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Science, Technology and Innovation

Key Figures 2003-2004

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Key Figures 2003-2004

Towards a European Research Area
Science, Technology and Innovation

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The "Key Figures 2003-2004" was prepared by the Unit K3 team: Fabienne Corvers, Henri Delanghe, Vincent Duchêne, Angela Hullmann, Kai Husso, Carmen Marcus, Marianne Paasi, Ian Perry, Viola Peter, Brian Sloan, David Uhlir and with the technical assistance of Fotini Chiou, Dermot Lally and Anastassia Vakalopoulou. Secretarial support was provided by Bénédicte de Smet, Marie Jonkers, Gaëtane Lecocq, Valérie Moermans and Lise Vanneck.

URL : www.cordis.lu/indicators

PREFACE

Since 2001, the global economy has experienced a downturn in economic performance, and this has intensified the challenges facing Europe in its efforts to progress towards a knowledge-based economy. But it is now more crucial than ever that Europe strengthens its resolve and remains on course towards the goal it set itself at the European Council of Lisbon in 2000. This goal - to transform the European Union by 2010 into “the most competitive and dynamic knowledge-based economy in the world” – remains our principal roadmap to higher and sustainable economic growth. Europe needs to quicken the pace of this transition in order to speed up economic recovery.

A cornerstone of the Lisbon strategy is the stimulation of knowledge and innovation, which is induced primarily by research and development. Compared with its main competitors, Europe is still under-investing in new knowledge. This is why, at the European Summit of Barcelona in March 2002, European Heads of State and Government set the goal of increasing Europe’s overall level of investment in research to 3% of GDP by 2010, and of raising the share of research funded by business. To help reach this target, the European Commission recently presented a wide-ranging action plan on “Investing in Research”. Europe needs more research if it is to consolidate economic recovery and enhance long-term competitiveness.

The 2003-2004 edition of Key Figures provides a set of indicators, which help us to take stock of Europe’s position in science, technology and the knowledge economy. On the eve of enlargement of the European Union, this year’s report also presents, for the first time, extensive data for the Acceding countries, and as much data as possible for the Candidate countries. The report highlights a number of developments of importance to the EU:

- While the EU’s investment in R&D grew at close to the same rate as in the US during the period 1997-2001 (4.5% per year in the EU versus 4.8% in the US), the proportion of its wealth devoted to R&D is still too low (just under 2% compared with 2.8% in the US). EU business R&D increased by about 50% between 1995 and 2001, but growth was much more substantial in the US (130%). EU research investment needs to grow considerably more rapidly, if we are to reach the Barcelona targets.
- At the same time the EU’s performance in converting knowledge into new technologies and economic success still gives cause for concern. It trails well behind the US in terms of patenting in key-technologies for the 21st century, while its share of the export market for high tech products stood at 20% in 2001 compared with 24% for the US.
- Most of the Acceding countries are in a process of catching up with the rest of the European Union in terms of S&T investment and performance. There are encouraging signs that many of them have increased their efforts considerably.

I hope that these and other quantitative insights contained in the report will provide a sound base for strengthening our policies in order to speed up the transition towards the knowledge-based economy.

Philippe Busquin

CONTENTS

Introduction

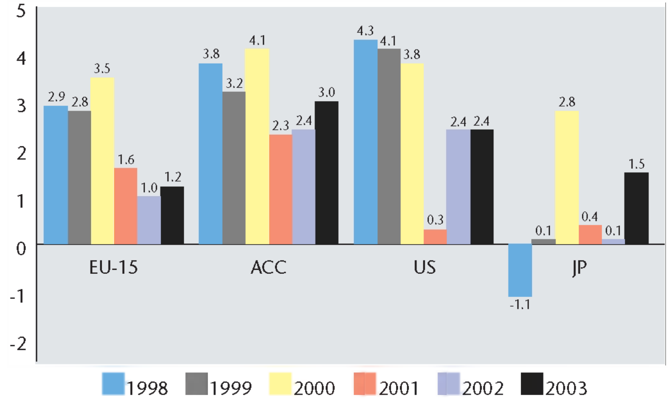
Growth Recovery in an Enlarged Europe

In the last two years, Europe's overall economic performance experienced a significant weakening, after years of exceptional growth by European standards. The Gross Domestic Product (GDP) of the European Union grew by 1.6% in 2001, a reduction of nearly 2% in comparison with 2000, when the highest growth rates of the last fifteen years were recorded. Economic growth gradually slowed down in 2002 and more or less stagnated in the first half of 2003. Most of the world's other main economies also experienced a slowdown and some of them even showed negative growth rates (i.e. real GDP actually declined). The US economy, after years of vigorous growth well ahead of the figures registered in the European Union, encountered near-stagnation in 2001. Japan, which had hardly recovered from the weak years before, reported economic growth very close to zero for the last two years (see Figure 1).

Although the EU's main competitors also show a weakening economic performance, the outlook for growth in the mid-term is bleak in Europe and there are downside risks. The public balance is deteriorating everywhere. Since 2001, most Member States have been facing a trend reversal, with rising unemployment, increasing deficits and public indebtedness, after years of sustained improvement of their public finances.

The transition to the knowledge-based economy should not be allowed to slow down in this context of sluggish economic

Figure 1 Real GDP Growth in the EU-15, the Acceding countries, US and Japan, 1998-2003, in % change on previous year (1995=100)



Source: DG-Research Key Figures 2003-2004
Data: Eurostat
Notes: Figures for 2003 are forecasts

performance and political uncertainty. Therefore, the Lisbon strategy becomes all the more important (Spring Report: European Commission, 2003d, p.29). As decided by the Heads of State and Government at the Lisbon Summit in 2000, this strategy aims at transforming the European Union by 2010 into "the most competitive and dynamic knowledge based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion". The set of measures and decisions taken then, better known as 'the

Lisbon strategy', entail reforms in three main dimensions: a) further consolidation and unification of the European economic environment; b) improvement of the creation, absorption, diffusion and exploitation of knowledge; and c) modernisation of the social model.

Thus not only does the Lisbon strategy remain Europe's overall roadmap to higher and sustainable economic growth, but also European policy-makers acknowledge that the progress needs to be accelerated for growth recovery. This year's Spring Report, for instance, stated that *"The Union's priority for the next 12 months must be to stimulate investment in knowledge and innovation alongside faster structural changes in order to boost productivity and employment"* (European Commission, 2003d, p.33). More recently, the European Council of Thessaloniki (European Council, 2003) asked the European Commission to launch an initiative in co-operation with the Investment Bank to support growth by increasing overall investment and private sector involvement in infrastructures and in research and development (European Council, 2003, p.17; European Commission, 2003e, 2003f).

Enlargement too reinforces the case for accelerating the process. Integrating new Member States does not imply a re-writing of the Lisbon strategy: the targets for the whole of the Union remain the same for the EU-25. The Lisbon strategy forms a common basis for reforms needed in the new Member States as well as in the EU-15, and therefore is a sound tool for integration. However, enlargement also means that additional efforts are needed from Member States to keep the Union on track in its transition to a knowledge-based economy.

Education, Research and Innovation for Competitiveness and Growth

Education, research and innovation are one of the main means to achieve the overall Lisbon objective. Recognising the pivotal role of education and training, the European Council invited Ministers of Education "to reflect on the concrete future objectives of education systems" and to concentrate on "common concerns and priorities". Hereby the Lisbon Council launched an unprecedented process in the area of education and training helping Member States to develop their own policies progressively by spreading best practice and achieving greater convergence towards the main EU goals.

The European Council of Barcelona (March 2002) emphasised the importance of research and innovation by setting the goal of increasing the level of expenditure in research and development to 3% of GDP by 2010. While investing more in R&D is one part of the equation, another is better co-ordination of European research. This has been initiated through the creation of the European Research Area (ERA) and related policy actions, such as the 'benchmarking of national research policies'. The European Research Area is the broad heading for a range of linked policies that attempt to ensure consistency of European research and facilitate the research policies of individual Member States in order to improve the efficiency of European research capabilities.

Both from a theoretical and empirical point of view, there is a broad recognition among economists and policy-makers of the impact of human capital, R&D, technological progress and innovation on productivity and economic growth. Work recently carried out for the European Commission suggests that one additional year of schooling can increase the aggregate productivity by 6.2% for a typical European country (European Commission, 2002). Countries where R&D expenditure by the business sector in relation to GDP has increased most from the 1980s to the 1990s have typically experienced the largest increase in the growth of multifactor productivity (MFP) (OECD, 2001b).

Europe is, however, still under-investing in knowledge and skills. The EU-25 is still lagging far behind the US and Japan in R&D investment and the exploitation of technological innovations, and in many domains the gap is still widening. If we are to consolidate economic recovery and enhance long-term competitiveness, efforts shoud therefore be maintained and increased.

The competitive knowledge-based economy: how far are we?

A. Two Composite Indicators of the Knowledge-Based Economy

Speeding up the transition to the Knowledge-Based Economy has been an important objective of all European policies during the last years. But how far has Europe been able to progress in recent years? Furthermore, on the eve of enlargement, what is the position of the new Acceding countries and how fast is their transition to the knowledge economy?

This section provides an overview of progress towards this important target using two "composite indicators"[1]. These indicators attempt to capture the complex, multidimensional nature of the knowledge-based economy by aggregating a number of key variables, and expressing the result in the form of an overall index. The two composite indicators used here refer to the overall investment and performance in the transition to the knowledge-based economy. They focus on the 'knowledge dimension' of that transition and, therefore, do not take into account the other dimensions (e.g. employment, sustainable development, etc.) of the Lisbon Agenda.

In order to advance effectively towards the knowledge-based economy, countries need to invest in both the creation and the diffusion of new knowledge. The composite indicator of investment in the knowledge-based economy addresses these two crucial dimensions of investment. It includes key indicators relating to R&D effort, investment in highly-skilled human capital (researchers and PhDs), the capacity and quality of education systems (education spending and life-long learning), purchase of new capital equipment that may contain new technology, and the modernisation of public services (e-government). Table 1 shows the sub-indicators of this composite indicator.

[1] These composite indicators are the result of co-operation between DG Research and the following Commission services: DG Education and Culture, DG Information Society, DG Enterprise and the Joint Research Centre in Ispra, Italy. The latter were responsible for calculating the composite indicators and carrying out sensitivity analyses (see website www.cordis.lu/indicators/publications.htm for more details).

Table 1 Component indicators for the composite indicator of investment in the knowledge-based economy

Sub-indicators	Type of knowledge indicator
Total R&D expenditure per capita	Knowledge creation
Number of researchers per capita	Knowledge creation
New S&T PhDs per capita	Knowledge creation
Total Education Spending per capita	Knowledge creation and diffusion
Life-long learning	Knowledge diffusion : human capital
E-government	Knowledge diffusion : information infrastructure
Gross fixed capital formation (excluding construction)	Knowledge diffusion : new embedded technology

Source: DG Research Key Figures 2003-2004

Investing more in knowledge is, however, only half the story. Investment also needs to be allocated in the most effective way in order to increase productivity, competitiveness and economic growth. For this to happen, and to be sustainable, investment in knowledge thus has to induce a higher performance in research and innovation and increased labour productivity, an effective use of the information infrastructure and a successful implementation of the education system. This relationship between investment and performance, however, is very complex and certainly not linear. It depends in part on favourable framework conditions and policies. Moreover, there is always a time-lag between investment and a recorded increase in performance.

The second composite indicator presented here regroups the four most important elements of the 'performance in the transition to the knowledge-based economy': overall labour productivity, scientific and technological performance, usage of the information infrastructure and effectiveness of the education system (see Table 2).

Table 2 Component indicators for the composite indicator of performance in the knowledge-based economy

Sub-indicators	Type of knowledge indicator
GDP per hours worked	Productivity
European and US patents per capita	S&T performance
Scientific publications per capita	S&T performance
E-commerce	Output of the information infrastructure
Schooling success rate	Effectiveness of the education system

Source: DG Research Key Figures 2003-2004

The following text presents the latest updated results of the composite indicators for both the investment and the performance in the transition to the knowledge-based economy. The data now go up to 2001 and show the recent progress made by the EU-15. Moreover, they reveal for the first time the position of the Acceding countries and the Candidate countries in their transition. Finally, a comparison of the US, Japan, the EU-15 and its Member States is presented.

B. Recent Progress made by the EU-15

As shown in Figure 2, investment growth slowed down in 2000-2001. All Member States except Sweden registered a declining growth rate in this period compared with 1995-2000. In Germany, investment growth even became negative in 2001.

The relative position of countries remains more or less unchanged since the mid-nineties. One can broadly distinguish three groups within the EU-15 in terms of efforts made to speed up the transition to the knowledge-based economy.

Greece, Portugal, Spain and Italy were still lagging behind in 2001. These four countries had an investment level below EU average and a growth of investment comparable to the average growth in 2000-2001 (Greece being slightly above average in terms of investment growth). However, compared to the second half of the nineties, their catching up with the rest of Europe appeared to have slowed down in 2001.

A second group consisting of France, United Kingdom, Germany, Austria, Ireland, Belgium and the Netherlands occupied an average position in terms of both their investment level and growth in 2001, although the cohesion of this group is less obvious than in the 1995-2000 period. The striking exception here is the drastic drop of Germany's investment growth rate, which was negative for the period 2000-2001. This decrease was due to relatively low growth rates in all fields of the composite indicator except for life-long learning. Belgium, The Netherlands and Ireland, on the other hand, had above-average growth rates.

Although less cohesive than in the previous years, the third group consisting of Finland, Denmark and Sweden was still far ahead in 2001, with clear above-average investment levels and, especially for Sweden, above-average growth rates. The decline of Finnish investment growth in 2000-2001 seems to be due to relatively low growth scores in overall research investment, PhD's and information infrastructure (e-government), whereas Denmark underscored particularly in training (life-long learning) and the production of new PhD's.

Turning to the EU's performance in the knowledge-based economy (see Figure 3), growth was also lower, but the slowdown was less pronounced than for investment. While EU growth in 2001 was positive, its progress was not as fast as in the second half of the 1990s. This deceleration in performance growth occurred for all EU countries except United Kingdom, The Netherlands and Greece. Greece had a relatively high growth rate in all fields of the performance indicator in 2000-2001. The United Kingdom's improved growth was due to a relatively high growth in overall productivity (GDP/hour worked) whereas The Netherlands showed a high growth in technological performance (patents). The performance level (horizontal scale) nevertheless increased between 2000 and 2001 for most countries - albeit at a slower pace.

The differences between groups of countries are much less marked than they were for investment. It shows the complexity of the relationship between knowledge investment and a country's performance, indicating that other factors than investment in knowledge are influencing a country's performance (e.g. broad macro-economic conditions, openness of a country's economy and ability to 'import' knowledge instead of creating it, etc.). Moreover, there is always a 'time-lag' between an increase in investment and any observed outcome, so that performance positions rather reflect the long-term investment behaviour. Finally, there is no linear relationship between an increase in investment and its outcome (relationship also depends on the efficiency of investment allocation).

However, as far as performance is concerned, two broad groups can be distinguished within the EU-15. Portugal, Spain,

Figure 2 Composite indicator of investment in the knowledge-based economy: EU Member States

Source: DG Research/JRC Key Figures 2003-2004

Data: Eurostat, DG Information Society

Notes : All 7 sub-indicators were included for the investment levels (horizontal axis), but the indicator on e-government could not be included in the comparison of the growth rates (no data available on e-government for 1995). LU is not included (no data for most of indicators). For more details about the calculations and methodology see website www.cordis.lu/indicators/publications.htm.

Figure 3 Composite indicator of performance in the knowledge-based economy: EU Member States

Source: DG Research/JRC Key Figures 2003-2004

Data: Eurostat, EPO, USPTO, ISI/CWTS, DG Information Society

Notes: All 5 sub-indicators were included. The data for the UK's schooling success rate are partial and not completely harmonised. To allow calculations, UK growth from 1999 to 2001 has therefore been taken as 0, which may lead to a marginal underestimation overall of the performance growth for UK and EU-15. LU not included. For more details about the calculations and methodology see website www.cordis.lu/indicators/publications.htm.

Greece and Italy were below the EU average. Greece and Spain improved their positions, but Italy and Portugal registered a decline in their performance level in 2001.

The second group, consisting of the remaining 10 EU countries (Luxemburg is not included on the graph), was slightly above-average in terms of performance level (especially Sweden and Finland) in 2001 and around average in terms of growth rate. During the period in question Ireland caught up with the European average.

C. Current position and progress of the Acceding and Candidate countries

As shown in Figure 4, all Acceding countries were lagging behind the European average in 2001 with regard to overall investment level. Their relatively low position was common to all types of investment covered by the composite indicator, although it was more marked in research expenditure.

However, in 2000-2001 they were all catching up with the rest of Europe, albeit at a different pace:

A first group consisting of Slovakia, Latvia and Estonia was catching up very rapidly. These countries recorded growth rates well above the EU-15 average in 2000-2001 in both education spending and overall investment (capital formation). In addition to this, Estonia also made significant efforts to increase research investment, while Slovakia's production of new PhD's grew faster than the European Union average.

Lithuania, Hungary, Cyprus, the Czech Republic and Poland form a second group with a somewhat lower – although, with the exception of Poland, still clearly above average – growth rate in 2000-2001. Hungary and Lithuania were catching up thanks to their relatively high growth in research investment, capital formation and education spending compared with the EU-15, while Cyprus recorded higher growth in research investment, education spending and in the number of researchers. The Czech Republic had higher growth scores than EU-15 in overall investment, education spending and in human resources (both for the production of new PhD's and the number of researchers). Finally, Poland recorded well-below average growth in 2000-2001 for R&D expenditure and capital formation, whereas its human resources in S&T (both PhD's and the number of researchers) grew close to the EU-15 average.

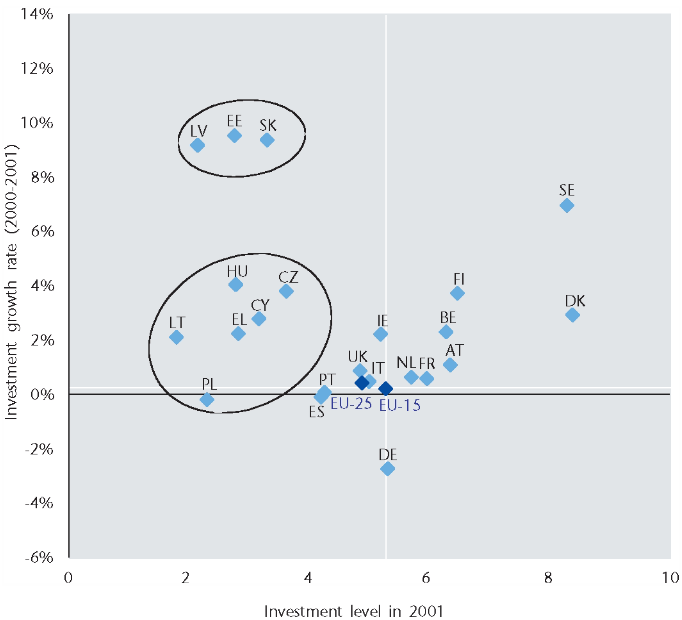
Similarly in terms of performance in the knowledge-based economy (see Figure 5), the Acceding and Candidate countries were all below the EU-15 average performance level in 2001. This was especially pronounced for technological performance (patents). When one looks only at scientific performance or overall productivity growth, the picture was less negative for these countries, although they were still far below the average EU level.

The cohesion between Acceding and Candidate countries in terms of performance (Figure 5) is much weaker than it is for the EU-15 (Figure 3).

If one compares the growth in performance of these countries with the EU average, one can make a distinction between two groups.

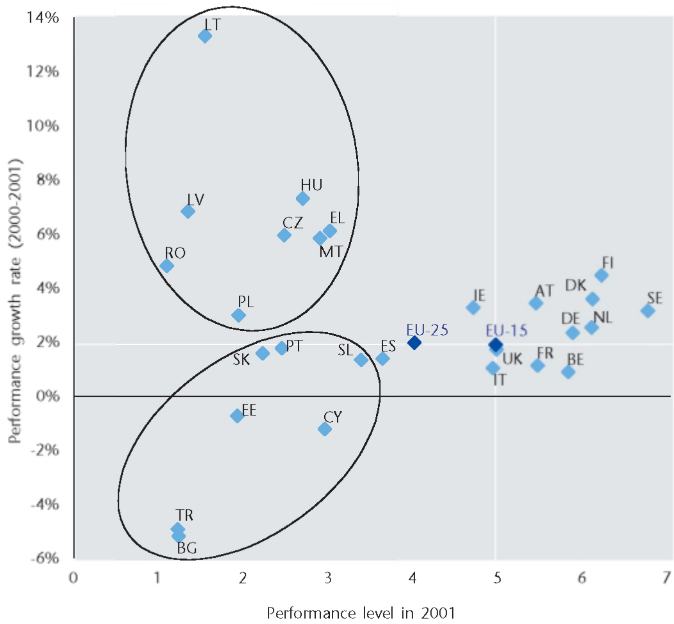
Bulgaria, Turkey, Cyprus, Estonia, and to a lesser extent Slovakia and Slovenia all had a performance growth below the EU average and were falling further behind compared with the

Figure 4 Provisional composite indicator of investment in the knowledge-based economy for comparison between the EU-15 and the Acceding countries



Source: DG Research/JRC Key Figures 2003-2004
Data: Eurostat
Notes : Only 5 sub-indicators were included : R&D expenditure (GERD per capita), PhDs (number of new S&T PhDs per capita), Researchers (number of researchers per capita), gross fixed capital formation (GFCF excluding building per capita), and e-government. The other two sub-indicators (educational spending and life-long-learning) are not available for all countries. LU, MT, SI are not included (no data for most of indicators). For more details about the calculations and methodology see website www.cordis.lu/indicators/publications.htm.

Figure 5 Provisional composite indicator of performance in the knowledge-based economy for comparison between the EU-15, the Acceding and Candidate countries



Source: DG Research/JRC Key Figures 2003-2004
Data: Eurostat, EPO, USPTO, ISI/CWTS
Notes : Only 3 sub-indicators were included: overall productivity (GDP per hours worked), patents (share of EPO and USPTO patents) and scientific publications per capita. Data on e-commerce and schooling success rate were not available for all countries. LU is not included. For more details about the calculations and methodology see website www.cordis.lu/indicators/publications.htm.

rest of the EU-25. In 2000-2001, Bulgaria recorded below-EU-average growth rates for all the sub-indicators of the performance indicator, whereas Turkey had a low growth of overall productivity. Estonia and Cyprus recorded under-average growth rates in scientific and technological performance, but had an average growth of overall productivity. Slovenia had above-average growth in technological performance in 2000-2001, but underscored notably in scientific performance. Slovakia, finally, recorded low growth rates in technological performance, whereas its overall productivity grew at a slightly faster pace than the EU average.

A second group - consisting of Lithuania, Latvia, Hungary, the Czech Republic, Malta, Romania and, to a lesser extent, Poland - were catching up with the EU in 2001. All countries of this group experienced an above-average growth of overall productivity. In addition, Hungary, Lithuania, Malta and Poland also recorded a higher growth of both technological and scientific performance than the EU-15. For the Czech Republic, the high growth of overall productivity in 2000-2001 was combined with an above-average growth in scientific performance, although technological performance grew at a slower pace than the EU-15 average.

D. The EU-15 compared with the US and Japan

The EU-15 as a whole had a lower level of overall investment in the knowledge-based economy in 2001 than the US and Japan (see Figure 6). However, some EU Member States, like Sweden, had levels similar or superior to that of the US. The US had more researchers per capita than EU-15, and a much higher level of research expenditure, whereas their production of new PhD's and capital formation were close to the EU levels. The same was true for Japan, although Japan's higher level investment here came more from a higher number of researchers than from a higher level of research expenditure.

The decrease in investment growth during the 2000-2001 period was much stronger for the US than for the EU-15 or Japan. The fall in investment growth for both the US and Japan was due mainly to a sharp decrease in capital formation in 2000-2001. In addition, the US also recorded lower growth than EU-15 in the number of researchers, however, the growth of US research spending was close to that of the EU.

