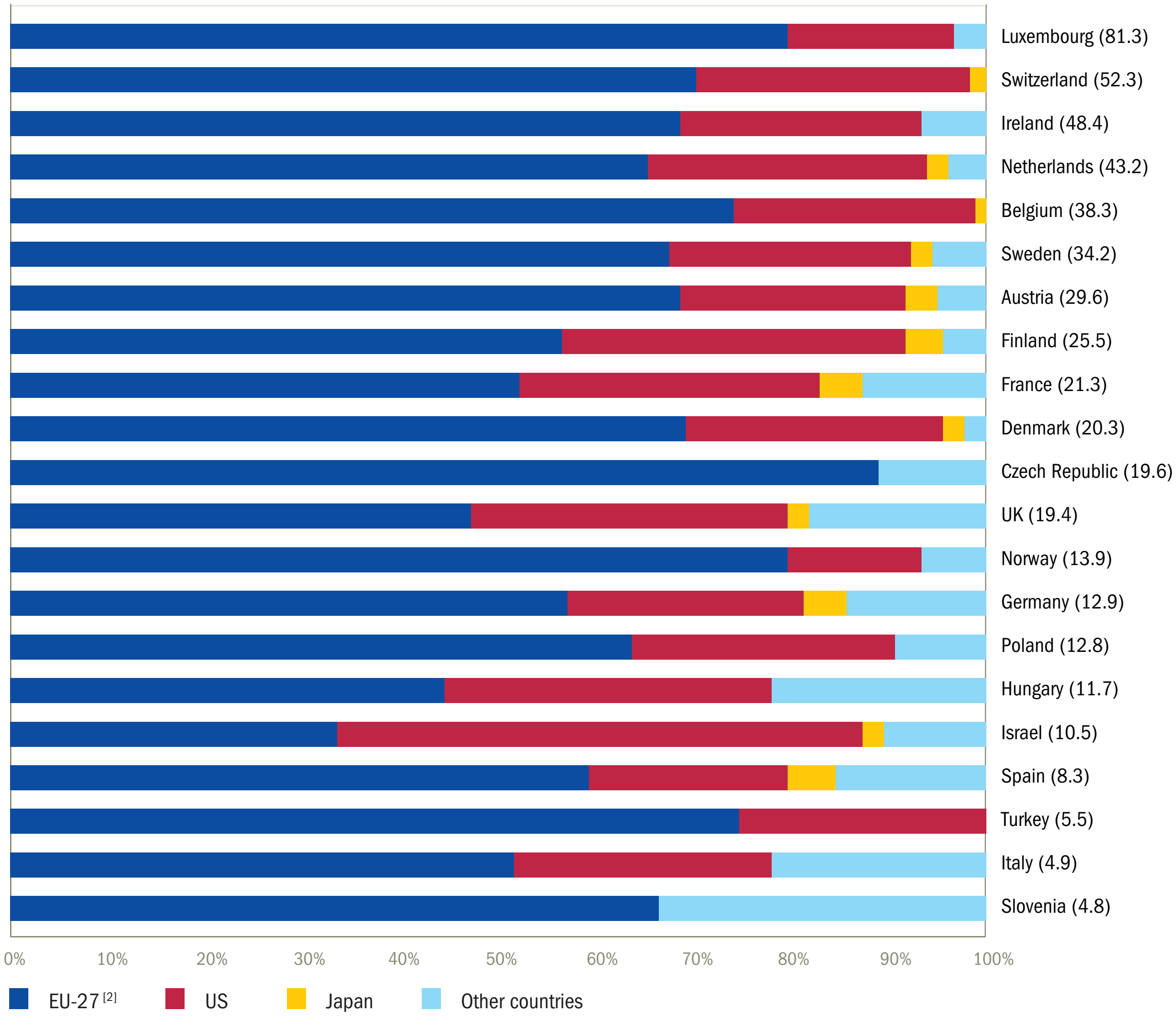
FIGURE II.5.14 Domestic ownership (%) of foreign inventions [1], 2003



Source: DG Research
Data: OECD
Notes: [1] The number of EPO patent applications owned by country residents but invented abroad as % of total EPO patent applications owned by country residents
The patents count is based on the priority date and the inventor's country of residence
[2] EU-27 is treated as one entity

STC key figures report 2008

FIGURE II.5.15 Domestic ownership of foreign inventions [1], 2003; in brackets: the share (%) of domestic EPO patent applications invented abroad



Source: DG Research

STC key figures report 2008

Data: OECD

Notes: [1] The number of EPO patent applications owned by country residents but invented abroad as % of total EPO patent applications owned by country residents
The patents count is based on the priority date and the inventor's country of residence

[2] In the cases of EU-27 Member States, EU-27 refers to all Member States except the Member State under consideration

Chapter 6. Opening up the ERA to the world

In January 2000, the EC identified the need to enhance the **international dimension of research** within and beyond Europe. It was recognised that research in Europe should align with the major concerns of the citizens and **address common problems** such as energy, environment and health, in association with partners from outside Europe. In 2007, the Green Paper on the ERA confirmed this objective of an **opening of the ERA to the world** as well as the **commitment of Europe to address global challenges together with Europe's international partners** by means of multilateral cooperation. The Green Paper stated that, in the global world of science and technology, European countries should **develop a coherent approach towards international cooperation** to ensure that S&T contributes effectively to stability, security and prosperity in the world.

These two policy issues can be formulated into two key questions: Is the European Research Area opening up to the world? Is European research showing a commitment to address global challenges by means of multilateral cooperation? This chapter will focus on the first question, as there is currently no European-level statistical collection on the financial research commitments by European countries to global challenges. This implies that the results presented reflect only part of the cooperation with countries outside Europe, as international cooperation is also financed by national budgets [210].

MAIN FINDINGS

Research in Europe is increasingly opening up to countries outside Europe. Statistics on mobility of S&T professionals, researchers, co-publications and co-patenting all indicate the same trend. At the Community level, the research framework programmes have opened up in extension and scope over the last 10 years. Most third-country participants come from the Russian Federation, the US and China. There are no comparable statistics on the financial commitments made by individual countries in Europe to address global challenges by multilateral research. However, the framework programme data indicate an interest of third countries in collaborating with European researchers on projects concerning health, environment, food and ICT.

6.1 Is the European Research Area opening up to the world?

As illustrated in Figure 1 of the Executive summary, around 75 % of research in the world is performed outside Europe. In parallel, research is distributed over a large number of countries well beyond the Triad. The changing landscape of global R&D is compounded by the fact that R&D activities in many countries are themselves becoming more international. In most industrialised countries, R&D performed abroad and by foreign affiliates represents some 16 % of total R&D expenditure and in many European countries even more [211]. Finally, research investment and funds for the exploitation of research outcomes are increasingly fungible, and the very production of research in Multi-National Enterprises is structured in global value chains. The increasing internationalisation of research has many consequences for research in Europe [212].

[210] Most European countries have long-lasting bilateral cooperation agreements with selected third countries, as a result of historical links, and/or for geopolitical, economic and trade reasons. This development is growing in importance on the policy agenda of all EU Member States. There is an increased awareness that it is possible, through coherent and joint efforts, to achieve more efficient use of resources, deeper impact of initiatives, and European leadership roles in a number of priority areas. See report 'Policy Approaches towards S&T Cooperation with Third Countries' by Jan Nill, Klaus Schuch, Sylvia Schwaag Serger, Joern Sonnenburg, Peter Teirlinck, Arie van der Zwan. December 2007. Analytical report on behalf of the CREST OMC Working Group.

[211] See part I of this report.

[212] See also the report 'Europe in the global research landscape', European Commission 2007.

Scientific production in Europe has a high involvement from researchers from non-European countries

The evidence presented in Part II of this report indicates that, over the last ten years, European research has opened up to countries outside Europe. The growth in mobility of S&T professionals has been greater for international mobility into Europe than for intra-European mobility. Furthermore, more foreign doctoral candidates in European countries come from non-EU countries than from EU Member States (14.1 % compared to 5.8 %).

Co-publication and co-patenting with foreign partners is an important channel for gaining access to knowledge in global S&T. The analysis in Chapter 5 shows an increase for nearly all EU-27 countries in numbers of co-publications with foreign research partners since the year 2000. The strongest links in scientific cooperation are between the US and Europe. The US is ahead of the EU in terms of cooperation with Asian counterparts [213].

The data on co-patenting activities with foreign partners reflect this general pattern [214]. Most EU-27 countries show an increase in international co-patenting activity, in particular Germany, Finland, France, Ireland, Poland and the United Kingdom. However, firms in the EU are lagging behind US firms when it comes to exploiting inventions made abroad. Of the patents produced outside Europe, relatively few are owned by firms in the EU.

The Community framework programmes have extended their capacity for international cooperation in the period 1998-2007

International scientific and technological cooperation has always been a part of EU research policy since the launch of the First framework programme in 1983. A wider opening to international cooperation was implemented under the Sixth framework programme from 2002 to 2006. While the former framework programmes focused almost exclusively on developing countries and on Central and Eastern European countries, the Sixth framework programme was open to third-country participation in all thematic areas. This dimension was strengthened under the Seventh framework programme (2007-2013) with new instruments designated under each of the specific programmes ('Cooperation', 'Capacities', 'People', 'Ideas') to promote international cooperation [215].

The participation of third countries in framework programmes has increased in the period 1998-2007

Figure II.6.1 shows the trend in third-country participation, which increased from 2.9 % of all participants in projects in FP5 to a first estimate of 5.5 % of participants in proposals listed for potential funding under the Cooperation and Capacities Specific Programmes in the first year of FP7. Associated countries [216] have also seen a similar increase from 5.3 % to 7.1 % under FP7.

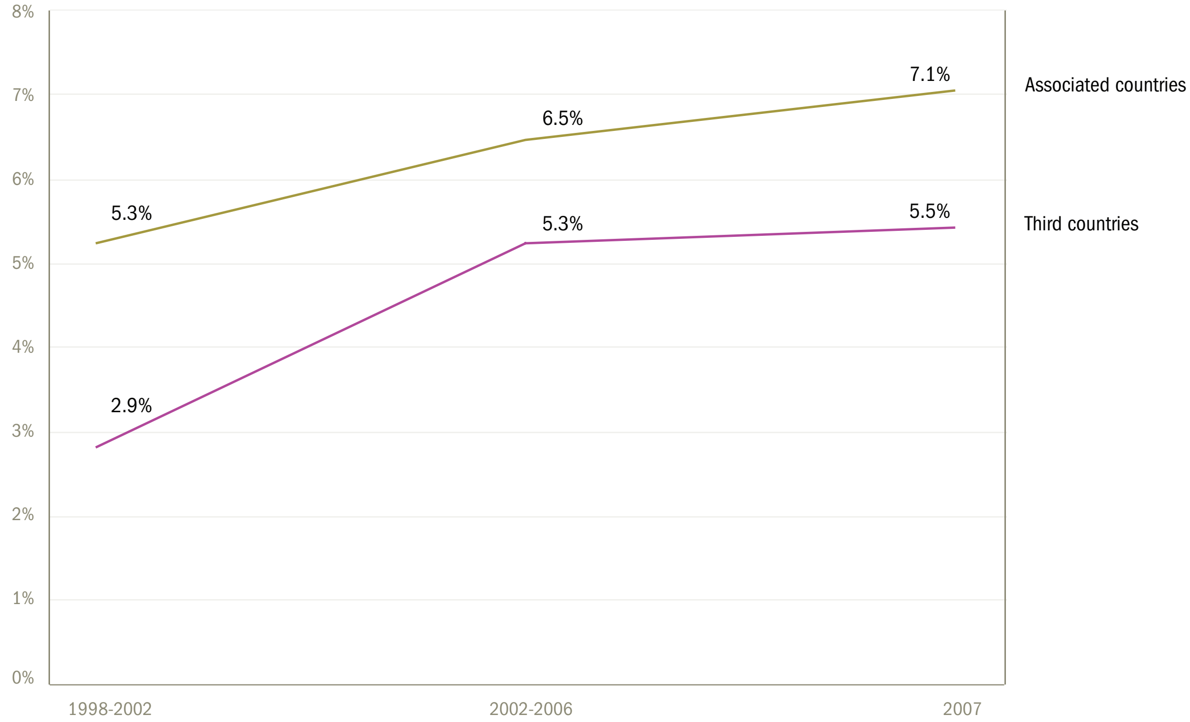
[213] See also OECD STI Scoreboard, 2007. Paris.

[214] See Part II, Chapter 5.3 as well as the Statistical Annex.

[215] For more details, see annex Methodological notes.

[216] Currently 11 countries (Albania, Croatia, the Former Yugoslav Republic of Macedonia, Montenegro, Serbia, Turkey, Iceland, Liechtenstein, Norway, Israel, and Switzerland) are associated to FP7 and a number of other countries have flagged their interest to enter into association negotiations. Associated countries are integrated into the European Research Area, therefore they are not included in the following analysis of third-country participation in FP activities. However, Figure II.6.1 illustrates the importance of these countries in terms of participation in FP activities.

FIGURE II.6.1 Associated and third country participation in the EC Framework Programmes, 1998-2007



Source: DG Research
Data: DG Research

STC key figures report 2008

In FP5 (1998-2002), 2,402 research teams from third countries participated in the joint research efforts in Europe. This participation increased in FP6 to a total of 3,942 third country research teams. Provisional results from the 2007 first calls for proposals in FP7 indicate 6,578 participants in proposals submitted to the Cooperation and Capacities Specific Programmes. Of these 1,071 are listed for potential funding.

Developing countries are the main cooperation partners within the EC framework programmes; emerging and industrialised countries have considerably increased their participation

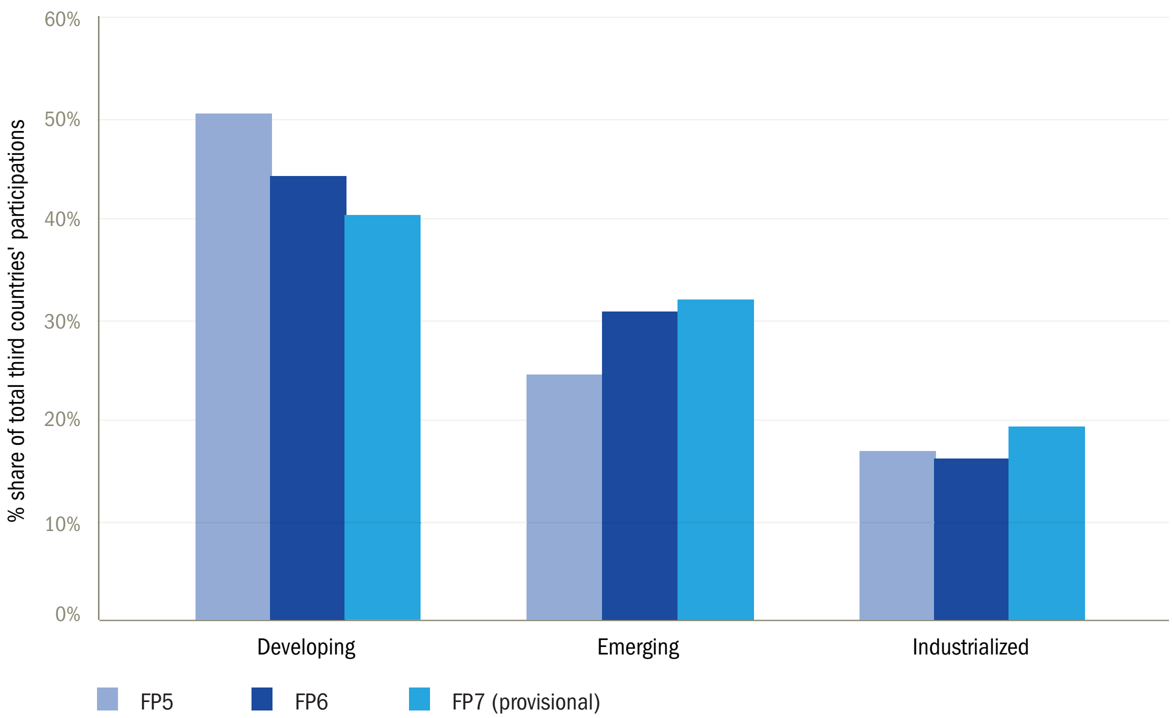
When looking at the overall distribution of the participation of third-country teams by economic region we see that, in absolute terms, developing countries have the highest number of participations and the highest EC financial contribution in both FP5 and FP6. They represent 53 % of third-country participations in FP5 and 47 % in FP6. EC funding to these countries has increased from approximately € 95.5 million to € 167.9 million. The second largest group of countries is the emerging economies [217], which increased their participation rate from 27 % in FP5 to 34 % in FP6 with a funding growth from € 46.5 million to € 131.7 million. Finally, the industrialised countries represent 20 % of all participants in both FP5 and FP6, with a tripling of funding over this period from € 7.5 million to € 23.7 million [218].

[217] Considered here are the Russian Federation, China, India, South Africa, Brazil and Mexico.
[218] The FP6 rules for participation allowed the funding of industrialised countries for the first time, under certain circumstances.

The initial estimations from the 2007 first calls under the FP7 Cooperation and Capacities Specific Programmes [219] confirm that developing countries still remain the leading participants with a share of 43 % of the total participation of third countries in proposals listed for funding [220]. Emerging economies rank second with 35 %, followed by industrialised countries with 22 % [154].

Figure II.6.2 compares participation rates for third countries by economic region for FP5 and FP6 with the FP7 provisional data on proposals listed for potential funding under the Cooperation and the Capacities Specific Programmes. It shows that, in relative terms, emerging economies and industrialised countries are increasing their participation shares, while the shares of developing countries are decreasing. However, in absolute terms developing countries still have the highest number of country participations.

FIGURE II.6.2 Evolution of third countries' participation by economic region in the FP5, FP6 and FP7 Cooperation and Capacities Programmes