The composite indicator of performance in the knowledge-based economy was lower for EU-15 than for the US in 2001, although Germany's position was marginally above that of the US (see Figure 7). More specifically, the US still had a higher level of technological performance than the EU-15, whereas overall productivity and scientific performance in 2001 were very close to the EU level. In terms of performance growth, one can observe a similar small decrease in both the EU and the US.

E. Conclusions

The slowing down of EU-15 investment in the knowledge-based economy is likely to be reflected sooner or later in a significant decline in its performance. This trend underlines the urgency of implementing the Lisbon Strategy. In particular, the EU needs to increase its efforts, so as to give renewed impetus to the catching up of some countries with the rest of the EU-15 and to close the gap as soon as possible with the US.

Figure 6 Provisional composite indicator of investment in the knowledge-based economy for comparison between the EU-15, Japan and US

Source: DG Research/JRC Key Figures 2003-2004
Data: Eurostat
Notes : Only 4 sub-indicators were included : R&D expenditure (GERD per capita), PhDs (number of new S&T PhDs per capita), Researchers (number of researchers per capita) and gross fixed capital formation (GFCF excluding building per capita). The other three sub-indicators (e-government, educational spending and life-long-learning) are not available for the US and JP. LU is not included. For more details about the calculations and methodology see website www.coris.lu/indicators/publications.htm..

Figure 7 Provisional composite indicator of performance in the knowledge-based economy for comparison between the EU-15, Japan and US

Source: DG Research/JRC Key Figures 2003-2004
Data: Eurostat, EPO, USPTO, ISI/CWTS
Notes : Only 3 sub-indicators were included: overall productivity (GDP per hour worked), patents (share of EPO and USPTO patents) and scientific publications per capita. No data were available on e-commerce and schooling success rate for the US and Jp. LU is not included. For more details about the calculations and methodology see website www.coris.lu/indicators/publications.htm..

Most Acceding countries are catching up with the EU-15. However, since their current investment and performance levels are far below the EU-15 average, they must continue to increase their efforts if they are to accelerate the catching-up process.

A striking new element is the drastic decrease of US overall investment growth in 2000-2001. This decrease was much stronger than in the EU-15. It was due mainly to a sharp decrease in US capital formation in 2000-2001, although the growth of US research spending was similar to that of the EU. Nevertheless, the EU will only close the gap with the US if it manages to boost its investment substantially in the next few years.

Structure of this year's Key Figures report

The rest of this report takes a more detailed look at the most important aspects of Europe's performance in scientific and technological research. For the first time, these 'Key Figures on Science and Technology' also include the most reliable and most recent data on the Acceding and Candidate countries. Part I of the publication presents indicators of investment in research (private and public investment, by sector, size of firms, etc) and human resources in S&T (PhD's, researchers and their education). Part II deals with the performance of Europe's research and innovation systems, presenting indicators such as scientific publications, patents and the importance of high-tech sectors in the economy.

Part I: Investment in the knowledge-based economy

The interest in the contribution of R&D and human resources to the growth and creation of a knowledge-based economy has reached new heights in the EU in recent years. Today, it is widely agreed that research and technological advancement together with the availability of a highly skilled workforce are among the key factors for innovation, competitiveness and socio-economic welfare. Likewise, the capacity to exploit knowledge has become a crucial element for the production of goods and services.

In 2000, the Lisbon European Council agreed upon the objective to make Europe the most competitive and dynamic knowledge based economy in the world. To reach the objective, the Barcelona Council in March 2002 set the specific target to increase the average level of R&D expenditure in the EU from 1.9% of GDP to 3% by 2010, of which two thirds should be funded by the private sector.

By 2003, most Member States had taken action to boost R&D investment and set national targets in line with the 3% objective. In April 2003, the Commission adopted a strategic Action Plan ("Investing in research"; COM (2003) 226) for accelerating progress towards the goal set by the Barcelona Council. The objectives and plans are challenging, among other reasons because of the economic difficulties experienced in Europe. Economic growth in the euro region slowed down in 2002 and stagnated in the first half of 2003.

Relevant statistical data and analysis are presented in Part I. Firstly, investment in research and R&D expenditure by the main sources of funding is analysed. Secondly, since in most countries the business sector plays the major role in R&D, private investment is looked at in more detail. Trends in venture capital investment are also presented. Thirdly, this section analyses key indicators on human resources in S&T, such as number of researchers and education data. The analysis covers the EU Member States, the Acceding and Candidate countries, the EFTA countries, the US, Japan and Israel.

I-1 Investment in R&D

This section examines recent developments in R&D investment. Figures on investment are derived from the data on gross domestic expenditure on R&D (GERD). It provides an overall picture of the level of commitment to the creation of new knowledge and to the exploitation of research results in different countries. The volume of R&D investment is a proxy for countries' innovation capacity, and reflects the magnitude of both accumulation and application of new knowledge. The 'R&D intensity' indicator compares countries' R&D expenditure with their gross domestic product. It also facilitates comparisons of the R&D activities between countries. R&D expenditure broken down by main sources of funds reveals information on the structure of financing and the relative importance of different sources in the national R&D system. The section also deals with the role of government in R&D financing, and expenditure on basic research.

Overall funds devoted to R&D

As Figure I-1a shows, in 2001, the EU-15 devoted €175bn in current terms to R&D (i.e. PPS 147bn[1]). In real terms, this figure was more than 15% higher than in 1998 and some 24% higher than in 1995. Thus, the recent trend in R&D investment in the EU-15 has been a bit more positive after the period of slow growth (especially before 1997). In 2001, the equivalent figures for the US and Japan were €315bn (PPS 234bn) and €143bn (PPS 87bn), respectively.

In terms of the absolute volume of R&D investment compared to the three economic blocks (EU-15, US, Japan), both the EFTA countries (€10bn; PPS 7bn, in 2001) and the 13 Acceding and Candidate countries (€5bn; PPS 9bn) are comparatively small investors. For instance, the 10 Acceding countries only spent an amount equivalent to less than 2% of the total EU-15 investment in research in current terms. In addition, in the period 1998–2001, the real growth rate recorded for the Acceding countries (16%) was less than one percentage point higher than that of the EU-15.

Despite the recent favourable development in the EU-15, the R&D investment gap between the EU and the US has continued to increase in favour of the US. In 2001, the gap was PPS 87bn in real terms, and €141bn in current terms (see Figure I-1b). The trend has been negative since the mid-1990s. For instance, in 2001, the gap was over twice as much as in 1994[2].

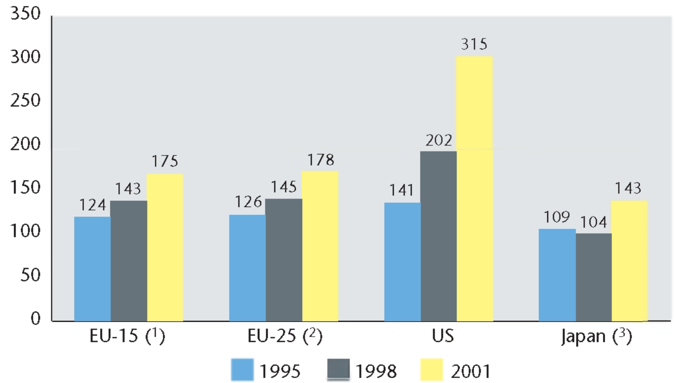
[1] Purchasing Power Standards, at 1995 prices. When calculating the volumes and growth rates of investment, the same standard is used throughout the report.

[2] In real terms, the gap was PPS 43.3bn in 1994 and PPS 86.9bn in 2001. In current terms, in 2001, the gap was already 6.3 times bigger than in 1994 (€22.5bn in 1994 and €141.4bn in 2001).

But then, on the one hand, the gap grew by some PPS 4bn from 2000 to 2001: this was clearly a smaller annual increase in terms of real volume than in the previous six years. On the other hand, from 2000 to 2001, the gap grew by €21bn in current terms. This was the second biggest year-to-year increase in the gap ever, but still much less than the growth of the gap by almost €46bn from 1999 to 2000, however.

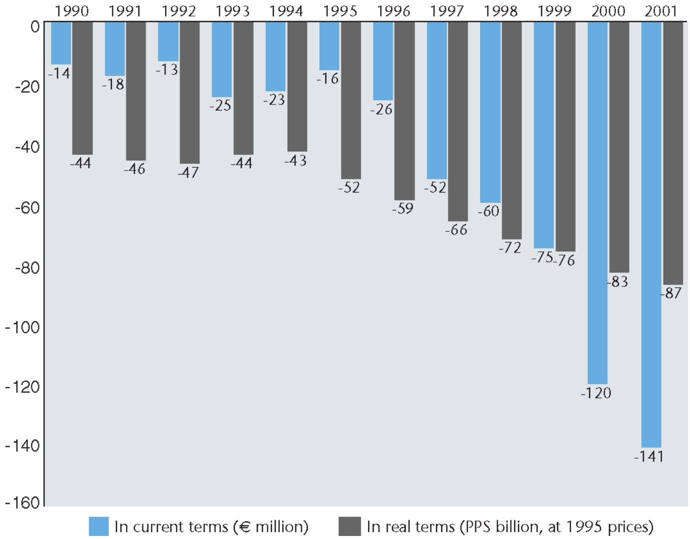
The EU-15 still does well when compared to Japan (Figure I-1a). In current terms, the difference between the EU-15 and Japan decreased in 1998–2001, but in real terms, the gap in 2001 was a record PPS 61bn in favour of the EU.

Figure I-1a R&D investment (€ billion, in current terms), 1995, 1998 and 2001



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Notes: (1) EU-15: 1998, 2001: data estimated by DG Research and do not include LU. (2) EU-25 values were estimated by DG Research and do not include LU and MT. (3) JP: 1995: data adjusted by OECD.

Figure I-1b R&D investment – the gap between the EU-15 (1) and the US in € billion and PPS billion (at 1995 prices), 1990–2001



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Note: (1) EU-15 data do not include LU.

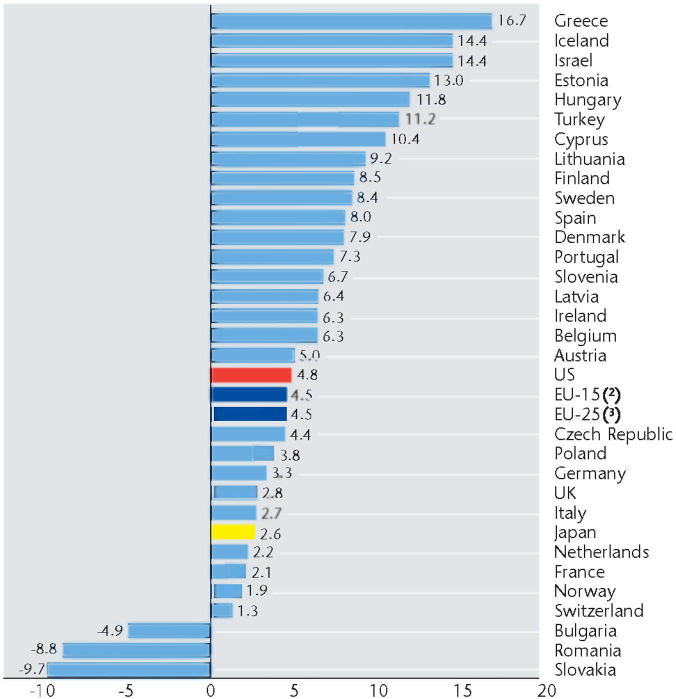
The EU-15 and the US show almost the same growth rates for R&D investment

Figure I-1c shows the average annual real growth of R&D investments by economic blocks and by country in the period 1997–2001. For the three economic blocks, the average annual rate of real growth of R&D investment was highest in the US (4.8% per year). The figure for the EU-15 was only 0.3 percentage points smaller. Compared to the situation in the period 1995–1999, when the difference in the growth rates between the EU-15 and the US was 2.2 percentage points in favour of the latter, the EU has managed to decrease the growth rate gap significantly in recent years[3]. Japan is clearly lagging behind the US and the EU rates.

Between 1997 and 2001, the growth rate was highest in the small economies and amongst the catching-up countries with relatively low absolute volumes of R&D activities and/or R&D intensities. The highest growth rates were recorded, in the EU, in Greece (17% per year), Finland (9%) and Sweden (8%), in EFTA, in Iceland (14%), and in the Acceding and Candidate countries, in Estonia (13%), Hungary (12%), Turkey (11%) and Cyprus (10%). The figure recorded for Israel was also exceptionally high (14%). At the opposite end of the scale, the figure for Switzerland (1.3% per year) was the lowest. Only three of the countries, Bulgaria, Romania and Slovakia – each with negative growth rates – were ranked below Switzerland.

[3] For the EU-15 to reduce the R&D investment gap relative to the US in real terms, the annual rate of growth in the EU should be much higher than that of the US. If one takes as a starting point the volumes of real investment in 2001 (EU: PPS 147.5bn; US: PPS 234.5bn), a 7.7% annual increase in R&D investment in the EU would be equivalent in volume terms to a 4.8% increase in the US (4.8% is the average annual rate of real growth of the US since 1997, see Figure I-1c). In this case, the rate of growth of 7.7% would be a thresbold value, with all the growth rates above it representing the relative volume of R&D investment narrowing the gap between the EU and the US. At the same time, with GDP growth of some 2% per year, the annual rate of growth of R&D investment of between 7% and 8% over this decade would make it possible for the EU to reach the 3% objective by 2010.

Figure I-1c R&D investment – average annual real growth rates (%), 1997–2001 (¹)



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Notes: (¹) or nearest available years: CH: 1996–2000; EL: 1997–1999; IT, NL, TR: 1997–2000; CY, EE: 1998–2001; BG: 1999–2001; FR: 2000–2002; BE, DK, ES, IE, SE, EU-15, CZ, HU, LT, LV, PL, SI, SK, EU-25, RO, NO, JP, IL: 1997–2001. All other countries: 1997-2002 (²) EU-15 value was estimated by DG Research for 2001 and does not include LU. (³) EU-25 value was estimated by DG Research for 1997 and 2001 and does not include LU and MT.

Compared to the US growth rate since 1997, the real increase in R&D spending in the major EU economies (DE, UK, FR, and IT) was clearly smaller, in the range 2–3% per year. They also recorded figures below the EU average. While being the largest R&D financiers in Europe, these major EU economies accounted for some 72% of the total R&D investment in 2001 but less than 56% of the total growth in investment between 1997 and 2001 in the EU-15.

R&D intensity is growing in the EU, but very slowly

In 2001, R&D intensity of the EU-15 reached a record figure of 1.98% (Figure I-1d). In spite of this achievement – the highest figure recorded ever for the EU-15 – the EU average was lagging well behind the intensity of the US and Japan and even more so than ever before. The gap was over 0.8 percentage points below the value for the US and 1.1 percentage points behind Japan. If we take into account the 10 Acceding countries, R&D intensity for the EU-25 in 2001 comes out slightly lower (1.93%) than that of the EU-15. The small difference between the figures was due to the fact that the combined volumes of both GDP and R&D expenditure in the Acceding countries are very low compared to those of the EU-15.

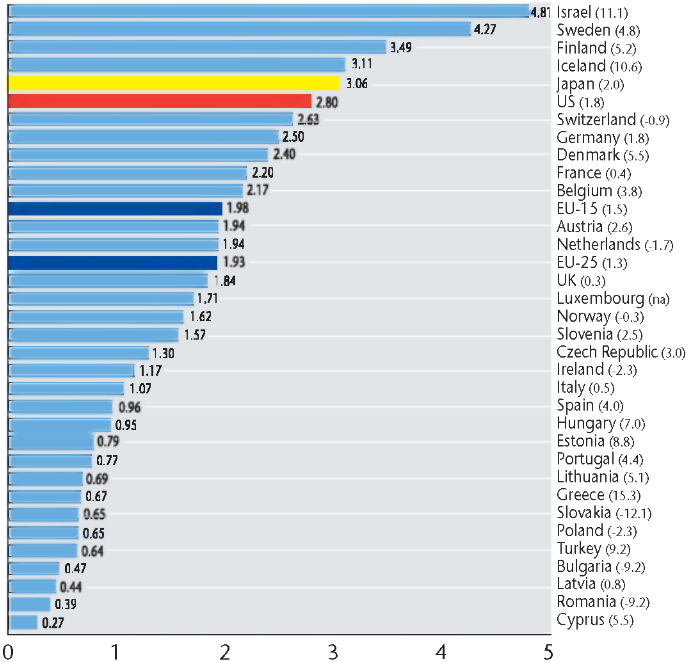
There are extremely large disparities in R&D intensities both between the individual countries and country groups. While Israel (4.8%) clearly tops the charts, the majority of the Nordic economies are in the top quartile of the ranking. The highest R&D intensity within the EU was recorded for Sweden (4.3%). R&D intensity for Finland (3.5%) was the second highest and clearly distanced from the rest of the EU economies, led by Germany (2.5%), Denmark (2.4%), France (2.2%) and Belgium (2.2%). Sweden and Finland were followed by Japan and the US together with two EFTA countries Iceland and Switzerland.

In the group of the Acceding and Candidate countries, Slovenia (1.6%) and the Czech Republic (1.3%) had the highest values. In general terms, with 0.3–1.0%, the lowest levels were recorded by the rest of the Acceding and Candidate countries and in three EU economies, Greece, Portugal and Spain. However, as can be seen from Figure I-1d, most of these catching-up countries – with the clear exceptions of Slovakia, Romania, Bulgaria, and Poland – have shown very high growth rates for R&D intensity since 1997.

In 1997–2001, the average annual growth of R&D intensity in the EU-15 (1.5%) was lower than in Japan (2.0%) and the US (1.8%) (Figure I-1d, see values in brackets). As a result, the EU is currently lagging even further behind Japan and the US than it did in the 1990s and 2000. The unfavourable overall trend of R&D intensity in the EU is mainly the result of the slow growth recorded for Italy, France and the UK, in the range of 0.3–0.5% per year.

In terms of relative growth of R&D intensity, small European economies and Israel have experienced most favourable developments. Greece (15% per year), Israel (11%), Iceland (11%), Turkey (9%) and Estonia (9%) have shown by far the highest figures. Hungary, Cyprus, Denmark, Finland and Lithuania have also recorded figures in excess of 5%.

Figure I-1d R&D intensity (GERD as % of GDP), 2001 ([1]); in brackets: average annual growth rates of R&D intensity (%), 1997–2001 ([2])



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Notes: ([1]) or latest available year: EL: 1999; IT, NL, LU, CH, TR: 2000; DE, FR, AT, PT, FI, UK, IS, US: 2002. EU-15, EU-25 data are estimated by DG Research and do not include MT. ([2]) or nearest available years: CH: 1996–2000; EL: 1997–1999; IT, NL, TR: 1997–2000; CY, EE: 1998–2001; BG: 1999–2001; BE, DK, ES, all other countries 1997-2002. IE, SE, EU-15, CZ, HU, LT, LV, PL, SI, SK, EU-25, RO, NO, JP, IL: 1997–2001; FR: 2000-2002. EU-15, EU-25 data are estimated by DG Research and do not include LU and MT.

R&D expenditure by sources of funds: large disparities between the EU-15 and the Acceding countries

Table I-1a shows the share of R&D expenditure by main sources of financing, i.e. business enterprises, government, other national sources and abroad, in each country in 2001. In Japan, the business share of financing was the highest, 73%. In the US, the business sector – which reflects more profit-oriented R&D activities – financed over 66% of all research. These figures stand out clearly when compared to the EU-15 figure of 56%. By contrast, the government share of R&D funding was clearly the highest in the EU-15, 34%. In the US, the figure was 29%, while it was lowest in Japan at just above 18%.

The business sector plays the leading role in R&D financing in all the EU Member States except Portugal, Italy, Greece and Austria. After Japan, the business sector's share of total funding was highest in Sweden (72%), Finland (71%) and Switzerland (69%). The EU economies of Belgium, Ireland and Germany recorded shares of around 66%.

In the major EU economies, the business enterprises' shares for France and especially for Italy and the UK were below the EU-15 average. In addition, in Greece and Portugal, the share was still at a strikingly low level, although the development in the latter has been very positive recently.

In the Acceding countries, the business sector's share of R&D funding was in excess of 50% in Slovakia, Slovenia and the Czech Republic, with the first reaching the EU-15 average. Otherwise, the figures for the rest of the Acceding countries

Table I-1a R&D expenditure by main sources of funds (%), 2001 (1)

	Business enterprise	Government	Other national sources	Abroad
Belgium	66.2	23.2	3.3	7.3
Denmark (2)	58.0	32.6	3.5	5.3
Germany	66.0	31.5	0.4	2.1
Greece	24.2	48.7	2.5	24.7
Spain	47.2	39.9	5.3	7.7
France	52.5	38.7	1.6	7.2
Ireland	66.0	22.6	2.6	8.9
Italy	43.0	50.8	-	6.2
Netherlands	50.1	35.9	2.6	11.4
Austria	39.0	42.1	0.3	18.6
Portugal	32.4	61.2	2.1	4.4
Finland	70.8	25.5	1.2	2.5
Sweden	71.9	21.0	3.8	3.4
UK	46.2	30.2	5.7	18.0
EU-15 (3)	56.1	34.0	2.2	7.7
Cyprus	17.5	66.5	6.5	9.4
Czech Republic	52.5	43.6	1.7	2.2
Estonia	24.2	59.2	3.9	12.7
Hungary (2)	34.8	53.6	0.4	9.2
Latvia	29.4	41.5	na	29.1
Poland	30.8	64.8	2.0	2.4
Slovenia	54.7	37.1	1.1	7.2
Slovakia	56.1	41.3	0.8	1.9
EU-25 (3)	55.8	34.4	2.2	7.6
Bulgaria	24.4	69.2	1.1	5.3
Romania	47.6	43.0	1.2	8.2
Turkey	42.9	50.6	5.3	1.2
Switzerland	69.1	23.2	3.4	4.3
Iceland	46.2	34.0	1.6	18.3
Norway	51.7	39.8	1.4	7.1
Israel	63.9	28.8	3.4	3.8
US (4)	66.2	28.7	5.1	na
Japan	73.0	18.5	8.1	0.4

Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Notes: (1) or latest available year: IT: 1996; BE, DK, EL, IL: 1999; FR, IE, NL, CH, BG, CY, EE, LV, TR: 2000; AT, US: 2002. (2) The sum of the breakdown does not add up to 100%. (3) EU-15, EU-25 data are estimated by DG Research and do not include LU, LT and MT. (4) Excludes most or all capital expenditure.

were low compared to those of the US, Japan and most of the EU-15 countries.

In general terms, the same countries that show the highest business sector shares of R&D investment also record the lowest shares for government funding. Public funding accounted for less than 30% of the total in Sweden, Ireland, Belgium, Switzerland, Finland and Israel. At the other end of the scale, the EU economies of Portugal (61%), Italy (51%) and Greece (49%), and in most of the Acceding and Candidate countries (but not CZ, RO, SI, and SK), the R&D system was still mostly dependent on government contributions.

In the EU-15, the share of funding from abroad was almost 8% of the total. Among the EU Member States, this share was the highest in Greece, almost 25%. The share of foreign funding was also rather high, almost 20%, in Austria and the UK. The situation is the opposite in Germany and Finland, with funding from abroad being very low, at around 2%. Among the EFTA countries, the figure for Iceland was comparatively high (18%). However, the highest share of funds from abroad in the comparison was seen in Latvia, at 29%.

Expenditure on basic research: high rate of growth in the US

For several reasons, basic research plays an important role in the R&D system. It generates new knowledge and understanding that provide the foundation for applied research and development. Because basic research provides reliable information on areas of future applications, more intense knowledge creation through basic research could be seen as a way to enhance innovation activities.[4]

In general terms, basic research has been under mounting pressures during the past decade or so. Because of short-term needs and economic priorities, there has been a tendency towards increasing the share of applied research and development in total R&D expenditure. However, the situation is very mixed, with some countries making more resources available for basic research and others less. In many countries, basic research still has a high status in the agenda of science, technology and innovation policies. There are good reasons for that. For instance, the emerging science-based areas of biotechnology and nanotechnology are promising areas for future applications and commercial activities.[5]

Due to the limited availability of data on basic research, it is difficult to get a full overall picture of the role of basic research in R&D systems. From 1995 onwards, data are available only for six EU Member States (DK, ES, FR, IT, NL, and PT), four of the Acceding countries (CZ, HU, PL, and SK), the EFTA countries (except LI), the US and Japan.

The share of basic research in total R&D expenditure shows considerable variation between countries (see Figure I-1e). The share of basic research is highest in three Acceding countries: the Czech Republic (40%), Poland (38%), and Hungary (29%). The share recorded for Switzerland was also compara-

[4] OECD 2001a, 2002a, 2002b; see also the Annex II on "Definitions and Sources" in the end of the report.

[5] OECD 2001b; European Commission / DG Research 2003; European Science Foundation 2003.

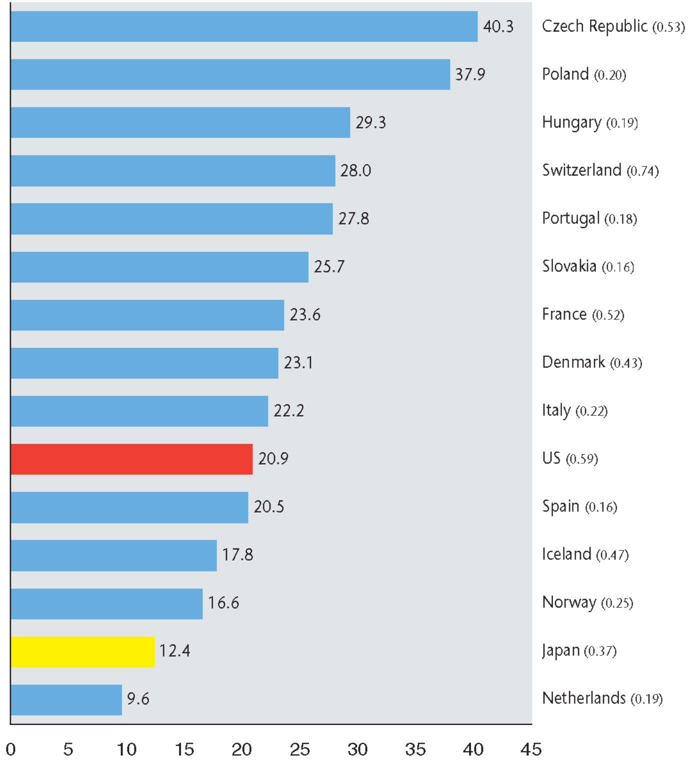
tively high, 28%. Within the EU-15, Portugal's figure was the highest, followed at some distance by France, Denmark and Italy, all these in the range 22–28%. While the figure for the US was also above 20%, the share of basic research in total R&D was very low in Japan, at only 12%.

Since 1997, the share of R&D expenditures allocated to basic research, which reflects the relative importance of basic research for R&D and innovation activities, has increased significantly in many countries. For instance, in the period 1997–2001, in the US, expenditure on basic research grew in real terms by almost 50%, while total R&D spending increased at the same time by less than 24%. The growth rate of expenditure on basic research was also clearly higher than that of total R&D expenditure in the Czech Republic, France and Poland. On the other hand, the rate of growth of expenditure on basic research has been clearly lower than that of the total R&D spending in certain countries such as Spain and Portugal.

In terms of expenditure on basic research as a percentage of GDP, Switzerland (0.7%), the US (0.6%), and the Czech Republic (0.5%) put more emphasis on basic research than others (Figure I-1e). At the other end of the scale, figures recorded for Spain, Slovakia, Portugal, Hungary and the Netherlands were all very low, below 0.2%.

There are various reasons for the different levels of expenditure on basic research. For instance, on the one hand, the share of 21% of total R&D expenditure in the US entails both scientific leadership and the business sector's intense activity in basic research. On the other hand, in many Acceding

Figure I-1e Basic research as % of total R&D expenditure, 2001 (1); in brackets: basic research as % of GDP, 2001 (1)



Source: DG Research Key Figures 2003-2004
Data: OECD
Notes: (1) or latest available year: NL: 1995; IT: 1996; DK, IS, NO, PT: 1999; CH, ES, FR, HU, JP: 2000.

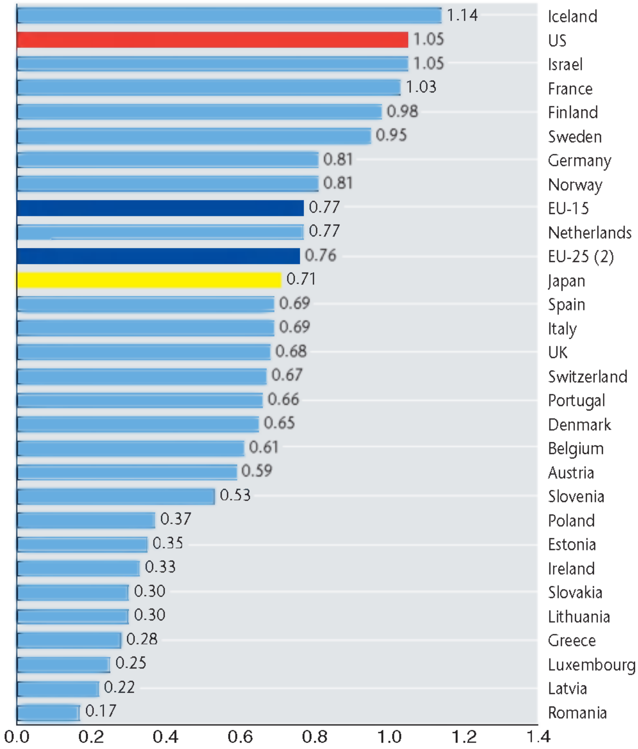
countries, high shares refer to the situation where the R&D-intensive enterprise sector is not yet well advanced and where the R&D system is still dominated by universities and government laboratories. In Japan, the low share recorded for basic research reflects a long tendency of placing more emphasis on applied research and experimental development. However, in the future, more support is being made available for basic research through Japan's second Science and Technology Basic Plan covering the period 2002–2006.

Government budget allocated to R&D: the EU is falling further behind the US

In recent years, governments have increased their support to enhance the accumulation and dissemination of knowledge throughout the economy and to create better conditions for innovation and multilateral co-operation within national innovation systems. Financing of R&D is one of the tools that enable governments to support the economy to cope with the changing market conditions and to strengthen its capacity for regeneration. Governments play an important role in stimulating R&D and supporting knowledge creation in all sectors of the economy. This sub-section explores the trends in government budget appropriations for R&D (GBAORD).

As a proportion of GDP, in 2003, the US government (1.05%) allocated far more funds to research than the EU-15 (0.77%) (Figure I-1f). This is the case despite the fact that the US government provides a lower share of total R&D funding than the governments in the EU-15. When the 10 Acceding countries are also taken in account, the figure for the EU-25

Figure I-1f Government budget allocated to R&D as % of GDP, 2003 (1)



Source: DG Research Key Figures 2003-2004
Data: Eurostat, OECD
Notes: (1) or latest available year: CH, PL: 2000; ES, IE, IT, UK, EU-15, EE, LT, LV, SI, EU-25, IL: 2001; DE, EL, FR, JP: 2002. (2) EU-25 data are estimated by DG Research and do not include CY, CZ, HU, MT.

was 0.76%. Hence, the impact of the Acceding countries on the EU figure was very limited. In Japan, the figure was slightly below that of the EU-15, at 0.71%.

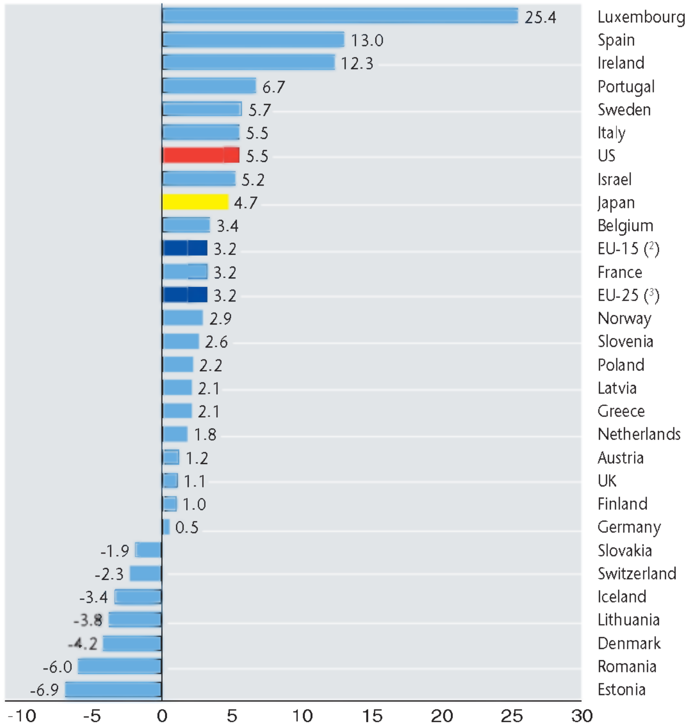
With shares of around 1.1%, Iceland together with the US and Israel stand out above the other countries. In the EU-15 group, at 1.0%, France, Finland and Sweden were the countries with the highest relative volumes. However, these countries have recently fallen behind the share of the US. In Germany and the Netherlands, government R&D budget in relation to GDP was around 0.8%. In general terms, with 0.2–0.5%, the lowest figures were recorded by the Acceding and Candidate countries and in three EU economies, Luxembourg, Greece and Ireland.

In the period 1997–2003, there were great disparities in the rate of growth of government R&D budgets between the major economic blocks and between individual countries (see Figure I-1g). The highest rate of growth among the economic blocks was seen in the US (5.5% per year[6]), followed at a close distance by Japan. Both in the EU-15 and the EU-25, growth rate was at just above 3%.

From 1997 onwards, annual growth was clearly the highest in Luxembourg (25% per year). Spain (13%) and Ireland (12%) also stand out above the others. In all these countries, the government has made goal-directed decisions to support the creation of a knowledge-based economy through investment in

[6] In February 2003, the US Congress made decisions that led to a further boost in federal R&D budget. As a result, in 2003, R&D will receive the largest annual dollar increase in history (+$14 billion, 14% increase relative to 2002).

Figure I-1g Government R&D budgets – average annual real growth rates (%), 1997–2003 (¹)



Source: DG Research Key Figures 2003-2004
Data: Eurostat, OECD
Notes: (¹) or nearest available years: CH: 1996–2000; PL: 1997–2000; ES, IE, IT, UK, EU-15, SI, EU-25, IL: 1997-2001; DE, EL, FR, JP: 1997–2002; SE: 1998–2003; EE, LT: 1999–2001; IS: 1999–2003; LU: 2000–2003; DK: 2001–2003. (²) EU-15 data do not include LU. (³) EU-25 data are estimated by DG Research and do not include LU, CY, CZ, EE, HU and MT.

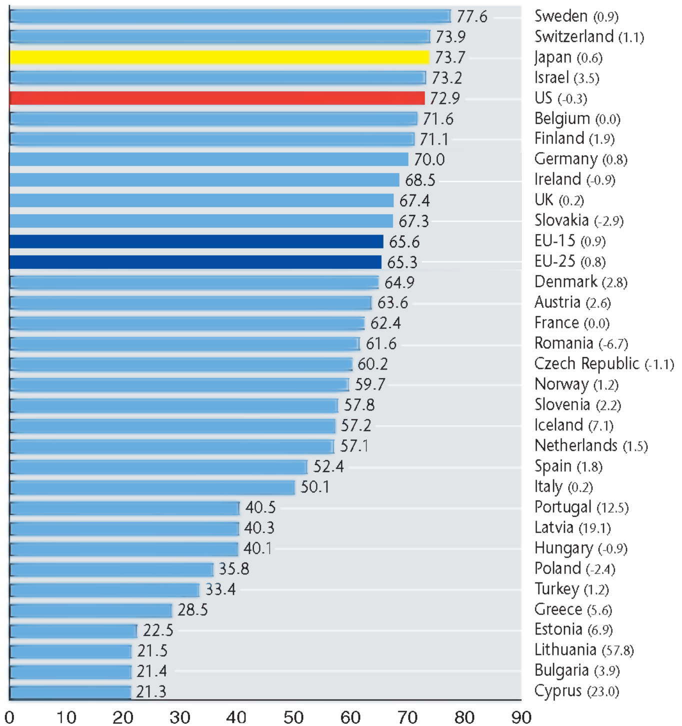
R&D. High growth rates were also recorded for Portugal, Sweden and Italy. For instance, in 2000, the Swedish government decided to allocate an additional 140 million euro to research and postgraduate education during the period 2000–2003.

Estonia, Romania, Denmark, Lithuania, Iceland, Switzerland and Slovakia all recorded negative real growth, but for different reasons. In the first two countries, the volume of investment has decreased recently even in current terms, and in Iceland and Slovakia it has stagnated. The Danish government's R&D budget for 2003 was clearly bigger than in the late 1990s, but the break in series in 2001 distorts the situation. In Finland, the growth rate has gone down recently. Considering the major growth in Finnish R&D investment in the latter part of the 1990s, the recent growth of budget-based R&D funding has been surprisingly low (1%). In the major EU economies, the rate of growth of funding was rather moderate in the UK (1.1% per year) and even less in Germany (0.5%).

I-2 Private investment in R&D

A key determinant of the future competitiveness of an economy is the level and intensity of overall expenditure on R&D. But it is also important to look at the sectors in which this R&D is performed. The business sector is probably most important in this regard. It is closest to consumers and best positioned to significantly improve or develop new products based upon new combinations of existing knowledge or knowledge newly developed through research in-house or

Figure I-2a Business Expenditure on R&D (BERD) as % of GERD, 2001 (1); in brackets: average annual growth rates, 1997-2001 (2)



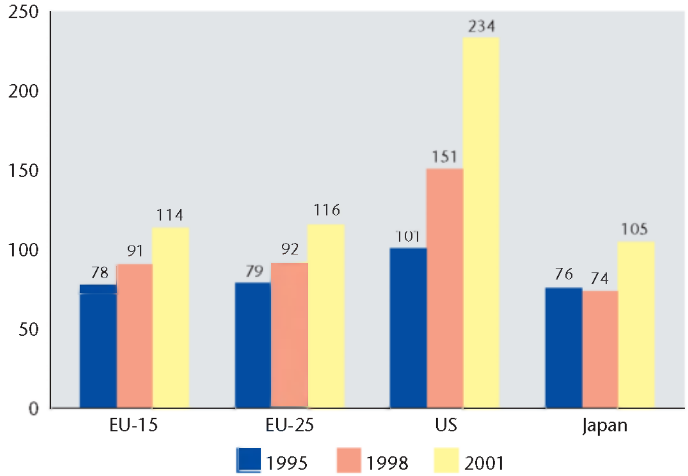
Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat.
Notes: EU-15: Data are estimated by DG Research and do not include LU. EU-25 data are estimated by DG Research and do not include LU and MT (1) or latest available year: PT, IS, DE, US: 2002; CY, BG, LT, EE, TR, LV, IT, NL, CH: 2000; EL, DK, BE: 1999; AT: 1998. (2) or nearest available years: AT: 1993-1998; BE, DK, EL: 1997-1999; CH: 1996-2000; FR, IT, NL, UK, LT, LV, TR: 1997-2000; CY, EE: 1998-2000; BG: 1999-2000; DE, PT, IS, US: 1997-2002.

elsewhere and to commercialise them. Business R&D expenditure is market-driven and accounts for most innovation expenditure. In a direct way and through dynamising other sectors this in turn leads to employment and economic growth. The level and intensity of business R&D expenditure is therefore a key determinant of an economy's future competitiveness, and a key concern of policy-makers. That is why the European Council has stipulated that two thirds of R&D expenditure should be financed by the business sector.

Business sector performs most R&D

Figure I-2a shows that in 2001 business expenditure on R&D (BERD) accounted for most of total domestic R&D expenditure (GERD) in Japan (73.7%), the US (72.9%), the EU-15 (65.6%) and the EU-25 (65.3%). The shares for both the EU-15 and the EU-25 are quite high, but substantially lower than the US and Japanese shares. However, growth rates for the period 1997-2001 of 0.9 % for the EU-15 and 0.8 % for the EU-25, as compared to –0.3 % for the US and 0.6 % for Japan, point to possible convergence in the future. There exists substantial diversity among EU Member States. Greece (28.5%) and Portugal (40.5%) remain quite far below the 50% level, while Italy (50.1%) and Spain (52.4%) find themselves at levels only just above the 50% level. On the other hand, the UK (67.4%), Ireland (68.5%), Germany (70.0%), Finland (71.1%) and Belgium (71.6%) are closer to the US, and Sweden (77.6%) even higher than Japan. With the exception of Slovakia (67.3%), none of the Acceding and Candidate countries have values higher than those for the EU-25, the EU-15, the US or Japan. And only Slovakia, Romania (61.6%), the Czech Republic (60.2%) and Slovenia (57.8%) exceed the 50% level. The other Acceding countries remain below that level to a smaller or a larger extent. The values for these countries can be expected to rise in the future as significant restructuring is taking place there.

Figure I-2b Evolution of Business Expenditure on R&D (BERD) (billion ecu/euro)



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat.
Notes: EU-15, EU-25: Data are estimated by DG Research and do not include LU and MT.

Ever present large absolute gap in business R&D expenditure relative to US

Figure I-2b shows that, even though some EU Member States are making substantial efforts, the EU-15 is far from catching up with the US, and in danger of being overtaken by Japan. Business expenditure on R&D is rising everywhere. In the EU-15, it increased substantially, by about 50%, between 1995 and 2001 (from 78 to 114 billion ecu/euro). But growth was even greater in the US. Business expenditure on R&D increased there by about 130% between 1995 and 2001, from 101 to 234 billion ecu/euro. In Japan, on the other hand, business expenditure actually decreased between 1995 and 1998 from 76 to 74 billion ecu/euro, to recover thereafter by about 40% to 105 billion. The figures for the EU-25 are not that different from the figures for the EU-15, reflecting the low absolute level of business expenditure on R&D in the Acceding countries.

Top EU-15 business R&D spenders comparable to top US ones

The previously mentioned large absolute gap in EU-US business R&D expenditure is not caused by the very large EU companies. These perform rather well relative to very large companies in both the US and Japan (Table I-2a). EU-15 firms account for a large and growing share of R&D expenditure by the top 300 international firms in terms of R&D investment. While between 1998 and 2002 the US share declined from 42.8% to 40.9% and the Japanese one from 22.7% to 21.7%, the European share increased from 28.1% to 31.3%. The EU-15 share continued to grow during the period 2001-2002, even though overall growth in R&D expenditure by the top 300 international firms in terms of R&D investment was negative. The problem lies more with small and medium sized companies. These need to be encouraged to spend more on R&D. But there is also need for an industrial policy which brings in new firms, especially in new and R&D intensive sectors.

Table I-2a R&D expenditure by top 300 international business R&D spenders by trade zone

	Number of firms	% of total R&D		Average annual growth rate of R&D investment %	Average annual growth rate of R&D investment %
	2002	1998	2002	1998-2002	2001-2002
US	127	42.8	40.9	3.1	-12.6
Japan	73	22.7	21.7	3.2	4.0
EU-15	81	28.1	31.3	7.1	7.1
Belgium	2	0.1	0.2	19.3	16.1
Denmark	2	0.2	0.3	11.2	9.0
Finland	1	0.6	1.3	24.5	24.5
France	22	5.9	6.8	8.2	0.0
Germany	24	11.9	12.4	5.4	19.5
Ireland	1	0.6	0.1	-27.4	-10.0
Italy	3	1.2	1.1	1.4	2.9
Sweden	5	2.1	1.7	-1.0	-16.8
Netherlands	6	1.4	2.5	19.5	3.2
UK	15	4.1	5.0	9.5	0.3
Other countries	19	6.3	6.1	3.5	14.0
Total	300	100.0	100.0	4.3	-2.2

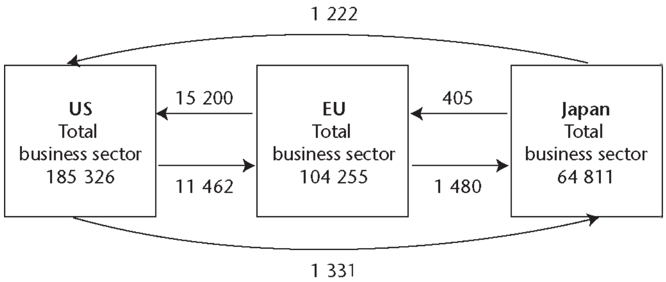
Source: DG Research Key Figures 2003-2004
Data: R&D Scoreboard 1999, 2002, 2003, DTI Future & Innovation Unit and Company Reporting Ltd.

This picture is confirmed when R&D expenditure by the top 5 European firms is compared with that by the top 5 US firms, and the same for the top 10, 20, 50 and 75 (Figure I-2c). While it is true that the R&D expenditure gap between US and EU firms increases the larger the group of companies that is compared, it is also the case that between 1998 and 2002 this gap has been reduced significantly.

US still remains more attractive than the EU

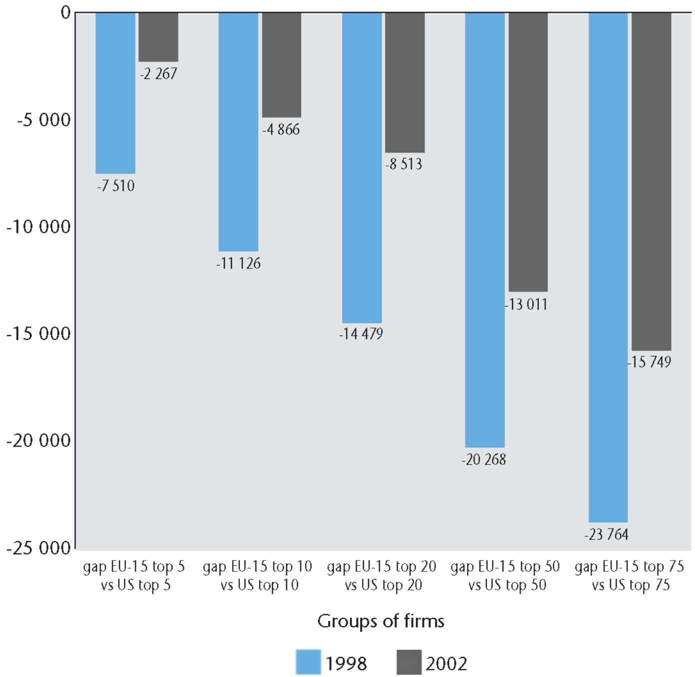
The figures presented in the previous table and graph refer to R&D expenditure made *world-wide* by the largest EU, US and Japanese companies. As such, it does not tell us anything about *where* this expenditure actually takes place. An analysis of the flows of companies' R&D expenditure between the Triad (US-JP-EU) reveals the following (see Figure I-2d).

Figure I-2d R&D Flows between the EU-15, US and Japan, 2000 (in 2000 € PPS)



Source: DG Research Key Figures 2003-2004
Data: OECD, Activity of Foreign Affiliates database and Secretariat estimates.

Figure I-2c R&D expenditure gap between top EU-15 and top US business R&D spenders (€ million current), 1998 and 2002



Source: DG Research Key Figures 2003-2004
Data: R&D Scoreboard 1999, 2003, DTI Future & Innovation Unit and Company Reporting Ltd.