Source: DG Research
Data: DG Research

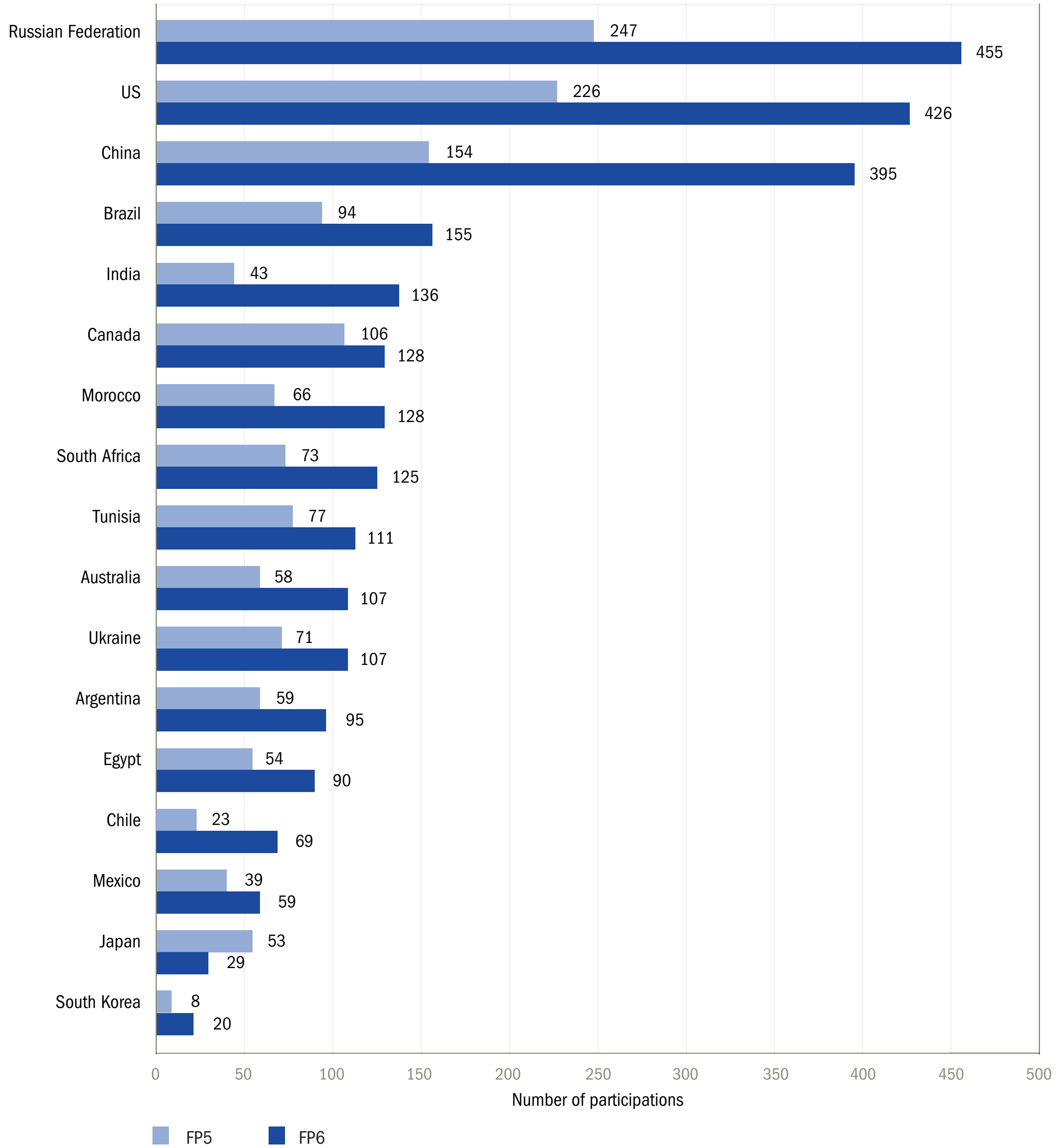
STC key figures report 2008

Most third-country participants in FP5 and FP6 came from the Russian Federation, the US and China

The five countries considered as emerging economies are in the top ten participating countries in FP5 and FP6: the Russian Federation ranks first, followed by China, India, Brazil, and South Africa [221]. The US leads the participation of industrialised countries, followed by Canada and Australia. Finally, Morocco leads the group of developing countries, followed by Tunisia, the Ukraine and Argentina. The leading countries participating in both programmes have all increased their participation in absolute terms between FP5 and FP6. However, in general third-country participation is still very low at 5.5 %. The Russian Federation, the US and China account for 32 % of third-country participation. Figure II.6.3 shows the number of participations by selected countries in FP5 and FP6.

[219] The following data from FP7 are based on provisional data (from June 2008) of applications submitted and listed to be funded in the Cooperation and Capacities Programmes, as a result of first calls for proposals launched in 2007.
[220] According to the list of countries to be funded under FP7, 137 countries are considered as 'developing countries'.
[221] The data presented in Figure II.6.3 (as well as in Figure II.6.4 and Table II.6.1) are not weighted, which implies an effect of 'country size', introducing a bias towards large countries.

FIGURE II.6.3 Participation of selected countries in FP5 and FP6



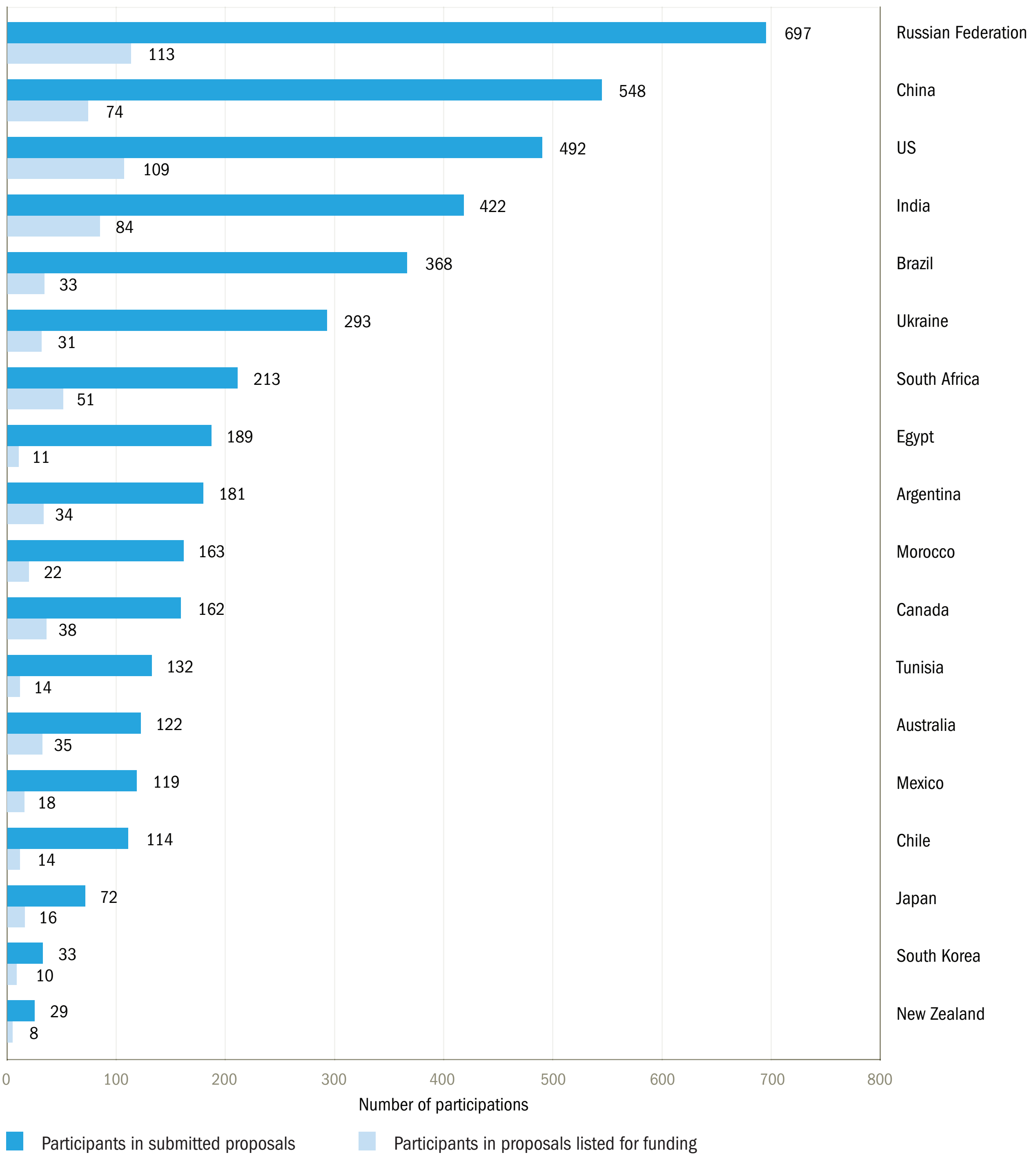
Source: DG Research
Data: DG Research

STC key figures report 2008

The Russian Federation, the US and China remain the leading countries under FP7

The provisional data on country participation in the FP7 Cooperation and Capacities Specific Programmes in the 2007 first call for proposals show that the three leading countries, the Russian Federation, China and the US, remain the same: the Russian Federation ranks first with 697 participations, China second with 548 participations and the US ranks third with 492 participations. India is in fourth position with 422 participations (see Figure II.6.4.). When it comes to proposals selected for funding, those involving industrialised countries have in general a higher success ratio than those involving other countries: 22 % in the case of the US and 29 % for Australia, while emerging economies vary between, for example, Brazil with 9 %, China and the Russian Federation with 14 % and 16 % respectively, and South Africa with 24 %.

FIGURE II.6.4 FP7 – Cooperation and Capacities Programmes – first calls for proposals 2007 – participation of selected countries in submitted proposals and in proposals to be funded [1]



Source: DG Research
Data: DG Research
Note: [1] Provisional data from June, 2008

Germany, France, Italy and the United Kingdom are the main cooperation partners for third countries, but smaller countries are increasing their collaborative links

All of the third countries under consideration have seen their collaborative links with EU Member States multiply several times over between FP5 and FP6. In general, Germany, France, Italy and the United Kingdom, being the largest research countries in Europe, have more extensive cooperative links than the other EU Member States. A typical example is cooperation with the Russian Federation and China: Germany leads, followed by the United Kingdom, France and Italy. However, other countries like the Netherlands, Sweden, Belgium, Finland, Greece, Hungary, Poland and Austria have strong links with the Russian Federation and China as well. Cooperative links with Brazil are highest for the United Kingdom, followed by Germany, France and Spain. Smaller countries such as the Netherlands, Belgium and Denmark also play a significant role in establishing global collaborative links (see Figure II.6.5).