Table I-2b Breakdown by controlling area of business R&D expenditure, 2000 € PPS

In the EU-15			In the US			In Japan		
US	11 462	11.0%	US	158 358	85.4%	US	690	1.1%
EU	89 907	86.2%	EU	15 200	8.2%	EU	1 480	2.3%
Japan	405	0.4%	Japan	3 167	1.7%	Japan	62 473	96.4%
Other	2 481	2.4%	Other	8 600	4.6%	Other	168	0.3%
Total	104 255	100.0%	Total	185 326	100.0%	Total	64 811	100.0%

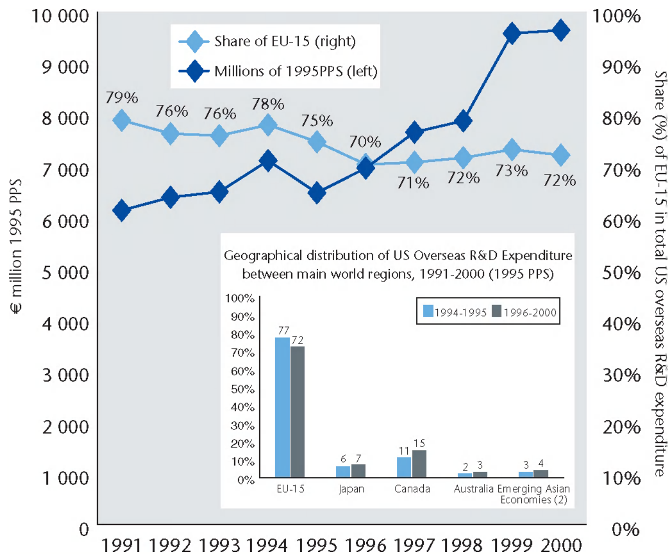
Source: DG Research Key Figures 2003-2004
Data: OECD, Activity of Foreign Affiliates database and Secretariat estimates.

The share of EU Business R&D expenditure controlled by US companies (11%) was in 2000 higher than the share of US Business R&D expenditure controlled by EU firms (8%, see Table I-2b). The US and EU contributions to the Japanese research system are, however, very limited in relative terms.

Considering the absolute R&D flows between the EU-15 and the US in 2000 (see Figure I-2d), the US attracted one third more business R&D expenditure from EU companies than they allocated in the EU (€ PPS 15.2 versus 11.5 billion). Between the EU and Japan the imbalance was even more dramatic: EU firms spent almost four times more on Japanese research than Japanese companies spent in the EU-15 (€ PPS 1.5 versus 0.4 billion). The flows between Japan and the US, on the other hand, were much more balanced. These data imply that, for the year 2000 alone, there was a net outflow of nearly € 5 billion of European R&D funding to the advantage mainly of the US research system.

Figure I-2e shows the evolution of US overseas R&D expenditure in the EU-15 and in the rest of the world. Whereas the

Figure I-2e US overseas R&D Expenditure in the EU-15, 1991-2000 (absolute figures and share in total US expenditure in main world regions) (inserted: geographical distribution between main world regions) ([1])



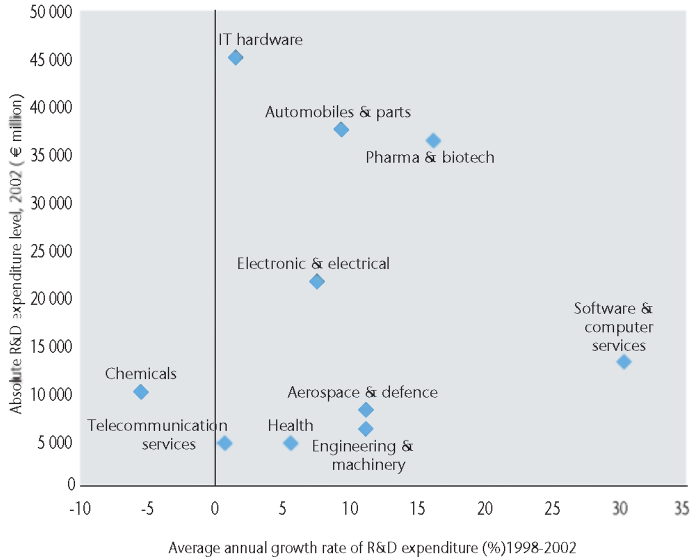
Source: DG Research Key Figures 2003-2004
Data: US Bureau of Economic Analysis: U.S. Direct Investment Abroad – Operations of U.S. Parent companies and Their Foreign Affiliates (Washington, DC, annual series).
Note: ([1]) 'US overseas R&D Expenditure' refers tot R&D expenditure performed by majority-owned (more than 50 percent ownership) non-bank foreign affiliates of non-bank U.S. parent companies. Data incude R&D expenditure conducted by affiliates, whether for themselves or for others under contract; exclude R&D expenditures conducted by others for affiliates under contract. Shares calculated here are the shares in the total US R&D expenditure made in the main world regions EU-15, Japan, Canada, Australia and the Emerging Asian Economies (China, Hong Kong, Singapore and Taiwan). ([2]): Data for China, Hong Kong and the Emerging Asian Economies in 1999 and 2000 have been estimated by DG Research.

absolute amount of US R&D expenditure made in the EU-15 continued to rise during the 1991-2000 period, the share of the EU-15 in total US R&D expenditure made world-wide declined substantially. The EU-15 represented nearly 80% of all US overseas R&D expenditure in 1991 against 70%-72% in the second half of the nineties. This relative decline for Europe occurred to the advantage of the other world regions, notably Canada, whose share of US R&D rose from 11 to 15%. The sharp increase of US R&D expenditure in China also deserves special note, rising from € 5 million in 1991 to € 120 million in 1998 (€ 1995 PPS).

Sector-specific distribution of R&D expenditure of largest spenders

Figure I-2f shows for selected sectors the 1998-2002 average annual growth rate of R&D expenditure by the top 300 international firms as well as 2002 absolute R&D expenditure levels. It shows that 'IT hardware', 'automobiles & parts' and 'pharma & biotech' constitute the top three sectors in terms of absolute R&D expenditure levels in 2002. Their growth rates over the past few years have differed though. While 'IT hardware' has grown hardly at all, the two other sectors have experienced rapid growth. 'Software and computer services' distinguish themselves by their very large growth rate, though they are still situated at a rather low absolute level. R&D expenditure in 'chemicals' was characterised by negative growth in the past few years.

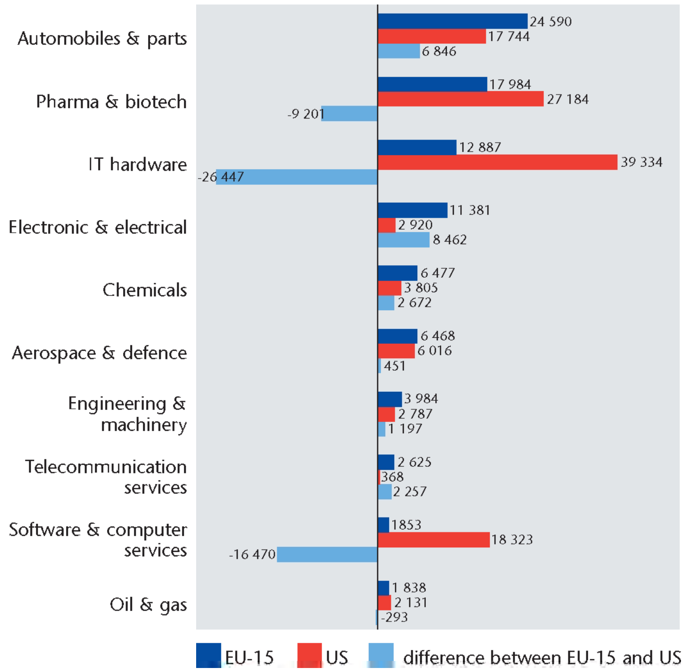
Figure I-2f R&D expenditure by top 300 international business R&D spenders in selected sectors - average annual growth rate, 1998-2002 and absolute level (€ million), 2002 (1)



Source: DG Research Key Figures 2003-2004
Data: R&D Scoreboard 1999, 2003, DTI Future & Innovation Unit and Company Reporting Ltd.
Note: (1) The 2002 categorisation of sectors is used. The 1998 one differs somewhat for a number of sectors, e.g. 'Automobiles', 'Pharmaceuticals', 'Software & IT services', 'Telecommunications'.

If one compares business R&D expenditure by the EU-15 and US firms out of the top 300 international firms by sector in Figure I-2g, then it can be seen that the EU-15 firms spend substantially less than their US counterparts in 'pharma & biotech', 'IT hardware' and 'software & computer services', but maintain substantial leads in 'automobiles & parts', 'electronics & electrical' and some other sectors.

Figure I-2g R&D expenditure by top EU-15 and top US business R&D spenders in selected sectors, 2002

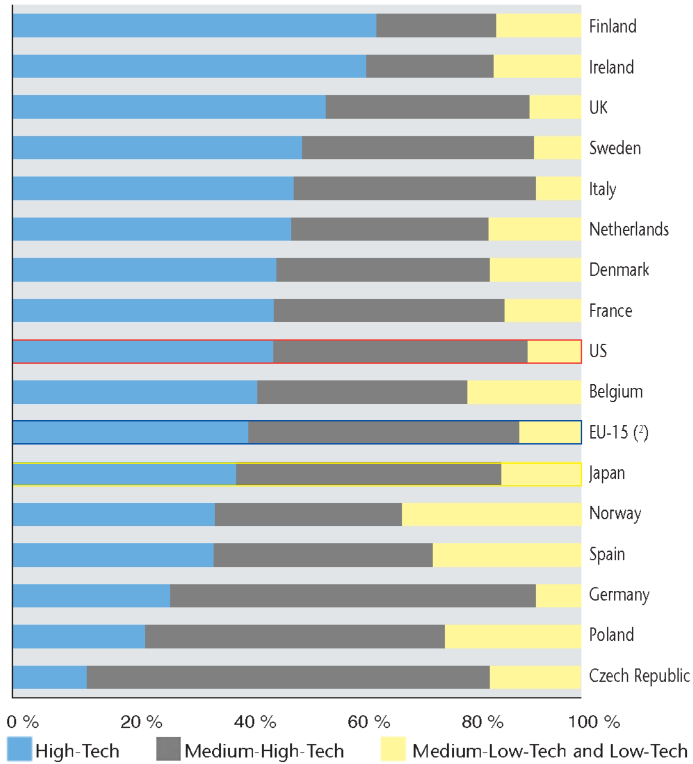


Source: DG Research Key Figures 2003-2004
Data: R&D Scoreboard 1999, 2003, DTI Future & Innovation Unit and Company Reporting Ltd.

Sizeable business R&D expenditure in high-tech industries

Figure I-2h shows that the shares of manufacturing BERD going to each of three industry types distinguished by the level of technology involved are not too different from each other in Japan, the US and the EU-15. In all three, high-tech industries account for 40% to 45% of manufacturing BERD, medium-high-tech industries for about 45%, and medium-low-tech and low-tech industries for 10% to 15%. Japan (14.1%) dedicates a somewhat larger share of its business sector R&D to medium-low-tech and low-tech industries than either the EU-15 (11.0%) or the US (9.4%). On the other hand, the US (45.8%) spends a somewhat larger proportion of its business sector R&D in high-tech industries than either the EU-15 (41.4%) or Japan (39.3%). The differences are greater between the EU Member States than between Japan, the US and the EU-15. The highest shares of business sector R&D dedicated to high-tech are found in Finland (63.9%) and Ireland (62.1%), while the lowest such shares are found in Spain (35.3%) and Germany (27.7%). With the exception of the latter two, in most EU Member States the high-tech shares are higher than in the US or Japan. The two Acceding countries, Poland and the Czech Republic, record high-tech shares lower even than those for Spain and Germany. Attracting foreign direct investment in the high-tech sectors may constitute one means to achieve higher proportions of high-tech business sector R&D.

Figure I-2h Share of manufacturing BERD by industry type, 2000 ([1])

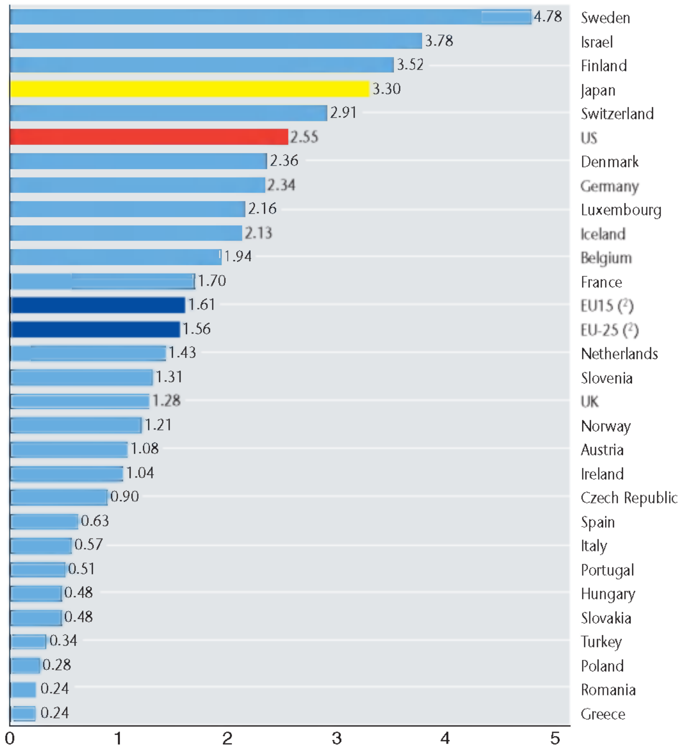


Source: DG Research
Key Figures 2003-2004
Data: OECD
Notes: ([1]) or latest available year: NO: 1998; DK, FR, IE, NL, SE, EU-15: 1999 ([2]) EU-15 data do not include EL, LU, AT, PT.

Large gaps in business R&D financing relative to US and Japan are ever present

The objective of business-financed research activities is to increase firms' future profitability and competitiveness. The relative efforts of business sector financing of R&D activities and its dynamics are important indicators for the profit-oriented creation of new scientific and technological knowledge and for efforts in absorbing existing knowledge from other sources – from the government sector, higher education and from abroad. Figure I-2i shows that relative to value added the Japanese business sector finances much more R&D (3.30%) than either the US (2.55%) or the EU-15 (1.61%) and EU-25 (1.56%). So the Japanese rate is more than double the one for the EU-15 or EU-25. There exists substantial diversity between EU Member States. The Southern European countries Greece (0.24%), Portugal (0.51%), Italy (0.57%) and Spain (0.63%) are situated at the bottom of the scale and do not reach 1%. The low figures for Italy and Spain, but also for countries such as the UK, Netherlands, France and Belgium are particularly worrying. On the other hand, Finland (3.52%) and Sweden (4.78%) exceed the Japanese figure by a substantial amount. The EU-25 rate is lower than the EU-15 one, suggesting that the business sector in the Acceding countries finances less R&D in relative terms than that in the EU Member States. With the exception of Slovenia (1.31%), the business sector in none of the Acceding and Candidate countries covered spends even 1% of its value added on R&D.

Figure I-2i Business financed R&D as % of Value Added of Industry, 2001 (1)



Source: DG Research Key Figures 2003-2004

Data: Eurostat, OECD

Notes: (1) or latest available year: EL, IT, IL: 1999; LU, NL, CH, TR: 2000; AT, PT, IS, US: 2002.
(2) EU-15, EU-25 were estimated by DG Research and do not include LU, EE, LT, LV and MT.

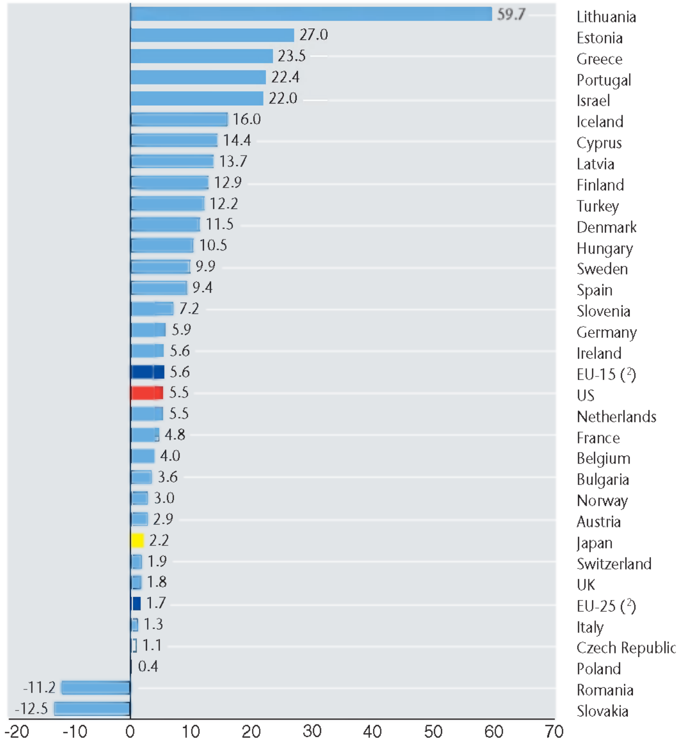
The business sector is, in relative terms, not catching up

The growth of business sector financed R&D indicates the efforts being invested in future competitiveness. Figure I-2j shows that in the late 1990s business R&D financing grew somewhat slower in the US (5.5%) than in the EU-15 (5.6%). The figure for Japan (2.2%) was less than half that for the US or the EU-15. The differences existing between EU Member States are quite large. With the exception of Italy (1.3%), the Southern European Member States, Spain (9.4%), Portugal (22.4%) and Greece (23.5%), starting from low levels of business R&D financing, exhibit rather high growth rates. The same is true for the Scandinavian Member States, Sweden (9.9%), Denmark (11.5%) and Finland (12.9%), even though they already start from high levels. The figure for the EU-25 (1.7%) is much lower than that for the EU-15, indicating that catching-up is unlikely to take place in the near future. This is remarkable as some Acceding and Candidate countries such as Lithuania (59.7%), Estonia (27.0%), Cyprus (14.4%) and Latvia (13.7%) exhibit very large growth rates. But the overall figures for the EU-25 are dragged down by the Czech Republic (1.1%) and Poland (0.4%), where growth is close to zero, Romania (-11.2%) and Slovakia (-12.5%) where there is negative growth.

Promoting SMEs

This indicator sheds light on the relative importance of public support for SMEs' scientific and technological knowledge production and absorption. Public funding of R&D gives governments an instrument for directing resources to chosen

Figure I-2j Industry financed R&D – average annual real growth (%), 1997 to 2001 (1)

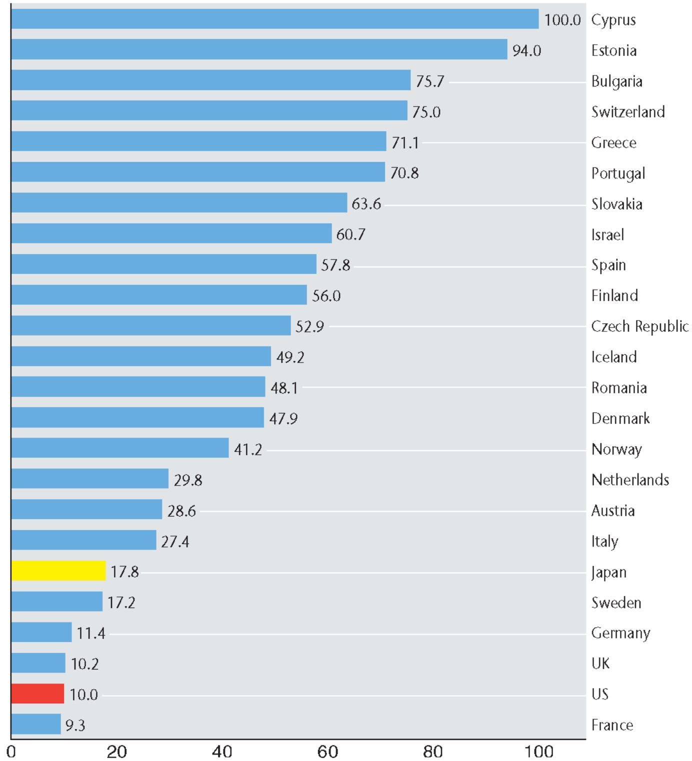


Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Notes: (1) or nearest available years: CH: 1996-2000; BE, EL, FR, IT, IL: 1997-1999; NL, TR: 1997-2000; AT, PT, IS, US: 1997-2002; EE, CY: 1998-2001; BG: 1999-2001; LT: 2000-2001 (2) EU-15, EU-25 were estimated by DG Research and do not include LU, LT and MT.

research priorities as well as to certain types of firms. SMEs appear to provide a fertile breeding ground for new ideas and innovative ways of doing business. However, they have problems due to lack of resources and the relatively high information and administrative costs of participating in research programmes. Figure I-2k reveals that the share of SMEs in publicly funded R&D executed by the business sector is considerably higher in Japan (17.8%) than in the US (10.0%). No overall figure could be calculated for the EU-15. With the exception of France (9.3%), however, the rates for all EU Member States are higher than the rate for the US. The highest rates are found in the Southern European Member States, Greece (71.1%), Portugal (70.8%) and Spain (57.8%). Rather high rates are also recorded, however, in Scandinavian Member States such as Finland (56.0%) and Denmark (47.9%). The Acceding and Candidate countries generally have large shares of SMEs in publicly funded R&D executed by the business sector. They range from 48.1% in Romania to 100.0% in Cyprus.

Figure I-2l shows that publicly funded R&D executed in the SME sector is growing considerably faster in Japan (17.7%) than in the US (12.2%). Unfortunately no overall figures could be calculated for the EU-15 or EU-25. Of the EU Member States only Spain (20.2%) exhibits a growth figure larger than the Japanese one. Most EU Member States are situated below the US level and at least two of them, Germany and Portugal, are characterised by negative growth rates. The same diversity appears as far as the Acceding and Candidate countries are concerned. Cyprus, the Czech Republic and Estonia demonstrate large growth, while Romania and Slovakia hardly

Figure I-2k Share of SMEs in publicly funded R&D executed by the business sector (%), 2001 (1)



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Notes: (1) or latest available year: AT: 1998; DE, EL, NL, UK, US: 1999; FR, IT, IL, CH: 2000; PT: 2002.

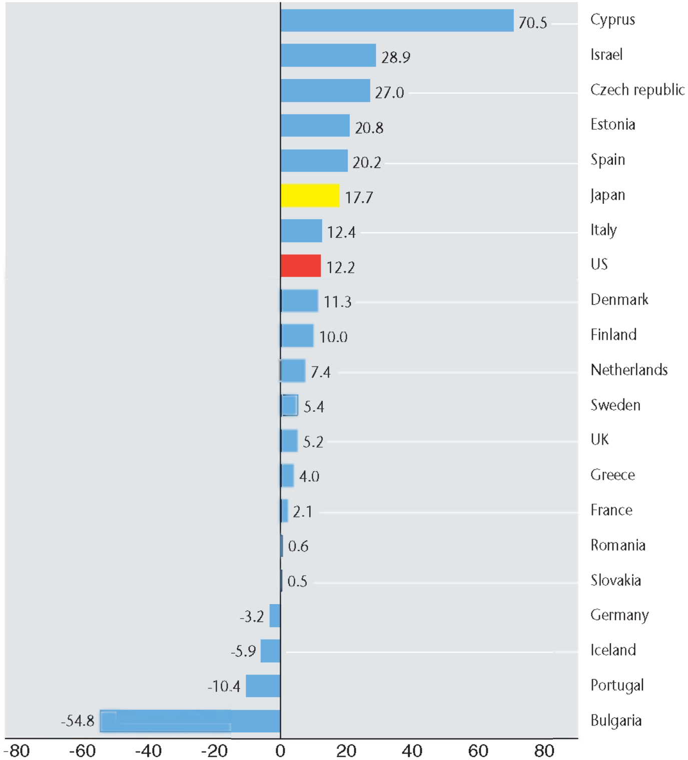
managed any growth at all, and Bulgaria showed negative growth. Referring back to the negative GERD growth rates for Bulgaria recorded in the previous section this shows that the decrease in total R&D expenditure in Bulgaria has hit SMEs hardest.

Venture capital investment

Venture capital (VC) investment finances seed, start-up and expansion phases of a firm's life cycle. It provides equity capital and managerial skills for high risk, promising new companies, which frequently are found in high-tech and knowledge intensive sectors. Therefore, venture capital investment creates and expands new business activities that generate additional business sector R&D and drive competitiveness and economic growth.

EU-15 venture capital financing of seed, start-up and expansion phases makes up only 48.7% of that in the US. Therefore, in spite of the drastic decline in US VC investment in 2001 and 2002 – EU-15 VC investment still lags behind dramatically (see Table I-2c). Also in the future EU-25, venture capital investment will still lag behind that of the US (49.3%) because in the Acceding countries the level of venture capital investment is still very low indeed. This may at first seem surprising as in the Acceding countries a very high number of start-ups have been created, but this can be explained by the specific characteristics of VC financed firms - often high-tech, very high risk new companies. An important issue in the Acceding countries is that the exit markets for VC investment are not yet well developed.

Figure I-2I Publicly funded R&D in the SME sector – average annual real growth (%), 1997 to 2001 ([1])



Source: DG Research Key Figures 2003-2004
Data: Eurostat
Notes: ([1]) or nearest available years: DE, EL, NL, UK, US: 1997-1999; FR, IT: 1997-2000; PT: 1997-2002; EE, CY, IL: 1998-2001; BG: 1999-2001; RO: 2000-2001.

Table I-2c also shows that the level of venture capital investment varies considerably between individual countries and depends among other things also on the size of the countries. However, the relatively high importance of the expansion phase in all countries is a common feature and shows that the VC industry finances more strongly the expansion phase than the seed and start-up phases. Typically, the expansion phase is connected with already existing profits while the seed and start-up phases are connected with a high degree of technological and market uncertainty.

The same pattern is also valid for the four Acceding countries. However, the EFTA countries allocate VC investment more strongly to the seed and start-up phases.

The crisis of the new economy is still negatively influencing investment in VC as can be seen in the very strong decline between 2001 and 2002 in the US, by –49.4% and in the EU, by –21.7%. Only in EFTA, namely in Switzerland, and in the Czech Republic, has VC investment increased between 2001 and 2002.

Table I-2c Venture Capital Investment, 2002

	Venture Capital Investment (€ MIO), 2002				Relative change (%), 2001-2002			
	Seed	Start-up	Expansion	Total	Seed	Start-up	Expansion	Total
Belgium	7.523	101.331	110.323	219.177	-72.6	41.5	-45.1	-27.0
Denmark	61.090	76.540	96.805	234.435	2.5	-17.0	-34.3	-21.6
Germany (7)	76.840	483.980	782.950	1 343.770	-55.4	-50.7	-49.6	-50.4
Greece	1.301	11.658	32.425	45.384	37.4	-61.8	-45.9	-50.4
Spain	13.009	93.117	623.247	729.373	176.1	-12.3	-18.3	-16.6
France	50.098	350.943	755.420	1 156.461	66.4	-34.0	4.9	-9.8
Ireland	1.808	25.623	75.875	103.306	64.2	-29.9	-12.2	-16.7
Italy	30.285	34.266	805.444	869.995	41.4	-87.3	8.1	-16.1
The Netherlands	7.977	193.365	646.943	848.285	531.6	5.8	-13.2	-8.7
Austria	5.172	22.307	88.223	115.702	-31.9	-34.2	2.6	-9.2
Portugal	0.013	10.248	51.304	61.565	85.7	-35.9	-10.1	-15.7
Finland	19.499	79.214	188.367	287.080	-21.6	-31.4	160.8	35.0
Sweden	9.655	239.379	300.063	549.097	-59.1	11.4	-54.8	-39.2
UK	8.160	590.182	1 944.957	2 543.299	-93.5	-26.6	12.0	-4.6
EU-15 (1)	292.430	2 312.154	6 502.346	9 106.929	-41.5	-33.7	-14.9	-21.7
Czech Republic	0.000	0.488	28.179	28.667	-100.0	-91.9	42.1	8.3
Hungary	0.000	2.371	8.268	10.639	-100.0	-84.9	-20.6	-59.3
Poland	0.000	9.799	53.667	63.467	-100.0	-56.9	-27.4	-35.8
Slovakia	0.218	0.564	2.077	2.858	371.6	-79.0	-64.1	-66.4
ACC (4)	0.218	13.222	92.191	105.631	-92.5	-72.0	-16.1	-34.0
EU-25 (2)	292.647	2 325.375	6 594.538	9 212.560	-134.0	-105.7	-31.0	-55.7
Switzerland	0.084	131.559	142.986	274.629	-99.7	171.0	67.0	71.3
Iceland	0.491	1.647	10.669	12.806	7 870.2	-72.6	-13.4	-30.1
Norway	11.888	61.269	115.091	188.248	566.1	-3.7	-27.7	-16.2
EFTA (3)	12.462	194.475	268.746	475.683	-55.5	64.6	4.5	17.9
Romania	0.000	2.443	5.885	8.329	0.0	54.6	-62.1	-51.3
US (5)	321.286	4 310.821	14 067.011	18 699.118	-65.1	-58.4	-45.3	-49.4
Japan (6)	-	4 584.680	1 311.842	5 896.522	-	-10.7	11.6	-6.5

Source: DG Research — Key Figures 2003-2004

Data: EVCA, NVCA, NISTEP

Notes: The definition of venture capital by stages is the same in all European countries (EU-15, EFTA and ACC) but differs with respect to that of the US and Japan. (1) EU-15 data do not include LU. (2) EU-25 data do not include LU, CY, EE, LT, LV, MT, and SI. (3) EFTA data do not include LI. (4) ACC data include CZ, HU, PL, SK. (5) US: a) Seed includes start-up b) start-up corresponds to early stage (6) JP: Seed is included in start-up. (7) DE data for 2002: Expansion includes € 35.3 million Bridge and € 43.04 million Turnaround.

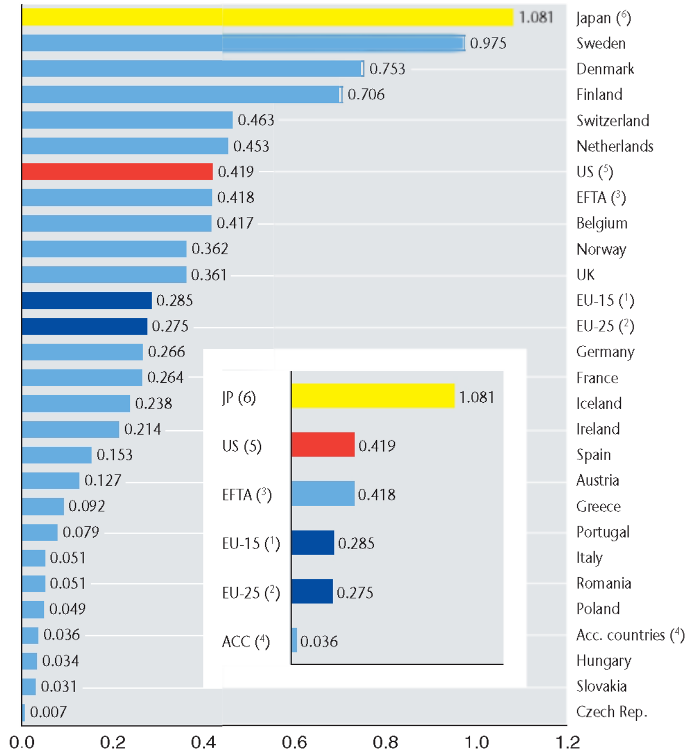
Venture capital investment in early stages

Venture capital financing of the seed and start-up phases of new firms - even if quantitatively only a small fraction of GDP - creates new business activities typically in high-tech industries and knowledge intensive sectors. Therefore, venture capital investment plays a critical role in the commercialisation of scientific and technological knowledge coming from public and private sector research. The creation of these new innovative businesses contributes to competitiveness and future growth in Europe.

In 2002, early stage VC investment played a more prominent role in the US with 0.42‰ of GDP than in the EU-15 and EU-25 (with 0.28‰ and 0.29‰ respectively) (Figure I-2m). However, the US has experienced a dramatic decline in early stage VC investment since 2001 which foreshadows a slower dynamic in the US innovative business sector in the near future. Some of the Member States, Sweden at around 1.0‰ followed by Denmark and Finland – invest more strongly in early stage VC than the US and the EU-15, while in Greece, Portugal, and Italy (between 0.01 and 0.05‰) as well as in the four Acceding countries its role is much more limited. Early stage VC investment plays a prominent role in EFTA countries with 0.42‰, in particular in Switzerland with 0.46‰.

The analysis of the dynamics of early stage VC investment since mid 1995, in Figure I-2n, shows that the crisis of the new economy in 2000 is causing a strong break in the positive trend. In the period 1995 to 2000, all countries - some of them very impressively - and country groups have a positive average annual growth of early stage VC investment. The EU-15 -

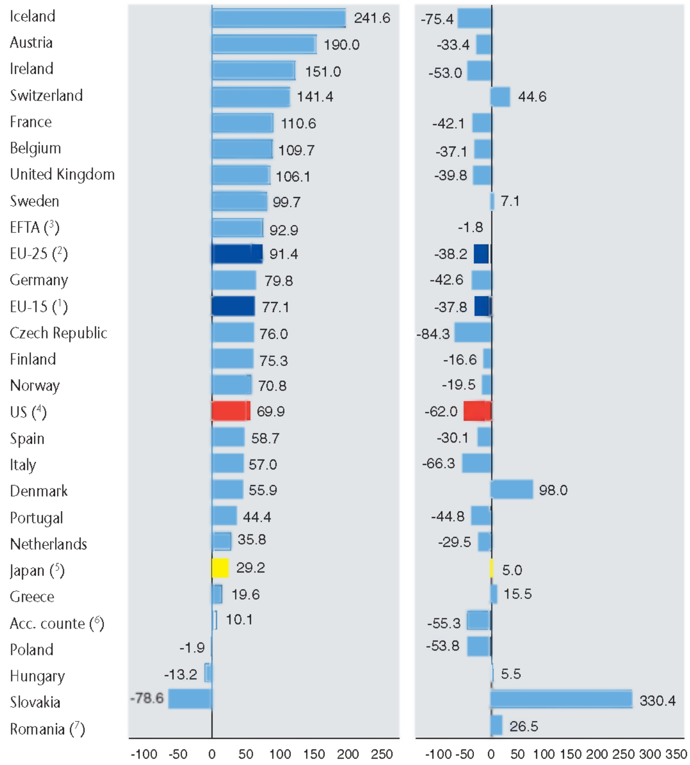
Figure I-2m Venture capital investment in early stages (seed and start-up) per 1000 GDP, 2002



Source: DG Research — Key Figures 2003-2004
Data: EVCA, NVCA, NISTEP
Notes: The definition of venture capital by stages is the same in all European countries (EU-15, EFTA and ACC) but differs with respect to that of the US and Japan. (1)-(6): see notes on Table I-2c.

starting at a lower initial level - has a higher rate of growth than the US and Japan. In particular, the average annual growth rate of early stage VC investment is higher in the EU-25 than in the EU-15 indicating a catching up in the Acceding countries prior to the crisis of the new economy. EFTA has even a slightly higher average annual growth rate in this period. In the period after the crisis, all country groups – except Japan - show negative trends. In particular, the decline of early stage VC investment is much stronger in the US than in Europe. In the period 1995 to 2000, in some individual countries the changes in early stage VC investment are enormous, like in Austria with 190% followed by Ireland – both starting at a very low initial level - and by France. After the crisis of the new economy, almost all countries experienced negative growth rates with the exceptions of Denmark, Sweden, Greece, Sweden, and Japan as well as Slovakia, Romania and Hungary.

Figure I-2n Seed and start-up Venture capital investment - average annual real growth (%), 1995-2000 and 2000-2002 (5)



Source: DG Research Key Figures 2003-2004
Data: EVCA, NVCA, NISTEP
Notes: (1)-(4): see notes on Table I-2c. (5) EU-25 and ACC: 1998-200 and 2000-2002.

I-3 Human resources in R&D: Researchers

Human resources are the vital elements of R&D and of all other activities related to S&T (European Commission 2003a). If the R&D expenditure target of 3% of GDP is achieved, the human resources for research will have to be available. This section analyses the number of researchers in the ERA, their share in the labour force, European S&T employees in the US and the participation of women in R&D.

Fewer researchers in the EU than in the US or Japan

In EU-15, about 972 500 researchers were employed in the year 2000. This number has shown an average annual growth rate of 3.9% since 1996 (Table I-3a). In the enlarged EU with 25 Member States, the number will be 110 000 higher, but still about 175 000 lower than the US. Japan is on a similar level to Germany, France, the UK and Spain grouped together. Poland is the largest employer among the new Member States; the other Acceding countries each employ between 300 and 15 000 researchers.

Whereas in EU-15 about 50% of researchers are employed by the private sector and in EU-25 even less, this share increases to about 64% for Japan and about 80% for the US. In Europe, only Ireland has a similar share to Japan, and only Austria, Sweden and Switzerland are above 60%. The higher education sector is the most important employer for researchers in Spain, Portugal, Hungary, Poland, Slovakia and Turkey.

Table I-3a Researchers (FTE) – total numbers and by sector (%), 2001 (¹)

	in % by sector			Total number of researchers	Average annual growth rates in % 1996-2001 (²)
	Business enterprise	Govern-ment	Higher education		
Belgium	54.5	4.0	40.4	30 219	7.28
Denmark	47.9	20.7	30.2	18 944	4.30
Germany	59.3	14.4	26.3	259 597	2.43
Greece	15.2	13.6	71.0	14 748	11.03
Spain	23.7	16.7	58.6	80 081	9.17
France	47.1	15.2	35.8	172 070	2.67
Ireland	66.1	8.7	25.2	8 516	7.32
Italy	39.5	21.7	38.9	66 110	-3.56
Netherlands	47.6	14.1	37.2	42 085	5.11
Austria	62.6	5.1	31.8	18 715	7.86
Portugal	15.5	21.0	50.3	17 584	6.55
Finland	56.9	12.3	29.8	36 889	8.64
Sweden	60.6	4.9	34.5	45 995	5.68
UK	57.9	9.1	31.1	157 662	4.37
EU-15 (³)	49.7	13.4	34.5	972 448	3.90
Cyprus	:	:	:	333	12.08
Czech Rep.	38.4	32.3	28.4	14 987	2.94
Estonia	:	:	:	2 681	-3.44
Hungary	27.8	31.8	40.5	14 666	7.10
Lithuania	:	:	:	8 075	1.40
Latvia	:	:	:	3 497	4.26
Poland	16.9	18.7	64.3	56 919	1.64
Slovenia	33.6	32.3	30.7	4 498	0.04
Slovakia	23.5	25.4	51.0	9 585	-0.86
EU-25 (³)	47.3	14.5	36.0	1 084 726	3.68
Bulgaria	:	:	:	9 217	-8.98
Romania	57.2	28.4	14.4	19 726	-8.23
Turkey	16.0	10.7	73.2	23 083	6.28
Iceland	45.9	22.8	27.7	1 859	8.52
Norway	55.7	15.6	28.7	19 752	3.09
Switzerland	62.9	1.6	35.5	25 755	4.45
US	80.5	3.8	14.7	1 261 227	4.28
Japan	63.7	5.0	29.6	675 898	1.83

Source: DG Research Key Figures 2003-2004
Data : OECD, MSTI 2003/Vol.1, for non-OECD members: Eurostat/Member States
Notes: The sectors do not add up to 100% (¹) or latest available year: AT, UK: 1998, BE, DK, EL, US: 1999; FR, IE, IT, NL, EU-15, EU-25, TR, CH: 2000. (²) or nearest available years: AT: 1993-1998, EL: 1995-1999, US: 1997-1999; BE, DK: 1996-1999; FR, IE, IT, NL, EU-15, EU-25, TR, CH: 1996-2000; PT, FI, SE, IS, NO: 1997-2001; CY, EE: 1998-2001. (³) EU-15, EU-25 data are estimated by DG RTD and total numbers do not include LU or MT. EU-25 by sector data exclude LU, CY, EE, LT, LV and MT.

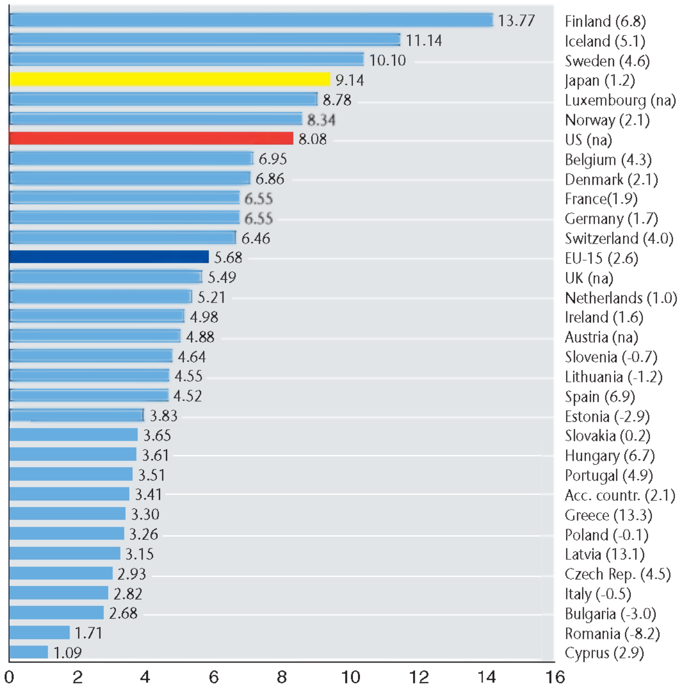
Huge variations in the representation of researchers in the labour force

The indicator 'researchers per 1000 labour force' reflects the role that research plays in national employment. In EU-15, about 5.7 researchers, in full-time equivalents (FTE), were employed per 1000 labour force in the year 2001 (Figure I-3a). This share is much lower than those of Japan at 9.1 and the US at 8.1. The differences between the European countries are huge. Finland with 13.8 researchers per 1000 labour force has by far the largest share, followed by Iceland, Sweden, Luxembourg and Norway, all above 8 should be interpreted carefully because of the small size of their R&D sector).

The Acceding countries had an average of 3.5 researchers per 1000 labour force. Slovenia showed the largest share, followed by Lithuania, both at around 4.6. Romania and Cyprus, with less than 2, had the lowest shares.

The dynamics tell a lot about the propensity of the countries to increase employment of researchers. Between 1996 and 2001, the EU-15 countries had increased their shares by on average 2.6%, the Acceding countries by 2.1%, and Japan by 1%. Between 1996 and 2001, Greece, Spain, Finland, Hungary and Latvia had very high growth rates of more than 6% per year. On the other hand, the worst performers have not made much progress regarding the employment of researchers: Romania decreased by 8.2% per year.

Figure I-3a Number of researchers (FTE) per 1000 labour force, 2001 ([1]); in brackets: average annual growth rates (%), 1996-2001 ([2])



Source: DG Research Key Figures 2003-2004
Data: Benchmarking Indicator, Eurostat/Member States
Notes: Data for DE, PT, JP are estimated. EU-15 data do not include UK, ACC data do not include MT. ([1]) or latest available year: PT, IS, JP: 2002; FR, IT, LU, NL, CH: 2000; BE, EL: 1999; AT, UK: 1998; US: 1997 ([2]) or nearest available years: PT, IS, JP: 1996-2002; SE, CZ, PL, RO, NO: 1997-2001; IT, NL, CH: 1996-2000; BE: 1996-1999; EL. 1997-1999; CY: 1999-2001; BG: 2000-2001.

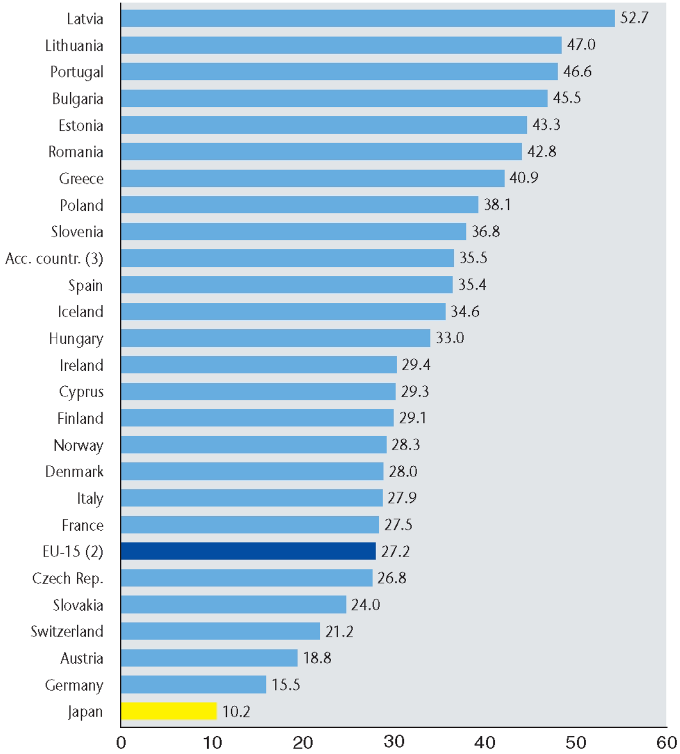
Great potential of women as researchers is under-exploited

Women are widely recognised as being an important resource for European research, and their huge potential is under-exploited. This is shown in the share of women in the total of researchers, which in nearly all countries was below 50% in 2001. As can be seen in Figure I-3b, only Latvia had a share of more than 50%. Estonia, Lithuania, Portugal, Bulgaria, Romania and Greece were all above 40%.

The EU-15 average was below one third, which compares to 36% in the Acceding countries. Germany, Austria, Switzerland and Slovakia had shares less than 25%. They are nevertheless above Japan which shows a share of only 10%.

This under-representation of women in research results from different factors such as lower participation in S&E related studies (see also section I-4), different career models, and historical and current discriminations. These reasons are important for the identification of starting points for the implementation of policy measures to encourage the participation of women in research. Women are an under-exploited resource for research in the European Union and have a huge potential for the future of research in Europe. For more detailed statistics and indicators on women in research see the European Commission's "She Figures" (European Commission / DG Research 2003b).

Figure I-3b Female researchers as % of all researchers (in HC), 2001 (1)



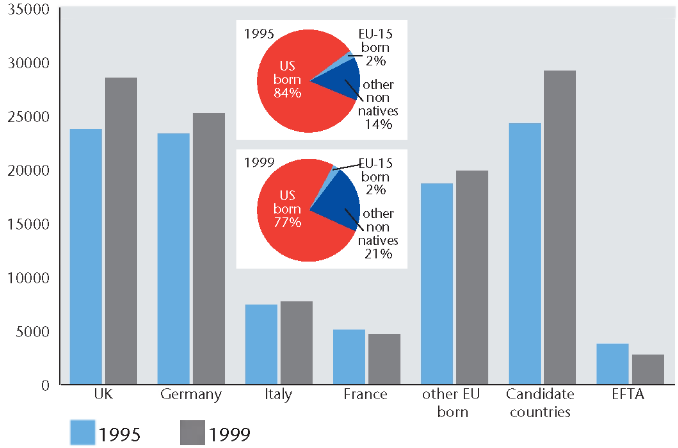
Source: DG Research Key Figures 2003-2004
Data: Benchmarking indicator, Eurostat/Member States, She Figures
Notes: Data are in headcount (HC) (1) or latest available year: IS: 2002, DE, FR, IE, IT, PL, CH: 2000, EL, PT: 1999; AT: 1998; (2) EU-15 average only includes data for available countries. (3) ACC data do not include MT.