TABLE II.6.1 Cooperative links between EU countries and selected third countries in FP5 and FP6 funded projects

NUMBER OF LINKS PER COUNTRY

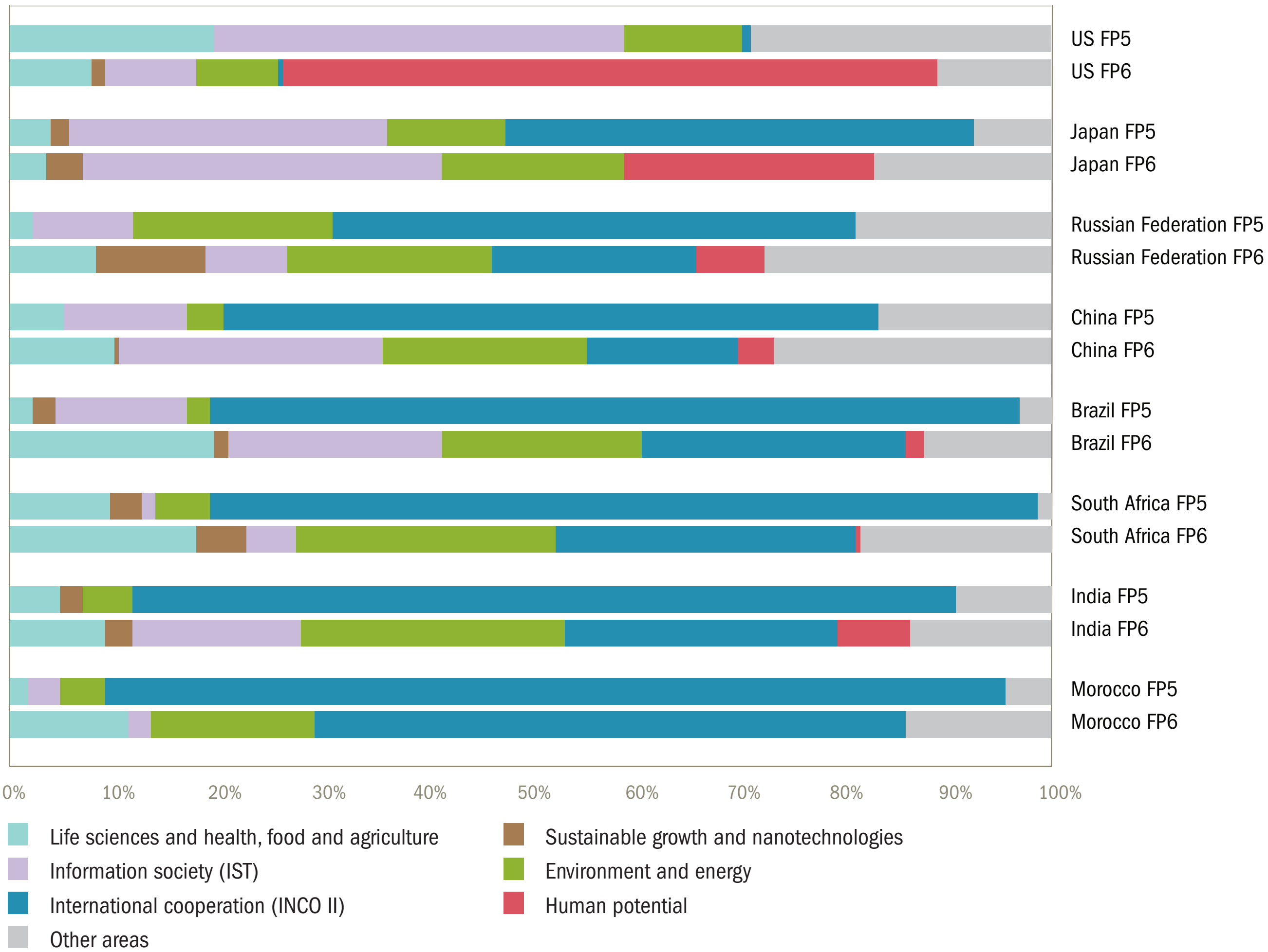
	Brazil		China		Russian Federation		India		South Africa		US	
	FP5	FP6	FP5	FP6	FP5	FP6	FP5	FP6	FP5	FP6	FP5	FP6
Belgium	31	60	35	139	8	189	4	56	13	82	1	95
Czech Republic	-	20	-	25	-	96	-	16	-	15	-	37
Denmark	3	43	3	121	8	129	2	51	11	54	1	76
Germany	52	179	80	420	75	772	9	138	24	194	2	421
Estonia	-	5	-	17	-	31	-	5	-	12	-	3
Ireland	3	24	3	36	10	58	-	8	5	18	-	46
Greece	20	39	13	103	20	158	2	38	9	39	-	108
France	61	140	59	298	27	577	5	97	16	174	1	315
Spain	55	131	24	200	7	292	4	70	18	96	-	154
Italy	69	113	63	291	25	423	10	106	35	134	-	236
Cyprus	-	2	-	7	-	16	-	2	-	4	-	5
Latvia	-	2	-	7	-	32	-	2	-	11	-	3
Lithuania	-	-	-	17	-	34	-	4	-	7	-	3
Luxembourg	-	5	9	10	-	10	-	-	-	-	-	2
Hungary	-	16	-	38	-	89	-	15	-	21	-	31
Malta	-	2	-	4	-	17	-	4	-	5	-	3
Netherlands	21	103	23	221	16	286	18	103	22	147	-	183
Austria	11	26	57	80	14	155	5	31	-	35	-	49
Poland	-	31	-	75	-	155	-	19	-	33	-	60
Portugal	23	27	26	48	1	85	2	12	12	34	-	32
Slovenia	-	9	-	20	-	41	-	2	-	12	-	20
Slovakia	-	5	-	16	-	40	-	6	-	13	-	9
Finland	8	18	15	76	34	113	9	21	4	25	-	50
Sweden	16	36	25	101	8	190	9	45	23	72	-	112
UK	-	186	-	405	-	636	-	183	-	261	-	371
> Total	373	1222	435	2775	253	4624	79	1034	192	1498	5	2424

Source: DG Research
Data: DG Research

STC key figures report 2008

Third country cooperation with Europe is mainly focused on major global challenges and on key technology areas

FIGURE II.6.5 Participation of selected countries in FP5 and FP6 by major thematic area



Source: DG Research
Data: DG Research

STC key figures report 2008

Emerging economies such as the Russian Federation, China, India and Brazil had the highest rate of participation in themes related to health, conservation of natural resources, agriculture and food under the FP5 INCO Programme. The Information and Communication Technologies Programme under FP5 attracted a significant number of participations from the Russian Federation, China and Brazil. This trend was reinforced under FP6. Other thematic areas became more attractive as well, in particular life sciences, food quality and environment.

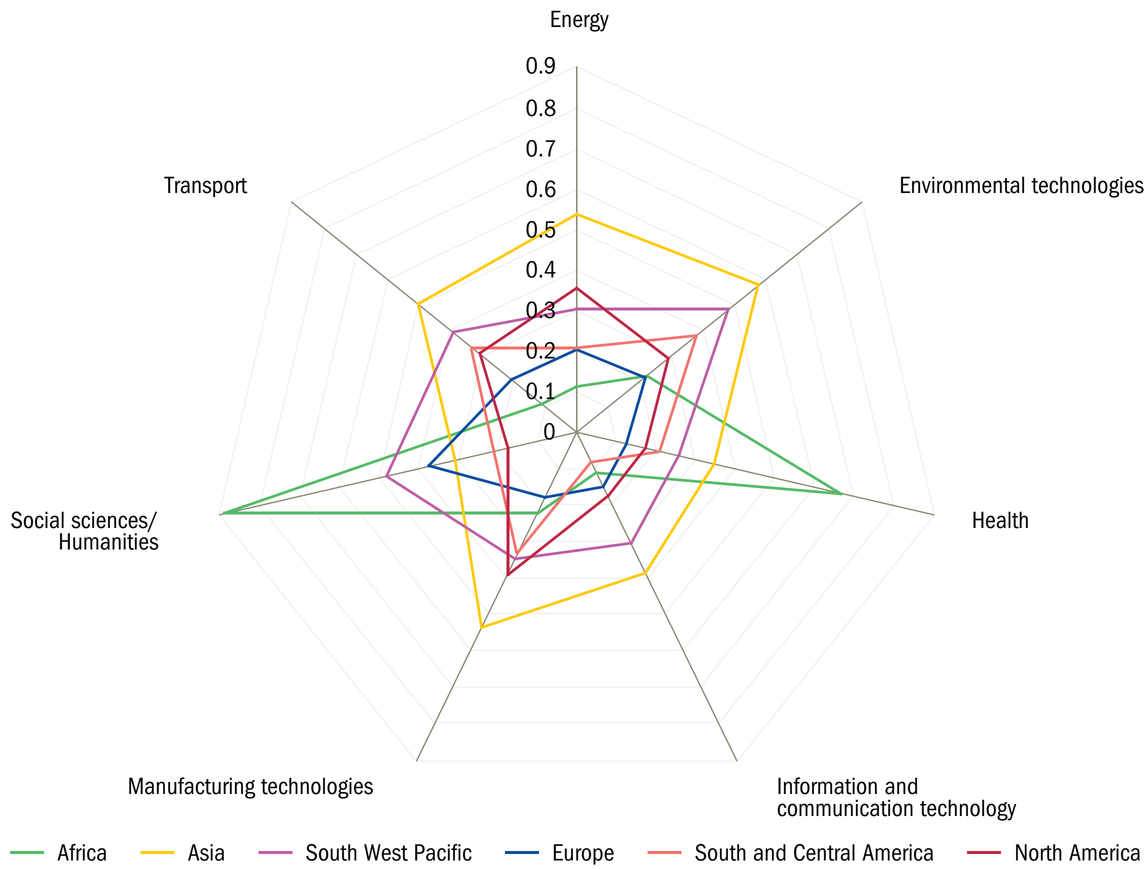
The US is the ***industrialised country*** with the highest share of participations in both FP5 and FP6. The participation figures include a high number of European researchers with post-doctoral fellowships at US universities under the Human Resources and Mobility scheme. US participation is concentrated mainly in Information Society Technologies, followed by Life sciences and health, food and agriculture, and Environment and energy. Japan's rather modest participation is mostly concentrated on IST.