US recruits foreign S&E employees mostly from outside the EU

The migration of researchers from Europe to the US is considered as being a threat to the stock of human resources in the EU. The following two figures give the overall numbers of S&E employees and H-1B visa beneficiaries in the US originating from Europe, and their relative significance compared to other origins. The total of 85 000 EU born S&E employees in 1999 (Figure I-3c) represents a very small proportion of both the US total of 3.5 million S&E employees and the total of 760 000 S&E employees from other countries of origin. The largest numbers are from the UK and Germany. Significant dynamics can be observed for the UK and the Candidate countries.

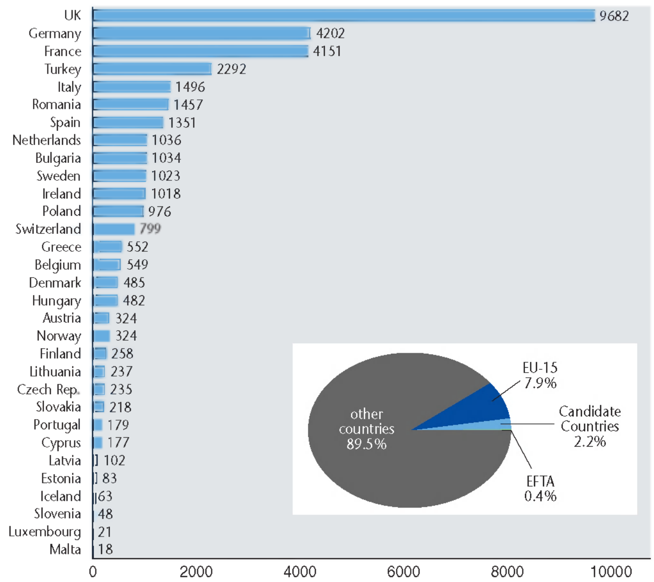
Similar observations can be made concerning the total of 26 000 H-1B visas granted to foreign qualified workers in 2001(Figure I-3d), Only 7.6% of the visa beneficiaries originated from EU-15.

Figure I-3c European S&E employees in the US, 1995 and 1999



Source: DG Research / MERIT (Brain drain study) Key Figures 2003-2004
Data: SESTAT, SRS, NSF

Figure I-3d H-1B visa beneficiaries by country of birth, 2001



Source: DG Research / MERIT (Brain drain study) Key Figures 2003-2004
Data: US Immigration and Naturalization Service , Table 44
Notes: H-1B visas: see Annex

Smaller financial endowment of R&D posts in the EU than in the US or Japan

R&D expenditure in relation to the number of researchers employed shows the average financial endowment of a research post. A huge amount of money is dedicated to the salaries of the researchers, but equipment, materials and services are also included in the total. (The labour costs represent on average about 60% of the total but differ significantly between countries and sectors.)

In EU-15, every research post was funded by an average of 171 000 euro in 2001 (Table I-3b). This is lower than both the US average (182 000 euro) and the Japanese average (212 000 euro). After the enlargement, the new EU-25 will have an average of 156 000 euro.

In EU-15, the R&D expenditure per researcher varies between 225 000 euro in the Business Enterprise Sector (BES) and 103 000 euro in the Higher Education Sector (HES). The Governmental institutions are at the average of all sectors.

Sweden is the EU Member State which spent the largest amount of money per researcher with 227 000 euro, followed by Germany (199 000 euro). In the rest of Europe, Switzerland was highest with 266 000 euro. Bulgaria, Poland and the Baltic States, all below 15 000 euro, were lowest.

The proportions between the sectors are more or less similar in the European countries, with the exceptions of the UK and Austria where the governmental institutions spent more money per researcher than the BES. In the US and in Japan this share was even higher and in Japan it reached a record level of 404 000 euro per researcher in the governmental sector. In the US, the HES is better funded than the BES, which reflects the commitment of the US government to R&D in the the education and public research systems.

Table I-3b R&D expenditure (in 1000 current €) per researcher (FTE), 2001 (1)

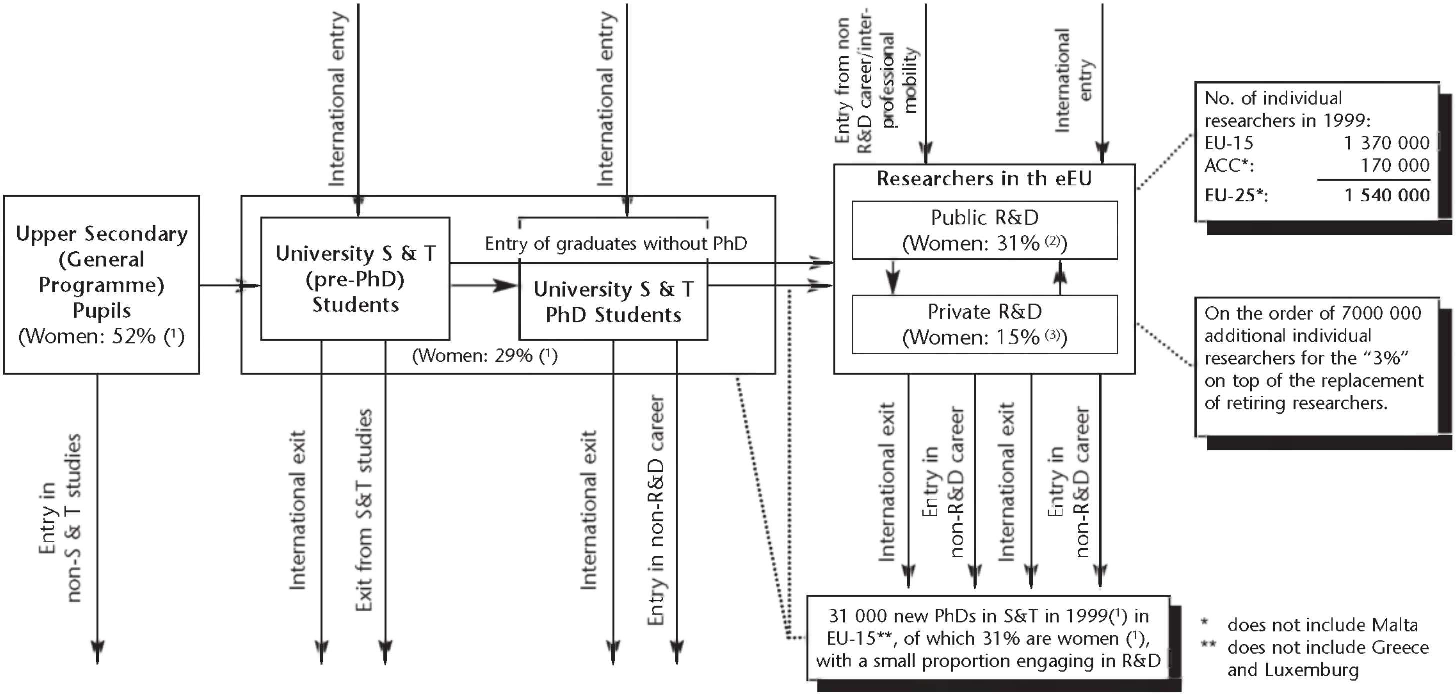
	Totals	Business enterprise	Higher education	Government
Belgium	153	201	90	127
Denmark	188	254	121	132
Germany	199	236	121	186
Greece	54	101	38	86
Spain	78	172	41	74
France	180	239	94	205
Ireland	139	151	111	130
Italy	188	239	150	165
Netherlands	186	223	145	170
Austria	180	183	168	228
Portugal	58	121	41	59
Finland	125	156	76	103
Sweden	227	291	128	132
UK	145	164	92	214
EU-15	171	225	103	170
Cyprus	81	67	47	140
Czech Rep.	55	87	31	41
Estonia	14	30	11	15
Hungary	37	54	24	30
Lithuania	9	55	5	12
Latvia	10	15	7	13
Poland	23	49	12	39
Slovenia	76	131	40	57
Slovakia	16	45	3	15
EU-25	156	214	90	147
Bulgaria	8	13	4	8
Romania	9	10	7	9
Turkey	60	125	50	35
Iceland	140	180	95	123
Norway	154	165	137	144
Switzerland	266	312	171	222
US	182	169	171	361
Japan	212	245	103	404

Source: DG Research Key Figures 2003-2004
Data : OECD, MSTI 2003/Vol.1, for non-OECD members: Eurostat/Member States
Notes: (1) or latest available year: AT, UK: 1998; BE, DK, EL, US: 1999; FR, IE, IT, NL, EU-15, EU-25, TR, CH: 2000. See also the notes on Table I-3a.

Supply chain of researchers

Figure I-3e displays the typical supply chain of researchers and some estimates based on the 3% objective for human resources. This figure was published in the European Commission's Communication on "Investing in research: an action plan for Europe" in 2003.

Figure I-3e Supply chain of researchers in Europe



Source: DG Research, European Commission (2003a), Annex, p. 76 Key Figures 2003-2004

(1) Eurostat (2003) Joint Unesco-OECD-Eurostat (UOE) data collection questionnaires. (2) Rees, T. (Ed.) (2002) National Policies on Women and Science in Europe. European Commission (OPOCE Ref. KI-NA-20-308-EN-C (3) Rübsamen-Waigmann, H., et al. (2003) Women in Industrial Research: A Wake Up Call for European Industry. STRATA ETAN, European Commission (OPOCE Ref. KI-46-02-759-EN-C).

I-4 Education for the knowledge-based economy

Education, especially at universities, is seen as a crucial factor in Europe's transition to a knowledge-based economy (European Commission 2003b). Ideally, researchers are recruited from university graduates in the fields of science and engineering (S&E). In most cases a PhD is obligatory for further academic or research careers. The effort and performance of the supply side of human resources in S&T are reflected in the number of new university graduates and PhDs. Additional information is provided by the numbers of female university graduates, enrolment of foreign students, expenditure on higher education, secondary educational attainment and lifelong learning.

More S&E graduates in Europe than in the US or Japan

In 2001, about 2.2 million persons graduated from universities or earned a PhD in the EU-15 (Table I-4a). Together with the ten Acceding countries, this number reached 2.9 million. The majority earned their degrees in social sciences, humanities and education, but approximately one quarter (675 000) graduated in S&E fields of study. In Ireland, France and Sweden this share was higher than 30%. Science played an important role in Ireland and the UK, whereas engineering was dominant in Sweden, Austria and Finland. In the Acceding countries, S&E was less significant than in EU-15. Only Lithuania had a remarkably large share of engineering graduates.

Table I-4a University graduates (ISCED 5 and 6) in 2001 (1)

	Graduates by field of study in %				Number of graduates		
	Science	Engineering	Health and food	Soc/ hum/ educ	All fields of study	In S&E fields of study	Total growth rates in % 1998-2001 (2)
Belgium	8	11	16	57	70 202	13 239	:
Denmark	8	14	13	47	39 017	8 456	40
Germany	9	17	24	40	296 640	76 617	-17
Spain	11	16	13	54	277 853	74 312	41
France	15	15	7	57	508 189	154 756	4
Ireland	19	12	8	49	45 818	14 038	8
Italy	8	15	19	57	202 309	46 590	7
Luxembourg	11	4	:	79	680	99	27
Netherlands	5	10	16	58	81 603	12 664	-7
Austria	7	21	12	56	27 099	7 423	-16
Portugal	5	12	17	60	61 136	10 257	:
Finland	8	20	21	41	36 141	10 104	-1
Sweden	10	22	19	43	42 741	13 702	51
UK	17	11	17	52	551 665	150 865	24
EU-15 (3)	12	14	15	52	2 241 093	593 122	14
Cyprus	6	6	11	56	2 813	336	:
Czech Rep.	10	11	13	51	43 629	9 586	28
Estonia	6	12	9	64	7 600	1 379	123
Hungary	2	10	9	73	57 882	5 820	-28
Lithuania	5	21	11	57	27 471	7 025	49
Latvia	5	7	2	82	20 308	2 473	22
Malta	4	5	14	75	2 003	186	:
Poland	3	7	3	56	431 104	44 842	80
Slovenia	4	17	12	61	11 991	2 432	5
Slovakia	9	17	13	49	26 272	6 733	83
EU-25 (3)	11	13	13	54	2 872 166	675 313	18
Bulgaria	4	15	8	66	47 504	9 117	36
Romania	6	18	11	59	76 230	18 365	13
Turkey	8	17	10	46	241 464	61 467	:
Iceland	14	5	11	69	2 066	393	39
Norway	8	8	20	53	32 092	5 161	9
US	9	8	13	53	2 150 954	369 391	6
Japan	3	19	12	49	1 067 878	233 386	-1

Source: DG Research Key Figures 2003-2004
Data: UOE database, Benchmarking indicators Eurostat/Member States,
Notes: The %'s in fields of study do not add up to 100% (1) DK, FR, IT, LU, FI, CY, HU: 2000. (2) DK, FR, IT, LU, FI, CY, HU: 1998-2000. (3) EU-15, EU-25 data do not include EL. EU-15 growth rate does not include BE, PT.

Latvia had a share of 82% in social sciences, humanities and education.

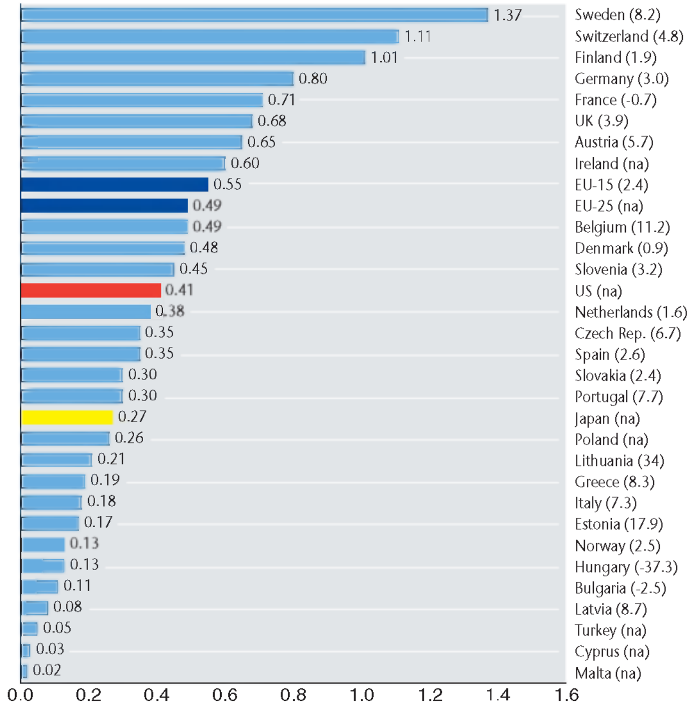
Compared to the US and Japan, EU-25 produces a higher share of graduates in S&E - in absolute numbers about 306 000 more than the US and even 440 000 more than Japan. This difference has been increasing in recent years. Between 1998 and 2001 the number of S&E graduates grew by 6% in the US and decreased by 1% in Japan. Whereas in EU-15 the growth rate was 14% increasing to 18% if the Acceding countries are taken into account.

PhDs in S&E: EU is more productive than the US or Japan

The number of new PhDs in S&E fields of study provides insight into the production of the human resources qualified for occupation as researchers. With a rate of 0.55 new PhDs per 1000 population aged 25-34 in 2001, EU-15 was considerably more productive than the US (0.41) and more than twice as productive as Japan (0.27) (Figure I-4a). Best performing countries in Europe with rates above 1 were Sweden, Switzerland and Finland, followed by Germany, France, the UK and Austria, all above 0.65.

The EU-25 average was 0.49. Of the Acceding countries, Slovenia had the highest share with 0.45 (even higher than the US); Czech Republic and Slovakia followed with around 0.35 and 0.30, respectively. Together with Poland and Lithuania, these Acceding countries were ahead of the worst EU-15 performers, Greece and Italy.

Figure I-4a New PhDs in S&E fields of study per thousand population aged 25-34, in 2001 (1); in brackets: average annual growth rates (%), 1998-2001 (2)



Source: DG Research Key Figures 2003-2004
Data: UOE database, Benchmarking indicators Eurostat/Member States
Notes. LT: Data include only PhDs at universities. Changes in LT education system distort data for 2000/2001 (1) or latest available year: EU-25: 2000-2001. EU-15, FR, IT, FI, UK, CY, US: 2000, EL: 1999. Population data for US, JP, TR are from 2002 (2) or nearest available years: EU-15, FR, IT, FI, UK: 1998-2000; EL: 1998-1999; HU: 1999-2001; BE: 2000-2001.

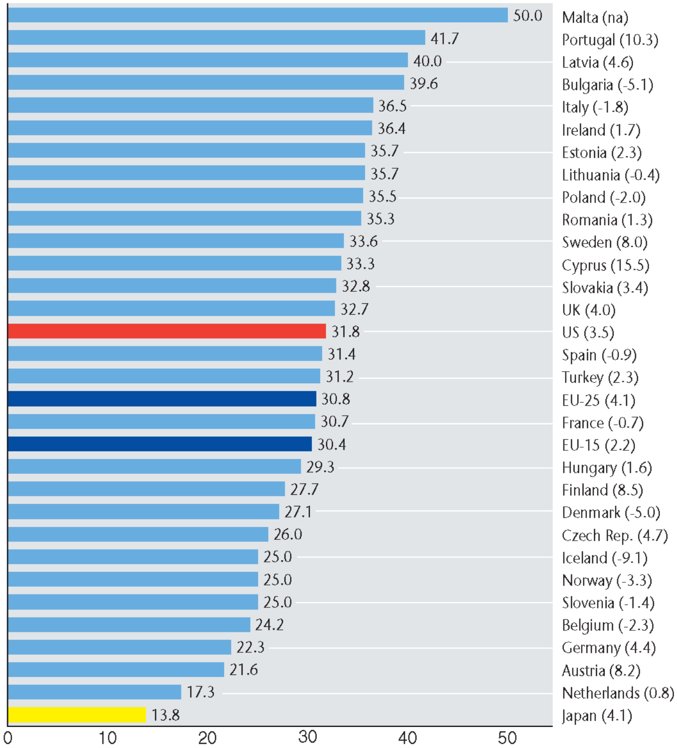
Estonia and Lithuania had huge annual growth rates of more than 17% in their shares of new PhDs. In Hungary, a decrease of 37% has taken place. The Acceding countries have an average annual growth of PhDs of 5%, which is double the value of the EU-15. Most European countries looked at experienced positive growth rates. France and Bulgaria had small decreases.

Under-representation of women in S&E fields of study

Although in nearly all European countries the share of women among the university graduates is around 50%, in some countries even slightly higher, the S&E fields of study show an under-representation of women. In 2001, only 30% of EU-15 S&E graduates were female (Figure I-4b). This is mainly due to the lack of women in engineering disciplines, but also in some natural sciences such as physics and to a lesser extent, chemical sciences. The share of women in S&E in the US was only slightly higher at about 32%, and in Japan much lower at about 14%.

Malta with 50% is the only country with equal representation of women in S&E fields of study. The other countries, where values range between 40% (Portugal) and 17% (the Netherlands) show a marked division between the shares of women in Southern and Eastern countries which are above the EU average and Northern and Western countries which are below the average. Ireland and - to a lesser extent - Sweden and the UK were positive exceptions. On the other hand, the Czech Republic and Slovenia show lower figures than their neighbouring countries in the East.

Figure I-4b Female graduates as % of all graduates in S&E fields of study, 2001 (1); in brackets: average annual growth rates (%), 1998-2001 (2)



Source: DG Research Key Figures 2003-2004
Data: Eurostat NewCronos database
Notes: (1) or latest available year: DK, FR; IT, FI, CY, HU, US: 2000. (2) or nearest available years: DK, FR, IT, FI, CY, HU 1998-2000; TR: 1999-2001; BE, PT, PL: 2000-2001.

The shares have increased on average between 1998 and 2001 by 2.2% in the EU-15 and by 4.1% in the EU-25. The US and Japan show similar dynamics. Some countries, such as Cyprus, Sweden and Portugal had much higher growth rates than the EU average. Amongst the countries with lower female representation in S&E, Austria and Finland show an annual increase of more than 8% of the share between 1998 and 2001. These figures imply that the big differences between the European countries reflect more recent developments in female representation in S&E fields of study. See also the European Commission's "She Figures" (European Commission / DG Research 2003a).

The origins of foreign students follow different patterns

Foreign students are a potential source of well-trained employees and researchers that are more likely to co-operate internationally in the future. Table I-4b lists by country the top ten countries or regions, from which foreign students hold a citizenship in 2001. In EU-15, most of the 800 000 foreign students come from EU-15 countries as well as Poland and Bulgaria. Greek students are the largest mobile group, followed by French and Germans. Within the individual EU-15 Member States, the numbers vary greatly. The largest group of foreign students in the UK and in Germany comes from Asia, mostly China, while in France, Africa is the source of the largest group of foreign students. Former colonial relationships have an impact on the numbers as well as more recent general migration patterns. Typical examples are students from African countries in France, Belgium or Portugal, and

Table I-4b Foreign students by country/*region* of citizenship 2001

	Total	Top Ten: country or region of citizenship 2001
EU-15	795 436	EL, FR, DE, IT, ES, PL, IE, UK, AT, BG
US (1)	582 996	India, China, Korea, JP, Taiwan, Canada, Mexico, TR, Indonesia, Thailand
UK	225 722	*Asia*, EL, *N. America*, *Africa*, DE, FR, IE, US, China, Malaysia
Germany	199 132	*Asia*, TR, *Africa*, PL, China, EL, IT, Russia, AT, FR
France	147 402	*Africa*, Morocco, *Asia*, Algeria, Niger, DE, *N. America*, Somalia, *S. America*, ES
Japan	63 637	Asia, China, Korea, *Europe*, Malaysia, *N. America*, Indonesia, Thailand, US, *S. America*
CC-13 (2)	62 303	EL, CY, SK, Macedonia, Albania, BG, LT, DE, CZ, UK
Spain	39 944	*S. America*, IT, FR, DE, *Africa*, Morocco, *N. America*, UK, PT, Colombia
Belgium	38 150	*Africa*, FR, Morocco, IT, NL, *Asia*, D.R.Congo, LU, ES, Cameroon
Austria	31 682	IT, DE, *Asia*, BG, TR, HU, Yugoslavia, SK, *Africa*, PL
Italy	29 228	EL, *Asia*, Albania, *Africa*, *S. America*, Croatia, DE, Cameroon, CH, San Marino
Sweden	26 304	FI, *Asia*, DE, *N. America*, NO, FR, US, PL, DK, UK
Netherlands	16 589	*Asia*, DE, *Africa*, Morocco, BE, *S. America*, TR, ES, Surinam, UK
Denmark	12 586	NO, *Asia*, IS, SE, DE, Bosnia & Herzegovina, UK, *Africa*, *N. America*, US
Portugal	14 202	*Africa*, Angola, Cap Verde, *S. America*, Brazil, FR, Mozambique, Venezuela, *N. America*, ES
Hungary	11 242	RO, SK, Asia, Yugoslavia, Ukraine, IL, DE, NO, EL, *N. America*
Turkey	16 656	*Asia*, CY, Azerbaijan, Turkmenistan, EL, Kazakhstan, Russia, Kyrgyzstan, BG, Albania
Romania	11 669	Moldavia, EL, *Asia*, Ukraine, *Africa*, Albania, Yugoslavia, Morocco, BG
Norway	8 857	Asia, SE, DK, *Africa*, Bosnia & Herzegovina, DE, *N. America*, UK, Russia, US
Ireland	8 207	*N. America*, UK, US, *Asia*, Malaysia, FR, DE, *Africa*, ES, Canada
Bulgaria	8 130	EL, FYR Macedonia, *Asia*, TR, Ukraine, Moldova, CY, India, Yugoslavia, *Africa*
Latvia	7 917	*Asia*, IL, LT, Russia, Sri Lanka, EE, Lebanon, Pakistan, DE, *N. America*
Czech Rep.	7 750	SK, *Asia*, EL, UK, *Africa*, Russia, Ukraine, *N. & S. America*, PL
Poland	6 659	Ukraine, *Asia*, BY, LT, *N. America*, Kazakhstan, NO, US, *Africa*, Russia
Finland	6 288	*Asia*, China, Russia, *Africa*, SE, EE, *N. America*, DE, US, UK
Cyprus	2 472	*Asia*, China, Bangladesh, EL, RU, Pakistan, India, *Africa*, BG, Yugoslavia
Slovakia	1 690	*Asia*, CZ, EL, Yugoslavia, *Africa*, Ukraine, IL, RO, UA Emirates, Kuwait
Slovenia	864	Croatia, Bosnia & Herzegovina, IT, Yugoslavia, Macedonia, DE, Ukraine, *S. America*, *Asia*, AT
Estonia	605	LT, LV, FI, Russia, *Asia*, *N. America*, SE, Canada, DE, BE
Iceland	421	DK, DE, NO, *N. America*, SE, FI, *Asia*, FR, US, IT
Malta	340	*Asia*, Russia, *Africa*, Yugoslavia, BG, Albania, China, NO, Libya, Palestine

Source: DG Research Key Figures 2003-2004
Data: Eurostat, NewCronos database; US: IIE (www.opendoors.iienetwork.org)
Notes: Students at tertiary level (ISCED 5/6). (1) US: Country of origin 2001/2002. No world regional grouping provided (2) data for CC-13 refer to 2000.

from Latin America in Spain, Portugal and from the Caribbean Islands in the Netherlands.

For the Acceding countries and the other three Candidate countries (CC-13), the patterns are totally different. In 2000, CC-13 hosted about 62 000 foreign students, a large number of the students coming from CC-13 as well as other Eastern European countries such as Russia, the Ukraine, Moldavia and the former Republic of Yugoslavia.

The US hosts the largest number of foreign students for a single country. In 2001, the number of Indian students exceeded the Chinese total. Both Germany (number 11 on the list) and the UK (number 14) sent fewer than 10 000 students to the US. Japan attracts more students from Asian countries, but the number of European and US students is non-negligible.

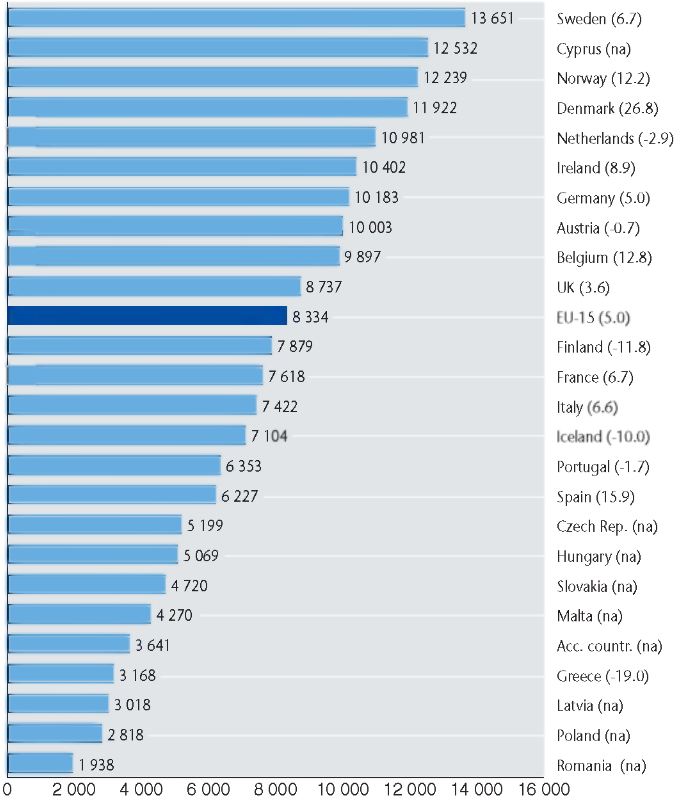
Education investment per student varies immensely

How much do European countries invest in the education of their students? The amount of money (in PPS) spent per student in tertiary public education is an indicator of the commitment to and the quality of higher education in each country.

In Europe, Sweden spent the most with more than 13 000 PPS per student in the year 2001, while Romania spent less than 2 000 PPS per student (Figure I-4c). The EU-15 average is 8 334 PPS, compared to 3 641 PPS in the Acceding countries. A small positive correlation can be observed between expenditure per student and the output data on Figure I-4a.

The changes between 2000 and 2001 show large variations in

Figure I-4c Expenditure per student in tertiary public education, in PPS, 2001; in brackets: growth rates (%), 2000-2001



Source: DG Research Key Figures 2003-2004
Data: Eurostat NewCronos database

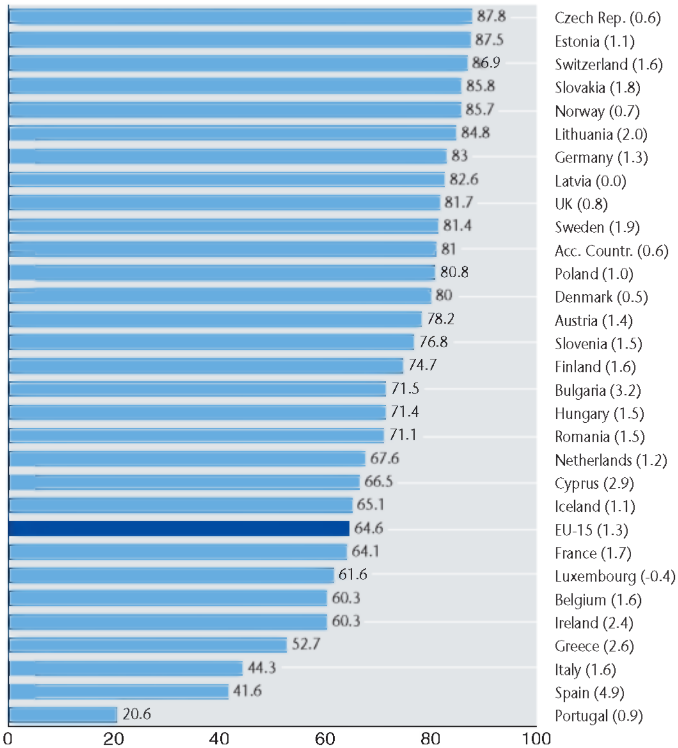
expenditure per student in some countries. In Denmark, the growth was as high as 27% from one year to the next and in Spain it was 16%. On the contrary, in Greece, expenditure per student decreased by 19% between the two years. Most of these changes are due to the changes in the number of students rather than to changes of political or social commitment to university education.

Acceding countries show huge resources of educated people

The creation of a knowledge-based economy does not only depend on the supply of a sufficient number of highly qualified and specialised university graduates. The overall level of education of a society is crucial for its potential to absorb and apply new knowledge and technologies. Data on educational attainment give an interesting insight into the wider base of human resources in a country. It is worthwhile to analyse the population with at least upper secondary education (ISCED 3).

Within Europe, the Acceding countries have a significantly high level of well-educated people (Figure I-4d). On average about 80% of the population aged 25-64 have finished upper secondary education. The EU-15 average is 65%. Best performers are the Czech Republic and Estonia, closely followed by Switzerland, Slovakia and Norway. Germany, the UK and Sweden are the only EU-15 Member States above 80%. The lowest levels at around and below 50% can be found in the Southern EU-15 Member States.

Figure I-4d Percentage of population aged 25-64 with at least upper secondary education, 2002, in brackets: average annual growth rates (%), 1998-2002 ([1])



Source: DG Research Key Figures 2003-2004
Data: Eurostat NewCronos database
Notes: ([1]) or nearest available years: DE, LU, UK, EU-15, CY, BG: 1999-2002; IE, IS: 2000-2002. SE: break in series between 2000 and 2001.

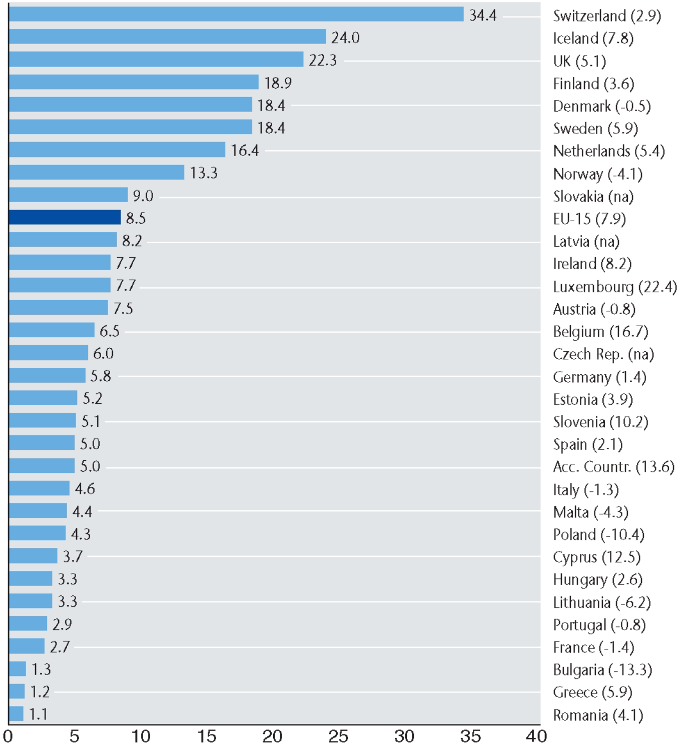
The Lisbon strategy set a goal for each country of reducing the number of people who have not attained upper secondary education by half by the year 2010. The average annual growth rates of the shares of population with at least upper secondary education in EU-15 is around 1% and in the Acceding countries is 0.5%. Only Spain shows a significant growth rate of about 4%. But even this growth rate will not suffice to reach the Lisbon goal by 2010 - for Spain it would have to be 6.9%. And, for instance, Portugal would have to achieve an average annual growth rate of 14.5% to reach the goal; while in the Czech Republic a rate of 0.9% would be sufficient.

Participation in lifelong learning could be improved

Education does not stop with employment. One of the central characteristics of a knowledge-based economy is the importance of continuing education during employment - the ideal of lifelong learning. The indicator presented in Figure I-4e defines lifelong learning as participation in any kind of education or training in the four preceding weeks. This short period emphasises the idea of regularity and continuation in the concept of lifelong learning.

In EU-15, in 2002, about 8.5% of the population aged 25-64 have followed education or training in the four preceding weeks prior to the reference week of the survey (Figure I-4e). In the Acceding countries, this share was lower, at 5%. Amongst the European countries, Switzerland is in the lead with one third, followed by Iceland and the UK, both just below one quarter. Finland, Sweden, Denmark, Netherlands

Figure I-4e Percentage of population aged 25-64 having followed any kind of education or training in the 4 preceding weeks, 2002; in brackets: average annual growth rates (%), 1997-2002 (1)



Source: DG Research Key Figures 2003-2004
Data: Eurostat NewCronos database
Notes: (1) or nearest available years: PT: 1998-2002; UK, CY, LT: 1999-2002; SI: 2000-2002; MT, PL, ACC, BG: 2001-2002.

and Norway are significantly above the EU-15 average. Slovakia and Latvia with 9% and 8.2% respectively have the highest shares of the Acceding countries. The countries with the lowest shares (less than 4%) are Portugal, France and Greece, the Acceding countries Cyprus, Lithuania and Hungary as well as the Candidate countries Bulgaria and Romania.

Again, a North - South and West - East difference can be observed, with only a few exceptions. And again, the dynamics, indicated by the growth rates between 1997 and 2002, do not point to an early convergence between the better and the worse performing countries.

Key Findings

- In 2001, the average R&D intensity in the EU was a record 1.98%. The average rate of growth of R&D investment (in real terms) in 1997-2001 in the EU (4.5%) was very close to that of the US (4.8%).
- R&D intensities recorded for the vast majority of the Acceding countries were very low, in the range of 0.3-1.0%.
- The EU-15 is far from closing the large absolute gap in business R&D expenditure with the US and is in danger of being overtaken by Japan.
- The large EU-US absolute gap in business R&D expenditure is not caused by the very large EU companies. These perform rather well relative to companies in both the US and Japan.
- The EU is still employing fewer researchers while at the same time producing relatively more graduates in S&E than the US or Japan; the private sector can be identified as the bottleneck.
- Acceding countries are not lagging much behind the EU-15 in university graduation rates and they are showing even better scores than the EU-15 in the field of general education.

Perspectives

In setting an R&D expenditure target of 3% of GDP by 2010 at the 2002 Barcelona Council, European governments made their ambition clear. Due to a number of developments in the economy – growing significance of knowledge for economic activities, closer interplay between stakeholders of national innovation systems and various effects of globalisation on RTD – research and innovation have taken on increased political and economic importance.

Over the past eight years, the EU-US gap in R&D expenditure has increased in both absolute and relative terms. Even though the EU has not yet managed to reduce this gap, its 2000-2001 growth rate was higher than past growth rates. In 2001, the EU invested more in R&D than ever before. As a result, the average EU R&D intensity was at a record 1.98% in that year, and the average annual real growth of R&D investment in the EU in the period 1997–2001 was at 4.5%, very close to the US rate (4.8%).

R&D is at the heart of knowledge production and results in the accumulation of economically useful knowledge. Therefore the gap in R&D investment and expenditure, and in human resources dedicated to R&D, is a matter of great concern. To ensure that European economies increase their competitiveness vis-à-vis the US, let alone become the most competitive knowledge-based economy in the world, it is clear that Europe needs to increase its efforts in R&D and education substantially. Consequently, both the quantity and quality of research inputs need to be enhanced.

There exist significant disparities within the EU, and between the EU, the Acceding countries and the Candidate countries, in terms of the absolute volume and growth of R&D investment, and the degree to which the 3% objective is being met. These differences concern not only the volume and growth of R&D financing and expenditure, but also its structure, i.e. the involvement of the business sector.

As in Japan and the US, most EU R&D expenditure takes place in the business sector. But there is still a large gap between levels of business R&D expenditure in the EU and the US. A sizeable part of EU business R&D expenditure takes place in high-tech industries. In relative terms, the business sector finances much more R&D in Japan and the US than in the EU. The disparities in private R&D financing between EU Member States are large. Especially in the Acceding countries, the business sector's share of total R&D financing is low, and no catching-up is taking place in this regard.

The EU-15 as well as the individual Member States are still behind the US as far as venture capital investment is concerned, which typically creates and expands new business activities in high-tech industries and knowledge intensive sectors. In the Acceding countries, the importance of VC investment is quite low at the present time, while it plays a more prominent role in EFTA, in particular in Switzerland. Europe, therefore, still shows weakness in one of the most important mechanisms for creating and expanding new, innovative businesses. To meet these challenges, an increase in government R&D investment is needed to create an environment that will encourage business sector investment. Both national and international joint-financing schemes, as well as research infrastructure support, constitute important inputs into the creation of a fertile environment for research and innovation activities. In addition, Community funding through Framework Programmes will enhance co-operative activities in R&D and education by bringing together different economic actors from various countries.

More attention has to be paid not just to R&D but also to human resources in S&T. This includes paying extra attention to basic and higher education, life-long learning, and the educational attainment of the labour force in general. The relatively small number of researchers in the EU may become a serious restriction for European R&D in the future. A sufficiently large output of high quality students, especially in science and engineering, should be ensured in order to meet the increasing demand for human resources needed to arrive at the 3% goal.

To increase the supply of human resources for S&T, more women need to be recruited into S&T professions. Furthermore, to increase the quality and volume of knowledge production, it would be necessary to attract researchers and students from abroad (including the return of EU nationals from abroad). The provision of a better environment and facilities for research (infrastructure, regulations, education and training, funding...) within the EU could be an important step towards attracting a highly qualified labour force.

These findings point towards the need to increase cohesion in terms of research and innovation among the current EU Member States and between them and the Acceding countries. Nordic countries such as Sweden and Finland have already met the 3% objective, clearly showing that it is a feasible and reasonable target for knowledge-based economies. Such countries can concentrate on increasing the interplay within their innovation systems and gaining a better balance between public and private R&D investment and performance. In terms of researchers and university graduates they are anyway amongst the best performers in Europe.

In other EU Member States such as Greece, Denmark, Ireland and Belgium, and in many Acceding countries, high rates of growth of R&D intensity demonstrate their ambition to enhance their integration into the European innovation system and their willingness to join in the common effort to reach the EU objectives. But more often than not in these countries serious shortfalls in human resources have to be addressed.

For some countries the 3% objective is not realistic in the short term. But even for them, it could serve as a valuable benchmark and future target. The rates of growth of R&D investment for most of the EU-15 and the Acceding countries are promising and paving the way towards reaching the objective. One may argue that in the far future, a rate of even 4–5% could be realistic and achievable.

Part II: Performance of the knowledge-based economy

The aim of countries to become knowledge-based economies, or to maintain or develop their knowledge-bases, has led to an increasing focus on a number of indicators. These indicators relate to important questions such as: What is the share of knowledge-based industries in country x? What is the growth rate of the number of scientific publications? What is the country's share of patents? These, among other indicators, capture the changing relationships between science and technology. When time series are regarded, the quantitative indicators are signalling the degree to which different countries have managed to move their traditional economies towards these targets.

A country's performance in the knowledge-based economy is not measured simply by outputs of science and technology, but must also be judged in relation to the important goal of increasing its competitiveness. Indeed these different aspects of performance are closely linked. A competitive economy is increasingly understood as an economy able to achieve sustained rises in standards of living for its population at low levels of unemployment (European Commission, 2001b). The key determinant of competitiveness is labour productivity. Gains in labour productivity are the result of increasing human capital, capital deepening and technical progress or innovation as measured by total factor productivity. The degree of innovativeness is determined by firms' own R&D activities leading to new products or processes and by spill-over effects that magnify the benefits of own R&D efforts, but also by diffusion effects associated with imported technology and the presence of multinational firms (European Commission, 2001b).

While the indicators to measure the performance achieved by countries in moving towards a (more) knowledge-based economy are all quantitative, they are proxies for a qualitative change towards the set goal. Scientific publications are a proxy for the knowledge produced predominantly in academia, while patents inform about technological achievements. The degree of innovativeness is reflected in the importance of value added and employment in medium and high-tech industries and knowledge-intensive industries, in the technology balance of payments, and in high-tech exports.

This Part analyses the performance of European economies from three different perspectives. First, scientific indicators measuring the performance of individual countries are presented, and these are followed by indicators relating to technological output – basically patents and high-tech trade. The final section examines indicators of competitiveness.

II-1 Scientific output

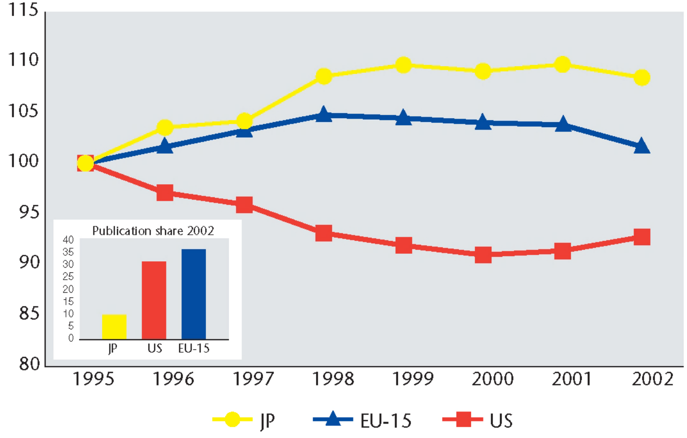
Scientific publications are increasingly used as a measure of scientific performance. Especially at the policy level, S&T related decisions are more and more based on recent scientific performances which are often used to benchmark against international trends and accomplishments.

Scientific indicators are not perfect, but the measurement of publications, citations, or scientific impact has occupied a growing number of specialists who have developed sophisticated indicators. Their increasing reliability and importance has led them to receive more and more attention from policy makers and scientists alike who wish to explore issues such as the quality of research and its funding.

Scientific publications in Europe – decrease or increase?

In the mid-1990s, the EU-15 took over from the US as being the largest producer of scientific literature in absolute terms as well as in world share. By the end of the century, the gap between the EU-15 and the US had grown to more than six percentage points in favour of the EU-15 (Figure II-1a). In 2001 Europe had to face a small decline of its share, although total publication numbers were still growing. From 2001 to 2002 however, the situation deteriorated for the EU-15 in terms of share (-2.1%), and its total number of publications also fell. With high growth rates during the latter half of the 1990s, the situation was similar for Japan. However, in terms of publication share Japan experienced a small loss in 2002 (-1.2%) but still managed to increase its total publication numbers. The situation has certainly improved for the US. While the US suffered from diminishing publication numbers and shares during the late 1990s, it has managed to grow in both categories since 2000. It may be too early to speculate about changes in trends, however, the capabilities of the US in terms of scientific production should not be underestimated. While the current EU-15 decrease is still minor, it may well foreshadow something worse and result from a relative decline in R&D investment in the EU-15 during the 1990s.

Figure II-1a The growth of share of world publications by the EU-15, US and Japan, 1995-2002 and publication share (%), 2002 (1995=100)



Source: DG Research Key Figures 2003-2004
Data: ISI, CWTS (treatments), DG Research (calculations)

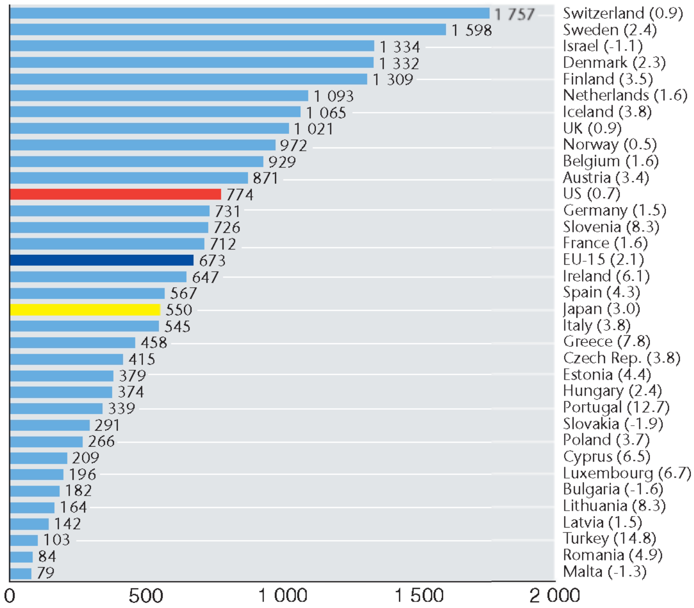
Productive countries in scientific publishing: Switzerland leads

The Nordic countries, the EFTA countries and Israel are performing exceptionally well in terms of scientific publications per capita (Figure II-1b). They are well above the EU average, and above the US and Japan. But are they really so much more productive than other countries? When it comes to scientific activity by population, the specialisation profiles of countries explain quite a lot, as there are different publication habits in different scientific and technological fields. For example, the nine top performing countries are also those that are very active in the life sciences (see Table II-1a).

This is an important consideration because the publication output of a scientist in clinical medicine might be up to ten papers a year, whereas an engineer in civil engineering is more likely to produce one paper a year. Therefore, if a country is specialised in engineering research, its publication output will be comparably lower than that of a country specialised in the life sciences and vice versa. Bearing this in mind, the results on the upper part of the graph are less surprising, but there are some surprises nonetheless. For example the position of Slovenia is most striking: despite the fact of not being scientifically specialised in the life sciences, Slovenia is very active in almost all other fields and thus compensates for the 'natural' disadvantage of not being specialised in the life sciences.

When it comes to the growth rates of scientific output, countries starting with a lower output score in general have higher growth rates than countries with an already high publication output. This is one finding repeated where one sees that the scientifically smaller countries (i.e. countries with a world share below 1%) have growth rates above the EU average. Notable exceptions are Spain, Italy, Poland and Sweden - medium-sized scientific countries - and Japan, the only large scientific country with a world publication share above 5%. Among the smallest countries in terms of scientific publications, relatively poor growth rates were registered by Latvia, Malta, Bulgaria and Slovakia. The latter three, plus Israel, even had negative growth rates. Israel's declining trend is mainly the result of years with a consecutive drop in publication numbers since 1999.