Morocco, Tunisia, the Ukraine and Argentina were the leading ***developing countries*** in terms of participation in both FP5 and FP6, with most efforts concentrated on the INCO Programme (in particular on Health and Infectious Diseases and Conservation of Natural Resources), followed by a smaller number of participations in Environment, Energy and in IST.

The major international cooperation themes under the framework programme reflect broadly the most frequent themes identified in foresight exercises in Asia and Africa

Different world regions have varying concerns about their future, although there are common prospects that appear in many world regions.

FIGURE II.6.6 S&T priorities of world regions as expressed in national foresight exercises



Source: DG Research
Data: EFMN

STC key figures report 2008

Figure II.6.6 shows that Africa prioritises S&T in health and in the social sciences/humanities. In Asia a variety of fields is seen as important for the future. They range from environmental technologies, energy and transport to ICT and manufacturing technologies. Here, social sciences/humanities seem to have a lower recognition than in most other regions. North America prioritises manufacturing and energy-related technologies, South and Central America, environmental technologies. There is a strong correlation for Africa and Asia between the themes in which they actively participate in the EC framework programme and the themes chosen in foresight exercises. Europe is seen as a strong research partner in the field of environmental technologies. However, it is interesting to note that the strong profile of ICT and Health in third-country participation in the framework programme is not apparent in the themes chosen in foresight exercises in third countries.

In conclusion, available statistics on the mobility of S&T professionals, researchers, co-publications and co-patenting indicate an increasing cooperation between researchers in Europe and researchers from countries outside Europe. At the Community level, the research framework programmes have increased their extension and scope over the last 10 years. From an initial focus on developing countries, the European framework programmes have extended to emerging and industrialised countries as well. Most third-country participants come from the Russian Federation, the US and China. Although the larger research countries in Europe – Germany, France, the United Kingdom and Italy – have the most collaborative links with third-country researchers, several smaller Member States have used the European framework programme to substantially increase their collaborative links.

Acknowledgments

The Key Figures 2008 report was prepared in DG Research under Directorate C 'European Research Area: Knowledge-based economy' (Director: Isi Saragossi) in unit C3 'Economic analysis and monitoring of national research policies and the Lisbon Strategy' (Head of Unit: Pierre Vigier).

The work was initiated by unit C3 in the second half of 2007 (Peder Christensen: acting Head of Unit). The analysis, text and graphs are the result of a collective work also involving JRC-IPTS, unit 'Knowledge for Growth', which contributed Chapter 2 of Part I and Chapters 1 and 4 of Part II, and DG Research, unit D2 'Analysis and monitoring of research policies around the world', which contributed Chapter 6 in Part II.

Principal authors were Johan Stierna (overall coordinator) and Matthieu Delescluse. Authors of individual chapters or sections were: Maria Herminia Andrade, Peder Christensen, Jan Larosse, Carmen Marcus, Philippe Moguerou, Antoine Schoen, Rene van Bavel, Ludger Viehoff and Virginia Vitorino. Dermot Lally was principal data manager.

We thank those who kindly provided critical advice and external peer review: Vincent Duchêne, Tassos Giannitsis, Georg Licht, Keith Smith, Lena Tsipouri, Arnold Verbeek, Reinhilde Veugelers and Edward Ziarko.

We also acknowledge data and input from units A3, B1, B2, B3, C1, C2, C4, L2, L3, T2 and T3 in DG Research, as well as unit F4 in DG Eurostat, unit D2 in DG Regional Policy, and unit D1 in DG Enterprise.

Methodological Annex

Symbols and abbreviations

Country codes

BE	Belgium
BG	Bulgaria
CZ	Czech Republic
DK	Denmark
DE	Germany
IE	Ireland
EL	Greece
ES	Spain
FR	France
IT	Italy
CY	Cyprus
LV	Latvia
LT	Lithuania
LU	Luxembourg
HU	Hungary
MT	Malta
NL	Netherlands
AT	Austria
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
FI	Finland
SE	Sweden
UK	United Kingdom
EU-27	European Union
HR	Croatia
MK	Macedonia, (Former Yugoslav Republic of)
TR	Turkey
IS	Iceland
LI	Liechtenstein
NO	Norway
CH	Switzerland
IL	Israel
ERA	European Research Area
US	United States
JP	Japan
CN	China
RU	Russian Federation
KR	South Korea
SG	Singapore
IN	India
AU	Australia
CA	Canada
ZA	South Africa
ROW	Rest of the world

Other abbreviations

:	'not available'
-	'not applicable' or 'real zero' or 'zero by default'

Definitions

The NUTS classification

Definition: The Nomenclature of Statistical Territorial Units (NUTS) is a single coherent system for dividing up the European Union's territory in order to produce regional statistics for the Community. NUTS subdivides each Member State into a whole number of regions at NUTS I level. Each of these is then subdivided into regions at NUTS level 2 and these in turn into regions at NUTS level 3.

Source: Eurostat

Gross domestic product (GDP)

Definition: Gross domestic product (GDP) data have been compiled in accordance with the European System of Accounts (ESA 1995). Since 2005, GDP has been revised upwards for the majority of EU Member States following the allocation of FISIM (Financial Intermediation Services Indirectly Measured) to user sectors. This has resulted in a downward revision of R&D intensity for individual Member States and for the EU.

Source: Eurostat

Value Added

Definition: Value added is current gross value added measured at producer prices or at basic prices, depending on the valuation used in the national accounts. It represents the contribution of each industry to GDP.

Purchasing Power Standards (PPS)

Definition: Financial aggregates are sometimes expressed in Purchasing Power Standards (PPS), rather than in euro based on exchange rates. PPS are based on comparisons of the prices of representative and comparable goods or services in different countries in different currencies on a specific date. The calculations on R&D investments in real terms are based on constant 2000 PPS.

Source: Eurostat

R&D expenditure

Gross domestic expenditure on R&D

Definition: Gross domestic expenditure on R&D (GERD) is defined according to the OECD Frascati Manual definition. GERD can be broken down by four sectors of performance:
- business enterprise expenditure on R&D (BERD);
- government intramural expenditure on R&D (GOVERD);
- higher education expenditure on R&D (HERD);
- private non-profit expenditure on R&D (PNPRD).

GERD can also be broken down by four sources of funding:
- business enterprise;
- government;
- other national sources;
- abroad.

Sources: Eurostat, OECD

Government budget for R&D

Definition: The government budget for R&D is defined as government budget appropriations or outlays for R&D (GBAORD), according to the OECD Frascati Manual definition. The data are based on information obtained from central government statistics and are broken down by socio-economic objectives in accordance with the nomenclature for the analysis and comparison of scientific programmes and budgets (NABS).

Source: Eurostat

Scientific Publications

Definition: Publications are research articles, reviews, notes and letters published in referenced journals which are included in the SCI database of the Institute of Scientific Information (ISI). A full counting method was used at the country level. However, for the EU aggregate, double counts of multiple occurrences of EU Member States in the same record were excluded.

Source: Thomson ISI, Web of Science; treatments and calculations: Leiden University – CWTS

Field-normalised citation score

The value represents the mean citation rate of the subfield in which a research unit has published (*FCSm,* the mean Field Citation Score), taking into account both the type of paper (e.g., normal article, review, and so on), as well as the specific years in which the papers were published. The definition of subfields is based on a classification of scientific journals into *categories* developed by ISI. To give an example, the number of citations received during the period 2000-2006 by a *letter* published in 2000 in subfield (X) is compared to the average number of citations received during the same period (2000-2006) by all *letters* published in the same subfield (X) in the same year (2000). In most cases, a research unit is active in more than one subfield (i.e. journal category). Therefore, a weighted average has been calculated, with the weights determined by the number of papers published in each subfield. Self-citations are excluded from the computation.

Source: Thomson ISI, Web of Science; treatments and calculations: Leiden University – CWTS

Methodology of co-publication analysis

The methodology used for the co-publication analysis involved three types of analysis:

a) Single country publications cover co-publications that involve domestic partners only; this is the sum of all papers written by one or more authors from a given country (and non-nationals resident in that country). Although the literature usually distinguishes between domestic single publications (including one or more authors belonging to the same institution) and domestic co-publications (i.e. authors within the same country but from different main organisations), for the aim of the current analysis the sum of the two categories have been used under the heading of 'single country publications'.

b) EU-27 transnational co-publications refer to international co-publications which involve at least one author from an EU-27 country. This category includes both co-publications by authors from at least two different EU Member States (as defined by research papers containing at least two authors' addresses in different countries) and co-publications between one or several authors from the EU-27 together with at least one author from a country outside the EU-27.

c) Extra-EU co-publications is a sub-category of the broader EU-27 transnational co-publications. It refers exclusively to international co-publications involving at least one EU author and at least one non-EU author, as defined by the authors' addresses in different countries.

An important methodological issue is the way in which a co-publication is quantified. The full counting method has been used in this report, meaning that a single international co-published paper is assigned to more than one country of scientific origin. If, for example, the authors' addresses signal three different countries in EU-27, the publication is counted three times – once for each country mentioned. Therefore, in a matrix of co-publications between countries, the number of publications mentioned is not a completely accurate indicator of the number of publications being co-authored, but rather how often a country or region is involved in co-publications.

Source: Thomson ISI, Web of Science; treatments and calculations: Fraunhofer ISI and Leiden University – CWTS

Scientific specialisation

Definition: The relative scientific specialisation index (RCA) is calculated for 28 disciplines on the basis of publications from 2000-2002 and 2004-2006. The fields 'multidisciplinary' and 'Social Sciences' have been excluded. The formula used is the hyperbolic tangent function for the ratio of the share of a domain or discipline in a country compared to the share of the domain in the total for the world: $RCA_{ki} = 100 \times \tanh \ln \{(A_{ki}/\Sigma_i A_{ki})/(\Sigma k A_{ki}/\Sigma_{ki} A_{ki})\}$, with A_{ki} indicating the number of publications of country k in the field i, whereby the field is defined by the 28 scientific disciplines used in the classifications.

LN centres the data on zero and the hyperbolic tangent multiplied by 100 limits the RCA values to a range of +100 to -100. Scores below -20 are considered a significant under-specialisation in a given scientific field, scores between -20 and +20 are around field average and mean no significant (under-)specialisation, and scores above +20 mean a significant specialisation in a given field. The RCA indicator allows the assessment of the relative position of a field i in a country beyond any size effects. Neither the size of the field nor the size of the country has an impact on the outcome of this indicator. Therefore, it is possible to directly compare countries and fields.

Source: Thomson ISI, Web of Science; treatments and calculations: Technopolis Group and DG RTD

Patent Cooperation Treaty (PCT) Patents

Definition: The Patent Cooperation Treaty (PCT) is an international treaty, administered by the World Intellectual Property Organization (WIPO), signed by 133 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single 'international' patent application instead of filing several separate national or regional applications. Indicators based on PCT applications are relatively free from the 'home advantage' bias (proportionate to their inventive activity, domestic applicants tend to file more patents in their home country than non-resident applicants). The granting of patents remains under the control of the national or regional patent offices. The PCT patents considered are 'PCT patents, at international phase, designating the European Patent Office'. The country of origin is defined as the country of the inventor.

The timeliness (at the international phase of the PCT procedure) is much better than for Triadic patents. However, the relatively low cost of a patent application on an international basis makes the PCT procedure not very selective. Many PCT applications will cover inventions whose value is known *a posteriori* to be low, while few of them will cover inventions of very high value. A high share of patent applications from a given country might turn out to have limited impact on its economy if the inventions all turn out to be of little or no use.

Source: OECD

Technological specialisation

Definition: The relative technological specialisation index (or RCA) is calculated for 19 technology domains on the basis of PCT patent applications (at the international phase, designating the EPO) from 2004-2005. The data were classified by earliest priority date and country of residence of the inventor.

The formula used is the hyperbolic tangent function for the ratio of the share of a domain in a country compared to the share of the domain in the total for the world: $RCA_{ki} = 100 \times \tanh \ln \{(A_{ki}/\Sigma_i A_{ki})/(\Sigma_k A_{ki}/\Sigma_{ki} A_{ki})\}$, with A_{ki} indicating the number of PCT patent applications (at international phase, designating the EPO) of country k in the field i. LN centres the data on zero and the hyperbolic tangent multiplied by 100 limits the RCA values to a range of +100 to -100. Scores below -20 are considered a significant under-specialisation in a given scientific domain, scores between -20 and +20 are around domain average and mean no significant (under-)specialisation, and scores above +20 mean a significant specialisation in a given domain. The RCA indicator allows the assessment of the relative position of a field i in a country beyond any size effects. Neither the size of the domain nor the size of the country has an impact on the outcome of this indicator. Therefore, it is possible to directly compare countries and domains.

Source: Fraunhofer ISI, based on EPO and WIPO data

Technology categories

Definition: The four manufacturing industry technology categories are defined as follows (NACE codes are given in brackets):

1. High-tech: office machinery and computers (30), radio, television and communication equipment and apparatus (32), medical, precision and optical instruments, watches and clocks (33), aircraft and spacecraft (35.3), pharmaceuticals, medicinal chemicals and botanical products (24.4).
2. Medium-high-tech: machinery and equipment (29), electrical machinery and apparatus (31), motor vehicles, trailers and semi-trailers (34), other transport equipment (35), chemicals and chemical products excluding pharmaceuticals, medicinal chemicals and botanical products (24, excluding 24.4).
3. Medium-low-tech: coke, refined petroleum products and nuclear fuel (23), rubber and plastic products (25), non-metallic mineral products (26), basic metals (27), fabricated metal products except machinery and equipment (28), building and repairing of ships and boats (35.1).
4. Low-tech: food products and beverages (15), tobacco products (16), textiles (17), wearing apparel, dressing and dyeing of fur (18), tanning and dressing of leather, manufacture of luggage, handbags, saddlery and harness (19), wood and products of wood and cork, except furniture (20), pulp, paper and paper products (21), publishing, printing and reproduction of recorded media (22), furniture and other manufacturing (36), recycling (37).

High-tech trade

Definition: High-tech trade covers exports and imports of products whose manufacture involved a high intensity of R&D. They are defined in accordance with the OECD's high-tech product list (see OECD (1997): Revision of the High-technology Sector and Product Classification (1997), *STI Working Papers 2*/1997, OECD, Paris). The indicators used in this report use the so-called 'product approach', i.e. they measure the world market share of exports of high-tech products.

Sources: Eurostat (Comext), UN (Comtrade)

Knowledge-intensive services

Definition: Knowledge-intensive services are defined as (NACE codes are given in brackets):
Post and telecommunications (64), computer and related activities (72), research and development (73), water transport (61), air transport (62), real estate activities (70), renting of machinery and equipment without operator and of personal and household goods (71), other business activities (74), financial intermediation, except insurance and pension funding (65), insurance and pension funding, except compulsory social security (66), activities auxiliary to financial intermediation (67), education (80), health and social work (85), recreational, cultural and sporting activities (92).

Sources: Eurostat, OECD

High-Tech Knowledge-intensive services

Definitions: High-Tech Knowledge-intensive services are defined as: post and telecommunications, computer and related activities, research and development (i.e. NACE Rev.1 codes 64, 72, 73). The output of knowledge-intensive high-tech services is defined as the value added of knowledge-intensive services. Total output is defined as total gross value added at basic prices according to the National Accounts definition.

Sources: Eurostat, OECD

Human Resources for Science and Technology (HRST), R&D personnel and researchers

The Canberra Manual proposes a definition of HRST as persons who either have higher education or persons who are employed in positions that normally require such education. HRST are people who fulfil one or other of the following conditions:
a) Successfully completed education at the third level in an S&T field of study (HRSTE – Education);
b) Not formally qualified as above, but employed in S&T occupations where the above qualifications are normally required (HRSTO – Occupation).

HRST Core (HRSTC) are people with both tertiary level education and an S&T occupation. Scientists and engineers are defined as ISCO categories 21 (Physical, mathematical and engineering science professionals) and 22 (Life science and health professionals).

The Frascati Manual proposes the following definitions of R&D personnel and researchers:
R&D personnel: 'All persons employed directly on R&D should be counted, as well as those providing direct services such as R&D managers, administrators, and clerical staff.' (p. 92).

Researchers: 'Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned.' (p. 93).

R&D may be the primary function of some persons or it may be a secondary function. It may also be a significant part-time activity. Therefore, the measurement of personnel employed in R&D involves two exercises:
- measuring their number in headcounts (HC): the total number of persons who are mainly or partially employed in R&D is counted;
- measuring their R&D activities in full-time equivalence (FTE): the number of persons engaged in R&D is expressed in full-time equivalents on R&D activities (= person-years).

ERA-related concepts

Centrality in a network structure

Centrality here refers to the relative position of individual nodes in a network structure. It is measured by looking at the number of nodes (FP participant organisations) and the number of ties (co-participation in FP projects) contained in the EUPRO database. Rankings are based on a composite indicator, computed as the unweighted sum of four centrality rankings (degree centrality: number of direct collaborative links of the organisation; eigenvector centrality: proximity to central organisations; closeness centrality: accessibility of all other organisations in the network; betweenness centrality: ability to control information flows between all other organisations). The rationale behind this composite indicator is that central vertices should rank high along each of the dimensions quantified by the centrality indices.

Definitions of an 'Open programme'

Preparatory studies [222] have utilised two different classification criteria: the *overall objectives* of a programme or the *eligibility rules for participation* in a programme.
The first classification criterion divides the programmes into four categories, depending on the *overall objectives* of the research programmes:

- programmes that are explicitly oriented to fund capacity-building schemes, research in generic technologies or global issues, where the participation of non-residents is an important contribution;
- programmes that fund the participation of resident researchers in transnational projects;
- programmes mainly focused on national or regional research but where selection criteria include world excellence;
- all other national and regional research programmes.

The second classification criterion is based on all different types of national and regional research programmes, including the four categories above, and divides all programmes into four categories depending on *the eligibility rules for participation*:

- programmes that allow participation of non-residents as partners without funding;
- programmes where non-resident researchers are eligible for funding as a partner but within a financial ceiling;
- programmes where non-resident researchers are eligible for funding as a partner and with no financial ceiling;
- programmes that allow funding for non-resident researchers as sub-contractors to a national partner.

The term 'non-resident as partner' refers to individuals or teams from non-domiciled foreign research institutions that participate as partner in a research project. This definition excludes 'sub-contracting' (cases where only national partners are eligible for funding but where these can sub-contract to non-residents). It also excludes non-residents with a temporary contract with a national institution (i.e. 'visiting fellows') as well as any other researcher with foreign citizenship resident in the country or employed by a national research institution.

Research Infrastructures

The term 'Research Infrastructures' (RIs) may be employed in a number of contexts with different scopes. In its broadest sense, research infrastructures refer to all facilities, laboratories and resources used by research personnel for research activities. This broad definition of RIs would match the 'capital' category of the Frascati manual, which includes 'land and buildings', 'equipment and research instruments' and 'computer software'.
However, the term 'RI' usually refers to large-scale facilities or resources, which may be single-sited, distributed or virtual, but which provide unique access and services to research communities in both academic and industry domains. These facilities typically have investment, operating or maintenance costs that are relatively high in relation to research costs in their particular field.

[222] Study financed by the European Commission in 1999, made by Technopolis, VDI/VDE-IT, IKEI and Logotech. 'Cross-Border Cooperation within National RTD Programmes'; Study financed by the European Commission in 2004-2005, made by Optimat and VDI/VDE/IT 'Examining the Design of National Research Programmes'.

Pan-European Research Infrastructures

1. Research Infrastructures must provide resources, facilities and services that are essential to the scientific or technological research community;
2. Research Infrastructures should typically have investment, operating or maintenance costs that are relatively high in relation to research costs in their particular field;
3. Research Infrastructures should be open to external researchers, i.e. provide access to conduct research, irrespective of the location of the RI (e.g. through Transnational Access contracts or any other bilateral and/or multilateral agreements);
4. Research Infrastructures should have a clear European dimension and added value, i.e. they should:
   - be considered rare for the specific discipline(s) and be of pan-European interest, relevance and top-level in their respective field and so be considered as 'European key infrastructures';
   - allow the performance and development of science at the cutting edge (i.e. by providing the best tools, continuously upgrading them, improvements to services and interface with users);
   - be working in international networks/collaborations;
   - be recognised at international level (even if a national RI) as organisations facilitating excellence in research (including comparisons with the US and Japan);
   - be attractive to and capable of receiving external users, by providing adequate scientific, technical and logistical support.

Examples of Research Infrastructures

Telescopes, synchrotrons and accelerators, satellite and aircraft observation facilities, networks of computing facilities, coastal observatories, research vessels, collections, special habitats, libraries, databases, biological archives, clean rooms, integrated arrays of small research installations, high-capacity/high speed communication networks, data infrastructures.

The concept of mobile researchers

There are several difficulties involved in conceptualising researcher mobility. A first difficulty stems from the very definition of a researcher. As defined by the Frascati Manual in OECD 2002, the standard classification used internationally in surveys, the International Standard Classification of Occupations, does not recognise 'researcher' as a profession, only 'research and development manager'. Secondly, there are no data on the mobility patterns of individual researchers over time. The data are collected based on the nationality or place of birth of researchers in the population of a particular country. Furthermore, the methodology of data collection has changed over time, so it is not possible to present time series and trends on mobility of researchers. For the sub-population of doctorate holders, it may be feasible in the coming years to present time series on mobility based on the results of the 'Careers of Doctorate Holders' project [223]. For the sub-population of doctoral graduates, time series on mobility may also be available in the coming years, depending on the implementation of the new methodology introduced in 2005 in education statistics [224].

[223] This project is funded by OECD, the UNESCO Institute for Statistics and EUROSTAT and initiated in 2004: the Careers of Doctorate Holders (CDH) project. It aims at developing a regular and internationally comparable production system of indicators on the careers and mobility of doctorate holders, building on surveys currently existing in some countries and on other data sources. The first results are available, but only for a limited number of countries. (see Auriol L. (2007), 'Labour market characteristics and international mobility of doctorate holders: results for seven countries', OECD STI Working Paper *2007/2).*

[224] A pilot phase was initiated by OECD and EUROSTAT, and has been continued in 2008.

Methodology for mobility

'Mobile'/'international' is defined on the basis of the country of citizenship. The data collected on mobile/international students changed in the Unesco-OECD-Eurostat data collection in 2005. Two new concepts were introduced to better capture student mobility across countries: country of permanent residence and country of prior education. This change has been motivated by the fact that the data collected before the 2005 UOE data collection are not appropriate for measuring all mobile/international students. Observations based on the citizenship criterion are affected by the differences in legislation governing the acquisition of nationality. Thus, certain foreign students may have lived in their host countries for many years and completed some or all of their prior education in the same country and, therefore, they may have never been 'mobile'. Citizenship alone is not a variable sufficient to measure incoming and outgoing students. However, the changes have not been fully implemented yet and are still in the pilot phase, not available for full exploitation.

Different facets of mobility

A first facet of mobility is geographical. Researchers could move within national borders, cross-border or transnationally. Mobility could even be virtual, based on ICT-based tools. The analysis in this report focuses on transnational (geographical) mobility of researchers in Europe. The transnational geographical mobility may or may not form part of a scientific career (including aspects such as the rewards an institution or a national research system attach to mobility for career prospects). Related differentiations are:
- the length of the mobility period (6 months, one year, a whole career);
- the positions occupied by the mobile researcher;
- the possible accumulation of mobility periods at different stages in a scientific career.

However, the concept 'Mobility of researchers' refers as well to other facets:
- Mobility of researchers between public and private sectors, and the reverse;
- Mobility of researchers between one discipline and another;
- Demographic and career aspects on mobility of researchers (including retirement).

More European-wide data are being developed on these different facets of mobility.

Marie Curie Actions

The Human Resources and Mobility (HRM) activity within FP6 had a budget of €1580 million, being the largest mobility scheme at EU level. The scheme, known as the Marie Curie Actions, aimed at providing advanced training tailored to researchers' individual needs in order to become professionally independent and to gain complementary or different scientific skills. Individual researchers interested in taking part in a Marie Curie Action had two options, to prepare a project together with a host institution of his/her choice and submit it to the European Commission (Marie Curie Individual Fellowships – IEF), or to apply directly to an institution that has been selected by the European Commission for a Host-Driven Action.

Eligible candidates were researchers from EU or Associated States, with at least four years of postgraduate research experience or a PhD, willing to spend a mobility period working in a host institution located in another EU or Associated State, different from his/her own and different from that where they have been recently.

The international dimension of the Seventh Framework Programme for research and technological development[225]

Each of the four specific programmes '**Cooperation', 'Capacities', 'Ideas', 'People'** supports international cooperation through various instruments and mechanisms. As far as **'Cooperation'** is concerned, international cooperation activities take different forms:

- The 'general opening', which can be either 'passive' – all thematic areas are open to all third countries – or 'targeted', namely particularly encouraged for certain countries/country groups or emphasised for certain themes.
- The Specific International Collaboration Actions' (SICA) programme aims to reinforce research capacity in European Neighbourhood Countries and to address the particular needs of developing and emerging economies by means of dedicated cooperative activities. Specific participation criteria apply to SICA: Participation of a minimum of two Member States or Associated Countries plus two targeted International Cooperation Partner Countries. The SICA is therefore to be seen as a mechanism for a specifically bilateral or bioregional cooperation.

In order to complement and to facilitate international participation in the different programmes, one of the seven activities under 'Capacities' is fully dedicated to international cooperation and covers support measures for third countries and regions. The objectives of these activities are:

- to create platforms for a structured S&T policy dialogue (INCO-NET) between authorities and stakeholders of the EU and the regions/countries concerned;
- to disseminate information, provide assistance, favour partnership building (BILAT), with a view to facilitate access and promote participation in the Seventh Framework Programme;
- to coordinate international cooperation activities of the Member States (ERA-NET) in order to enhance their international engagement and achieve critical mass in given areas and specific countries/regions.

The **'People'** specific programme also has a substantial international dimension: It aims to increase the quality of European research by attracting research talent to Europe, providing opportunities for European researchers to work abroad and fostering mutually beneficial research collaboration with researchers from outside Europe. A new instrument, the International Research Staff Exchange Scheme – IRSES – has been developed in the Seventh Framework Programme for strengthening institutional partnerships between European research organisation and 'counterparts' from countries with which the Community has S&T agreements or which are covered by the European Neighbourhood Policy.

The **'Ideas'** Specific Programme aims to support excellence by funding investigator initiated frontier research across all fields of science carried out by individual researchers or research teams. The principal investigator can be of any nationality, but the work must be carried out in Europe.

[225] SEC (2007) 47 'A New Approach to International S&T Cooperation in the EU's 7th Framework Programme (2007-2013)', 12 January 2007.

Index of graphs, statistical tables and maps

Executive Summary		
FIGURE 1	Participation in global R&D – % shares	6
FIGURE 2	Gross Domestic Expenditure on R&D (GERD) financed by business enterprise and by government, 1991-2006	7
FIGURE 3	Gross Domestic Expenditure on R&D (GERD) – real growth (%) between 2000 and 2006	9

Part I		
FIGURE I.1.1	EU-27 – Evolution of GERD and GDP in real terms, 2000-2006	19
FIGURE I.1.2	Evolution of R&D intensity, 2000-2006	20
TABLE I.1.1	Gross Domestic Expenditure on R&D (GERD)	21
FIGURE I.1.3	R&D intensity (GERD as % of GDP), 2006	22
FIGURE I.1.4	Growth of R&D intensity and GERD, 2000-2006	23
TABLE I.1.2	GDP, GERD and R&D intensity – average annual growth (nominal)	25
FIGURE I.1.5	R&D intensity – annual growth	26
FIGURE I.1.6	R&D intensity – progress towards the 2010 targets (in percentage points)	27
FIGURE I.1.7	R&D intensities for the four sources of funds, 2000 and 2006	28
FIGURE I.1.8	GBAORD as % of general government expenditure – average annual growth, 2000-2007	30
FIGURE I.1.9	GERD financed by business enterprise and by government as % of GDP average annual growth, 2000-2006	31
FIGURE I.1.10	R&D expenditure by main sources of funds (%), 2006	33
FIGURE I.1.11	GERD financed by the private sector as % of total GERD, 2005	34
FIGURE I.1.12	EU-27 – R&D expenditure by sector of performance, 2006	35
FIGURE I.1.13	GOVERD and HERD as % of GDP – average annual growth, 2000-2006	36
FIGURE I.1.14	Share of public sector expenditure on R&D (GOVERD + HERD) financed by business enterprise	37
TABLE I.1.3	EU-27 – Evolution of business R&D investment	39
FIGURE I.1.15 (a)	Manufacturing value added – % distribution by type of industry, 2003	40
FIGURE I.1.15 (b)	Manufacturing BERD as % of manufacturing value added by type of industry, 2003	40
FIGURE I.1.15 (c)	Manufacturing BERD by type of industry as % of total GDP, 2003	41
FIGURE I.1.16	R&D intensities of 14 major car manufacturers (CM), 2005	42
FIGURE I.1.17	EU-27 – Manufacturing sectors: value added versus BERD average annual real growth, 1995-2003	44
FIGURE I.1.18	EU-27 – Services sectors: value added versus BERD – average annual real growth, 1999-2003	45
FiGURE I.2.1	EU-27 – Human resources for science and technology and the sub-groups R&D personnel (HC, FTE) and researchers (HC, FTE) – total and female (thousands)	48
FIGURE I.2.2	Scientists and engineers as % of labour force, 2006	49
FIGURE I.2.3	R&D personnel (HC) as % of total employment, 2000 and 2005	50
FIGURE I.2.4	Number of researchers (FTE thousands) by world region, 2000 and 2006	51
FIGURE I.2.5	Number of researchers (FTE), 2006	52
TABLE I.2.1	Evolution of the total number of researchers (FTE), and per thousand labour force, 2000-2006	53

Part I		
FIGURE I.2.6	EU-27 – Business sector – R&D expenditure (BERD), Researchers (FTE) and total R&D personnel (FTE) – growth against previous year	54
FIGURE I.2.7	R&D expenditure (PPS€ 2000) per researcher (FTE) by sector, 2000-2006	55
FIGURE I.2.8	Share of population aged 25-64 with tertiary education (%), 2000 and 2005	56
TABLE I.2.2	Tertiary graduates per thousand population aged 20-29 by field of education, 2005 and average annual growth, 2000-2005	58
FIGURE I.2.9	Number of doctoral graduates, 2005 and average annual growth (%), 2000-2005	59
FIGURE I.2.10	Doctoral graduates per thousand population aged 25-34, 2000 and 2005	60
FIGURE I.3.1	World shares of scientific publications (%), 2000 and 2006	62
FIGURE I.3.2	Scientific publications in relation to public expenditure on R&D	63
FIGURE I.3.3	Contribution to the 10 % most cited scientific publications, 2000-2003 and 2003-2006	64
FIGURE I.3.4	EU-27 and US – Scientific specialisations based on scientific publications, 2004-2006	65
FIGURE I.3.5	Specialisations in high-growth scientific disciplines, 2004-2006	66
TABLE I.3.1	Patent applications filed under the PCT, by priority year and residence of inventor	68
FIGURE I.3.6	Technology specialisations (2004-2005)	70
FIGURE I.3.7	EPO patent applications per million population, 2004	71
TABLE I.3.2	EU-27 – Technology specialisation – the top 40 NUTS 2 regions	72
FIGURE I.3.8 (map)	EU-27 – fields of maximum technological specialisation for the 100 NUTS 2 regions with the highest numbers of EPO patent applications, 2001-2003	73
FIGURE I.3.9 (a) (map)	EU-27 – technological specialisation in biotechnology at NUTS 2 regional level, 2001-2003	74
FIGURE I.3.9 (b) (map)	EU-27 – technological specialisation in information and communication technologies (ICT) at NUTS 2 regional level, 2001-2003	75
FIGURE I.3.10	Exports of high-tech products – world market shares, 2000-2006	78
FIGURE I.3.11	High-tech exports as % of total national exports, 2000 and 2006	79
FIGURE I.3.12	High-tech value added as % of total national manufacturing value added, 2000 and 2005	80
FIGURE I.3.13	Value added of knowledge intensive high-tech services as % of total national services value added, 2000 and 2005	81
FIGURE I.3.14	Employment by type – % shares, 2006	82
FIGURE I.4.1	BERD by main sources of funds (%), 2006	84
FIGURE I.4.2	R&D expenditure of affiliates of US parent companies abroad in the four main countries or zones of destination (as % of total)	85
FIGURE I.4.3	R&D expenditure flows between EU-15 and the US (billion PPP$), 1997, 2003 and 2005	85
FIGURE I.4.4	R&D expenditure by foreign affiliates, 1995 and 2005 as % of R&D expenditure by business enterprise	86
FIGURE I.4.5	Shares of turnover and R&D expenditure of affiliates under foreign control in total manufacturing turnover and total manufacturing R&D expenditure, 2005	87
FIGURE I.4.6	Inward R&D investment in manufacturing – % shares by investing region (EU-25, EFTA, US, Other), 2005	88

Part II		
FIGURE II.1.1	The most active research universities – normalised citation impact by country, 1997-2004	94
FIGURE II.1.2	Share of government intramural expenditure on R&D (GOVERD) in total public sector expenditure on R&D (GOVERD + HERD)	95
TABLE II.1.1	Funding models for universities, 2006	97
FIGURE II.1.3	The countries with the most central participants in FP5 and FP6	99
FIGURE II.1.4 (map)	FP6 R&D collaborations between European universities that cooperate in more than ten research projects	100
FIGURE II.1.5 (map)	Web-based hyperlinks between universities in EU-15 at NUTS 2 regional level, 2008	101
FIGURE II.2.1	Structure of public funding of R&D in Europe	103
FIGURE II.2.2	Public funding for coordinated research in Europe	104
FIGURE II.2.3	EC funding for research and innovation (annual average funding)	105
FIGURE II.2.4	Number of participations in European programmes per thousand researchers	106
TABLE II.3.1	Projects funded as preparatory phases for the construction (or major upgrade) of research infrastructures (ESFRI roadmap), (May 2008)	111
TABLE II.3.2	Expenditure on research infrastructures (RIs) in Europe (billion euro)	113
TABLE II.3.3	Comparison between capital expenditure on R&D in 2005 and the average annual funding for research infrastructures (RIs) under the Structural Funds (million euro)	114
FIGURE II.3.1	Foreign users of research infrastructures (RIs)	115
FIGURE II.3.2	Shares (%) of research infrastructures (RIs) by domain with more than 50 % foreign users	115
FIGURE II.3.3	Number of institutional participations by country in research infrastructure projects funded by FP6 (I3 and TA)	116
FIGURE II.3.4	Number of foreign users by operator country in research infrastructure projects funded by FP6 (I3 and TA)	117
TABLE II.3.4	The ten biggest transnational flows of research infrastructure (RI) users in FP6	118
FIGURE II.4.1	Non-national human resources in science and technology core (HRSTC) in nine EU Member States: numbers (thousands) and shares (%), 2000-2006	120
FIGURE II.4.2	Number and % share of doctoral candidates in EU-27 by country of citizenship, 2005	121
FIGURE II.4.3	EU-27 – number and % share of doctoral candidates with the citizenship of another Member State in the reporting country, 2005	122
TABLE II.4.1	Doctorate holders by sex and country of origin	123
FIGURE II.4.4	Marie Curie Fellowships – Flows (incoming plus outgoing) as % of total PhD/Doctoral graduates, 2006	124
TABLE II.4.2	Number of jobs posted on the Researchers' Mobility Portal	125

Part II		
FIGURE II.4.5	Number of jobs posted on the Researchers' Mobility Portal by country	125
FIGURE II.5.1	EU-27 – Evolution of scientific publications and co-publications, 1990-2006	127
FIGURE II.5.2	The five main co-publication partners of each EU-15 Member State (%), 2000-2006	128
FIGURE II.5.3	The five main co-publication partners of each of the 12 new Member States (%), 2000-2006	129
FIGURE II.5.4	EU-27 – Evolution of patent and co-patent applications, 1990-2004	130
FIGURE II.5.5	Number of EPO patent applications by higher education institutions (HEIs) in selected countries, 1994-2003	131
FIGURE II.5.6	EU-27 – Main cooperation partners of innovative enterprises as % of innovative enterprises, 2002-2004	132
TABLE II.5.1	Shares of the EU and the US in the total number of scientific publications cited in patents for five science-intensive technological fields, 1990-2003	133
FIGURE II.5.7	Worldwide Open Access repositories	135
FIGURE II.5.8	Open Access journals	135
FIGURE II.5.9	Number of transnational scientific co-publication partners for each pair of world regions, 2000-2006	136
FIGURE II.5.10	Total number of EU-27 co-publications with world regions for selected scientific fields, 2000-2006	137
FIGURE II.5.11	EU-27 co-patents with US, Japan and China, 2000-2004	138
FIGURE II.5.12	Foreign ownership (%) of domestic inventions, 2003	139
FIGURE II.5.13	Foreign ownership of domestic inventions, 2003	140
FIGURE II.5.14	Domestic ownership (%) of foreign inventions, 2003	140
FIGURE II.5.15	Domestic ownership of foreign inventions, 2003	141
FIGURE II.6.1	Associated and third country participation in the EC Framework Programmes, 1998-2007	144
FIGURE II.6.2	Evolution of third countries' participation by economic region in the FP5, FP6 and FP7 Cooperation and Capacities Programmes	145
FIGURE II.6.3	Participation of selected countries in FP5 and FP6	146
FIGURE II.6.4	FP7 – Cooperation and Capacities Programmes – first calls for proposals 2007 – participation of selected countries in submitted proposals and in proposals to be funded	147
TABLE II.6.1	Cooperative links between EU countries and selected third countries in FP5 and FP6 funded projects	148
FIGURE II.6.5	Participation of selected countries in FP5 and FP6 by major thematic area	149
FIGURE II.6.6	S&T priorities of world regions as expressed in national foresight exercises	150

European Commission

EUR 23608 EN

A more research-intensive and integrated European Research Area
Science, Technology and Competitiveness key figures report 2008/2009

Luxembourg: Office for Official Publications of the European Communities

2008 – 168 pp. – 21 x 29.7 cm

ISBN 978-92-79-10173-1
DOI 10.2777/27864

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

KI-NA-23608-EN-C

The Science, Technology and Competitiveness report examines the progress made in EU's research investments and efficiency since the launch of the Lisbon agenda in March 2000. It provides answers to a number of questions, such as: Is Europe investing more in research? Is Europe becoming a more attractive place to invest in research? Is Europe progressing towards a more integrated European Research Area and making its research system more competitive? Is Europe moving rapidly enough towards a more adaptable and knowledge-intensive economy able to face the globalisation challenge?

Publications Office
Publications.europa.eu

ISBN 978-92-79-10173-1