Figure II-1b Number of scientific publications per million population, 2002 ([1]); in brackets: growth rates of publications (%), 1995-2002



Source: DG Research — Key Figures 2003-2004
Data: Publication data: ISI, CWTS (treatments), population data: OECD: MSTI 2003/1; Eurostat: NewCronos
Notes: ([1]) Population: 2001

Activity by field shows different specialisation profiles

Table II-1a shows the activities, in terms of scientific publications, in 27 countries of the European Research Area as well as important competitors and partners. It shows the relative specialisation of each country in 6 main science and technology fields.

Countries tend to specialise and focus, i.e. are (very) active, in a limited number of fields. Specialisation is in part related to country size: for example the US, which is scientifically as well as technologically the most complete economy, produces a large number of scientific publications in almost all disciplines listed. But size of a country is not the only reason; not surprisingly, very often the scientific profile matches the technological profile of a given country.

Most countries are scientifically specialised to a certain degree. For example all Scandinavian countries, the UK, Ireland, Netherlands, Switzerland and Israel are highly active in the life sciences in their broadest sense, while most eastern European countries are very active in the fields of engineering, physics and chemistry. The same is true for Portugal and Greece. Japan and Turkey display interesting profiles; Turkey is rather active in engineering, Japan in computer sciences as well as in the life sciences. One reason for their rather strong activities might be the fact that both are preferred co-publication partners of US scientists (see following pages).

Table II-1a Relative activity index (RAI) by EU-15, Acceding- and other countries, 1996-1999

	Engineering	Physics, Astrophysics & Astronomy	Mathematics, Statistics& Computer Sciences	Chemistry	Earth & Environm. Sciences	Life Sciences
Greece	+		+		+	
Poland		+		+		
Bulgaria		+		+		
Latvia		+		+		
Italy		+				
Slovenia	+			+		
Cyprus						
Turkey	+					
Germany		+		+		
Russia		+		+		
Estonia		+			+	
Slovakia				+		
Spain				+		
Czech Republic				+		
France						
Japan			+			
Israel						
UK						
US						
Austria						
Switzerland						
Denmark					+	
Belgium						
Norway					+	+
Ireland						
Iceland					+	+
Finland						+
Sweden						+

Source: DG Research Key Figures 2003-2004
Data: ISI, CWTS (treatments)
Note: Countries are given according to descending specialisation from engineering to life sciences. Yellow: not specialised, blue: specialisation around field average; blue +: specialised. LU and MT have been left out due to small publication numbers. Composition of fields and calculation of index: see Annex.

Co-publication patterns & main partners

By analysing the co-publication patterns of the countries from the European Research Area as well as their main partners, interesting patterns can be detected (Figures II-1c - e).

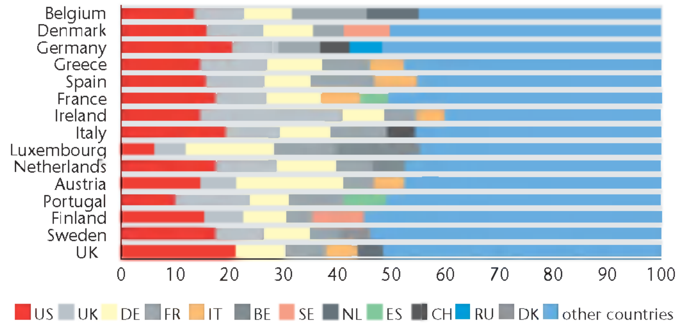
It does not come as a surprise that in absolute volume, the US, Germany, UK and France dominate as co-publication partners for all countries. These are also the countries with the largest publication shares. An exception is Japan which – despite the fact that it is one of the five largest producers of scientific literature – is not among the top five partners of the EU-15 or Acceding countries.

Most EU-15 countries have the highest share of their co-publications with US scientists (on average 15%), followed by UK and German co-publications, 11% and 10% respectively. The other main partners are mainly geographically close such as Sweden – Denmark – Finland or Belgium – the Netherlands – Luxembourg. Switzerland is one of the top 5 partners for Italy and Germany. Russia (RU), the only eastern European country among top 5 partners, is only important for Germany.

The Acceding countries show differing co-operation patterns. For these countries it is not the US which is the number one co-publication partner, but Germany which is involved in an average of 11.1% of their publications.

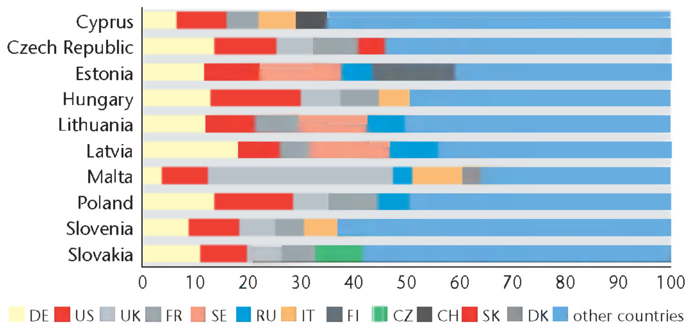
The picture for the remaining countries is rather heterogeneous. For Israel, Japan and Turkey, the US is by far the main partner. As for most countries, the US is either the most important or the second most important co-publication partner, a fact which is mirrored when one sees the relatively equal shares of the main partners of the US itself.

Figure II-1c Five main co-publication partners of EU-15 countries (%), 1996-1999



Source: DG Research Key Figures 2003-2004
Data: ISI, CWTS (treatments)

Figure II-1d Five main co-publication partners of Acceding countries (%), 1996-1999



Source: DG Research Key Figures 2003-2004
Data: ISI, CWTS (treatments)

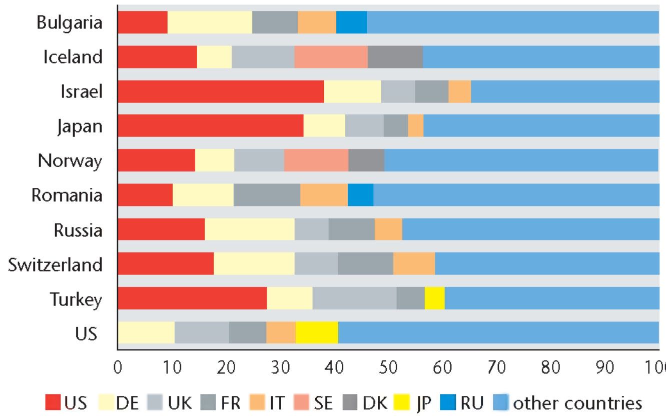
These absolute co-publication shares are of course largely a function of country size which closely relates to the number of co-operation opportunities. Another way of looking at scientific co-operation partners and preferences, minimising size effects, is given through revealed relative preferences.

Relative preferences – small European countries are more open for partners from far away

If actual co-publication numbers are related to expected numbers for a given group of countries, it is possible to generate a list indicating a country's most preferred partners in this group. Table II-1b shows such a list constructed for 34 countries. It should be understood that the most preferred countries in this table are not necessarily the most important partners in terms of total numbers of co-publications.

Very often, researchers from small countries co-publish with researchers from a handful of preferred other countries and thus sometimes achieve quite a high concentration rate as partner country. This applies for example to the Baltic States, Slovenia, Slovakia, Luxembourg and Ireland. These tendencies lead to interesting results. For example, in Table II-1b one sees that Austria prefers three partners from its small Eastern neighbours ahead of the larger countries Germany and Hungary. However in absolute terms, German and Austrian researchers co-published more than 3 700 papers in 1996-1999 while Austrian-Slovakian partners published only 380 in the same period. In fact Germany is in absolute terms the largest co-publishing partner of Austria (see Figure II-1c). However, while about 2 000 co-publications can be expected

Figure II-1e Five main co-publication partners of other countries (%), 1996-1999



Source: DG Research Key Figures 2003-2004
Data: ISI, CWTS (treatments)

for the former, only about 110 are expected for the latter. Therefore the ratio calculated from actual vs. expected numbers indicates a relatively stronger preference for Slovakia. Slovakia on the other hand co-published more than ten co-publications with only 25 of these 34 countries, thus creating stronger concentrations with these countries.

To sum up, the inclusion of the generally smaller Eastern European countries in the analysis show some surprising and remarkable preferences. Geographic proximity seems to be the decisive factor for scientific co-operation not only for the EU-15 countries, but also for the Eastern countries among others.

It is quite noticeable that there is no scientific border between the EU-15, Acceding and Candidate countries. While, in absolute terms, the US is an important scientific partner for most European countries, in terms of relative specialisation it is rarely among the top five partners of a European country. Interesting cases are Turkey and Israel. Both strongly prefer the US, and the US also has higher than expected co-publication ratios with both countries.

Public-private co-publications in the EU-15

Another important aspect of co-operation is the partnership between academic and private researchers. Such co-publications are an indicator of the scientific and industrial interface showing to what extent scientific knowledge is exploited by industry and vice versa. It is a classical indicator of knowledge transfer, yet it remains under-exploited in policy analyses.

Public-private co-publications generally represent a small percentage of the total publications of a given country. The EU-15 produced some 6 100 co-publications in 2001, compared to 9 200 for the US and 2 000 for Japan.

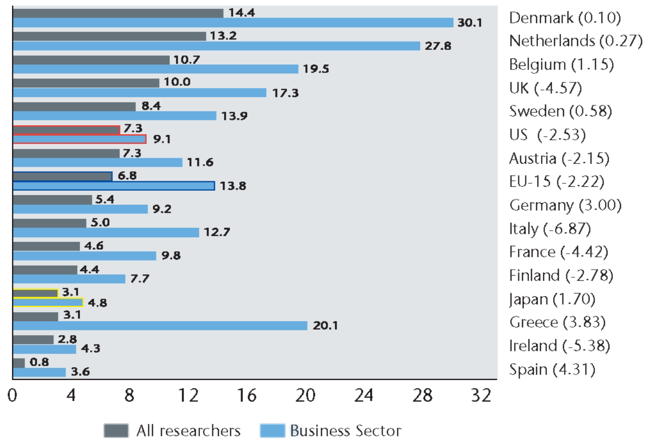
If one analyses the public-private co-publications in relation to the number of researchers, interesting results can be obtained. The countries with the highest number of researchers (see Part I-3) US, Japan, Germany, UK and France score about average, while the smaller countries Denmark, Belgium, the Netherlands and Sweden are leading. Ireland, Greece and Spain have the lowest ratios. The US is far ahead of the EU-15 and Japan, which are close together (Figure II-1f).

Table II-1b Five preferred co-publication partners by country

	1.	2.	3.	4.	5.
EU-15					
Belgium	NL	FR	PT	LT	SI
Denmark	IS	NO	SE	LV	FI
Germany	AT	LV	RU	BG	LU
Greece	SI	PT	SK	BG	RO
Spain	PT	CY	BG	FR	BG
France	BE	RO	ES	LU	IT
Ireland	UK	PT	NL	BE	NO
Italy	RO	ES	CY	CH	BG
Luxembourg	DK	FR	UK	US	-
Netherlands	BE	CY	UK	PL	IE
Austria	SK	SI	CZ	DE	HU
Portugal	SI	ES	EL	SK	NO
Finland	EE	CY	SE	NO	IS
Sweden	EE	LV	IS	NO	FI
UK	IRL	TR	PT	US	EL
Acceding countries					
Cyprus	FI	ES	CH	RO	NL
Czech Republic	SK	SI	AU	PL	DE
Estonia	FI	RU	DK	NO	DE
Hungary	RO	BG	FI	AU	SI
Lithuania	SE	PL	FI	RU	DK
Latvia	SE	RU	DK	DE	FR
Poland	SK	LT	CZ	SI	RU
Slovenia	SK	PL	EL	AU	CZ
Slovakia	CZ	SI	AU	PL	EL
Other countries					
Bulgaria	RO	HU	EL	RU	ES
Romania	BG	HU	FI	IT	EL
Turkey	UK	US	IL	JP	DE
Switzerland	CY	DE	AU	IT	FR
Iceland	DK	SI	FI	UK	US
Norway	SE	DK	FI	SI	SK
Israel	US	HU	TR	DE	RU
Japan	US	RU	HU	UK	TR
Russia	LV	LT	DK	PL	BG
US	JP	IL	TR	IT	DE

Source: DG Research Key Figures 2003-2004
Data: ISI, CWTS (treatments)
Notes: Calculations based on 1996-1999 data. No calculations have been made for MT because of too low co-publication numbers. Countries marked in yellow are already less preferred – i.e. have negative expected co-publication ratios.

Figure II-1f Public-private co-publications (000) by total researchers and business researchers (FTE) 2001 ([1]); in brackets: growth rates of public-private co-publications (%), 1995-2001



Source: DG Research Key Figures 2003-2004
Data: ISI, CWTS (treatments). Ongoing CESE-IRRA project under FP5.
Notes: ([1]) or latest available years: AT, UK: 1998; BE, DK, EL, US: 1999; FR, IE, IT, NL: 2000. Data in full-time equivalent (FTE). Public-private publications: 2001. LU and PT have been left out due to too low annual publication numbers. EU-15 data without LU or PT.

If one divides co-publications by the number of business researchers only, Denmark and the Netherlands show the highest ratios, while Japan, Ireland and Spain show the lowest. Moreover, the US (at 9.1) is now far below the EU-15 average (13.8). These differences might be partially explained by variations in the relative importance of public and private researchers in the various countries. With the exception of France, all European countries above the EU-15 average have relatively equal numbers of public and private researchers. In this group, the highest deviation can be stated for Germany with about 40% of researchers in the public sector and 60% in the private sector. In Denmark, France and the Netherlands, this imbalance is far less pronounced. The countries at the bottom end - Ireland, Greece and Spain - have comparatively uneven proportions of public and private researchers. However, this imbalance cannot explain the differences observed. Italy and Greece, for example achieve a higher ratio than Spain when only business researchers are taken into account. However these three countries all have similarly disproportionate shares of public and private researchers.

A second explanation could be industry structures. If all researchers are taken into account, those countries that have significant publication shares in more basic disciplines, especially in the life sciences, score relatively strongly. There is not only a higher propensity to publish in the life sciences, but also an apparently higher propensity for public-private co-publications. The large public health sector in the US could explain its strong position. In other fields where the propensity to publish and the number of publications is much lower (e.g. engineering) the propensity for public-private co-publications also tends to be lower. One would therefore expect countries with a technological specialisation in such fields to have lower total publication shares and lower public-private co-publication shares.

When it comes to growth rates, the picture is less bleak for those countries starting with a low share such as Spain and Greece. Germany and Japan also recorded increases. Most countries however have experienced a decline in public-private co-publications between 1996 and 2001.

II-2 Technological output

Patents allow inventors to protect and exploit their inventions over a given time period, and provide a valuable measure of the inventiveness of countries, regions and enterprises. Moreover, since they disclose information about new inventions, patents also play a role in the diffusion of knowledge. Patent indicators not only help to shed light on patterns of technological change, but also measure activities that are closely associated with competitiveness in many important international markets.

Smaller Member States show the strongest growth, but patenting by Acceding countries remains low

The EU continues to be less present in the US Patent and Trademark Office (USPTO) than the US is in the European Patent Office (EPO) (Table II-2a). While around 47% of EPO patent applications come from EU-15 countries, compared with 28% and 17% from the US and Japan respectively, the EU-15 share of USPTO patents was only 16% (with the US at 52% and Japan at 21%).

Since 1995, Portugal (albeit from a low base) and Ireland have shown strong growth in their patent shares at both EPO and USPTO, but Austria, France, Italy and UK have all seen their shares of patents fall in both systems over the same period. As for the Acceding countries, generally their international patenting activity remains very weak. These countries still have very low levels of patenting at the EPO and at the USPTO. Nevertheless, there are signs that the number of patents from the Czech Republic, Hungary, Slovakia and Slovenia are increasing.

Table II-2a Patents ([1]): Shares (%) and average annual growth rates in shares (%)

	Shares EPO (2000)	Growth in shares EPO (1995-2000)	Share USPTO (2002)	Growth in shares USPTO (1995-2002)
Belgium	1.23	-0.6	0.43	1.2
Denmark	0.78	1.4	0.27	4.9
Germany	20.60	1.2	6.76	0.5
Greece	0.04	0.6	0.01	6.1
Spain	0.69	3.2	0.19	3.4
France	6.87	-2.2	2.41	-2.0
Ireland	0.23	10.7	0.08	5.0
Italy	3.61	-0.4	1.05	-0.3
Luxembourg	0.06	8.9	0.03	2.2
Netherlands	2.88	4.0	0.83	0.6
Austria	1.03	-0.7	0.32	-0.8
Portugal	0.03	4.3	0.01	19.3
Finland	1.29	3.9	0.49	4.9
Sweden	2.13	0.4	1.00	3.3
UK	5.33	-1.3	2.30	-1.0
EU-15	46.79	0.4	16.17	0.2
Cyprus	0.00	a	0.00	a
Czech Rep.	0.06	11.9	0.02	5.5
Estonia	0.01	a	0.00	a
Hungary	0.10	7.4	0.03	-7.6
Lithuania	0.00	a	0.00	a
Latvia	0.00	a	0.00	a
Malta	0.01	a	0.00	a
Poland	0.03	1.8	0.01	-0.8
Slovenia	0.03	5.2	0.01	12.9
Slovakia	0.02	12.2	0.01	16.4
EU-25	47.06	0.4	16.26	0.2
Bulgaria	0.01	a	0.00	-3.9
Romania	0.01	a	0.00	a
Turkey	0.02	28.2	0.01	23.5
Switzerland	2.44	-1.7	0.82	-3.3
Iceland	0.03	12.7	0.01	10.9
Liechtenstein	0.02	-5.3	0.01	-4.0
Norway	0.34	3.0	0.15	2.1
Israel	0.75	5.8	0.62	7.1
US	27.54	-1.5	51.76	-0.8
Japan	17.20	0.2	20.86	-0.4

Source: DG Research Key Figures 2003-2004
Data: OECD
Note: ([1]) EPO data are patent applications by year of application and USPTO data are granted patents by year of grant. (a) growth rates not calculated for countries with less than 20 patents during the previous three years. SK: growth 1997-2002 for USPTO patents.

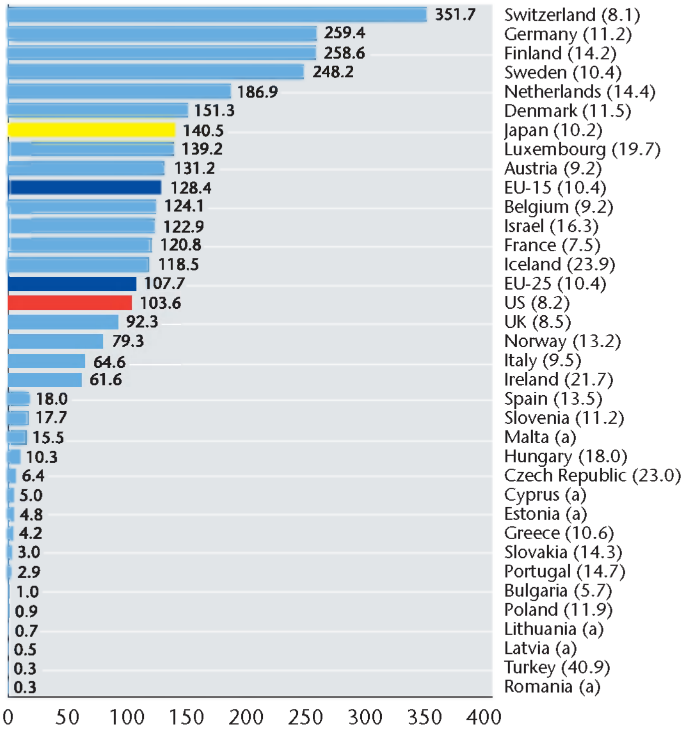
Patenting performance relative to country size: EU has four times fewer USPTO patents per capita than the US and Japan

Clearly the biggest countries tend to have the largest share of patents, so it is important to relate performances to the size of each country or zone. Figures II-2a and II-2b relate patents at the EPO and the USPTO, respectively, to countries' populations.

Expressed in these terms, the EU's performance is lower than when one looks simply at its share of patents. At the EPO the EU is eclipsed by Japan (141 patent applications per million population versus the EU's 128), but remains ahead of the US (104). However, at the USPTO, the US and Japan have roughly four times more patents per head of population than the EU: 300 patents per million population for the US, 275 for Japan, and 71 for the EU.

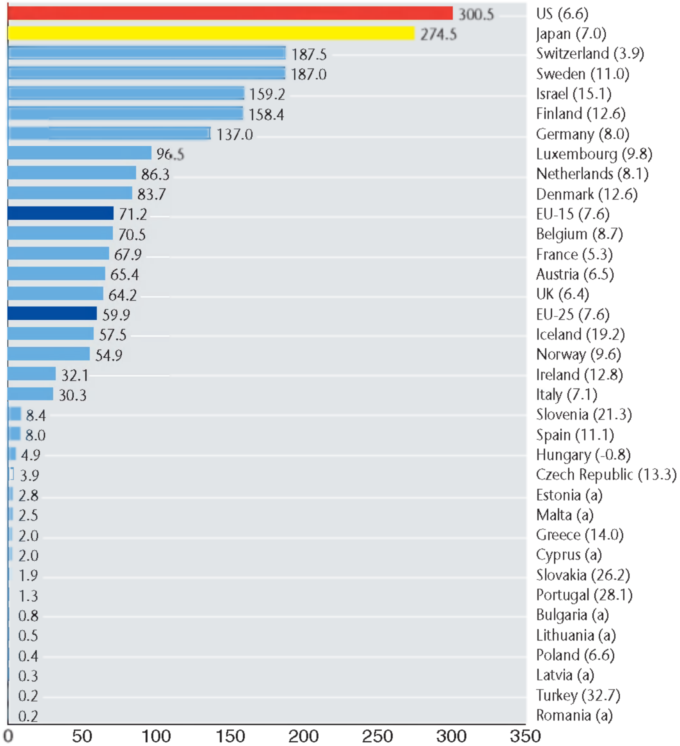
Sweden and Switzerland are notable for producing a lot of patents in relation to the size of their population at both the European and US patent offices. Finland, Netherlands, Denmark and Luxembourg are also in the top 10 countries at EPO and USPTO in terms of patents per capita.When one looks at the EU-25, patents per capita are 107 at the EPO and 60 at the USPTO, significantly lower than the corresponding EU-15 values (128 and 71 respectively). This is due to the very low rates of international patenting in the Acceding countries, and implies that enlargement will tend to reinforce the 'European paradox' (Europe's perceived strength in science and comparative weakness in technological development and commercialisation).

Figure II-2a Patent applications at the European Patent Office - per million population, 2000; in brackets: growth rates (%), 1995-2000



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Note : (a) Growth rates not calculated for countries with less than 20 patents during the previous three years.

Figure II-2b Patents granted at the US Patent Office - per million population, 2002; in brackets: growth (%), 1995-2002 (1)



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Note : (a) Growth rates not calculated for countries with less than 20 patents during the previous three years. (1) SK: growth for 1997-2002.

Triadic patents: a possible measure of higher value patenting

Not all patents are of the same economic value. One approach for trying to identify those patents with a higher commercial value is to examine so-called "triadic patents". These relate to patented inventions for which protection has been sought at the three major patent offices: the EPO, the USPTO and the Japanese Patent Office. It is thought that these patents may be associated with a higher expected commercial return, since it is costly to patent through three patent systems. They also eliminate any "home advantage" effect which is present when looking at EPO and USPTO patents: i.e. the US is dominant in the US patent system partly because it is its home market, while European inventors are the dominant players at the EPO.

Figure II-2c shows the number of triadic patents per million population in 1998. One sees again that, in relation to its population, the EU performs worse than Japan and the US: the EU has 36 triadic patents per million population compared with 81 for Japan and 53 for the US. On the other hand, its share of triadic patents is fairly healthy albeit still slightly lower than the US: the EU accounts for 33% of triadic patents applied for by the OECD countries, the US 36%, and Japan 25%. Switzerland and Sweden once again emerge as strong patenting countries in relation to their size.

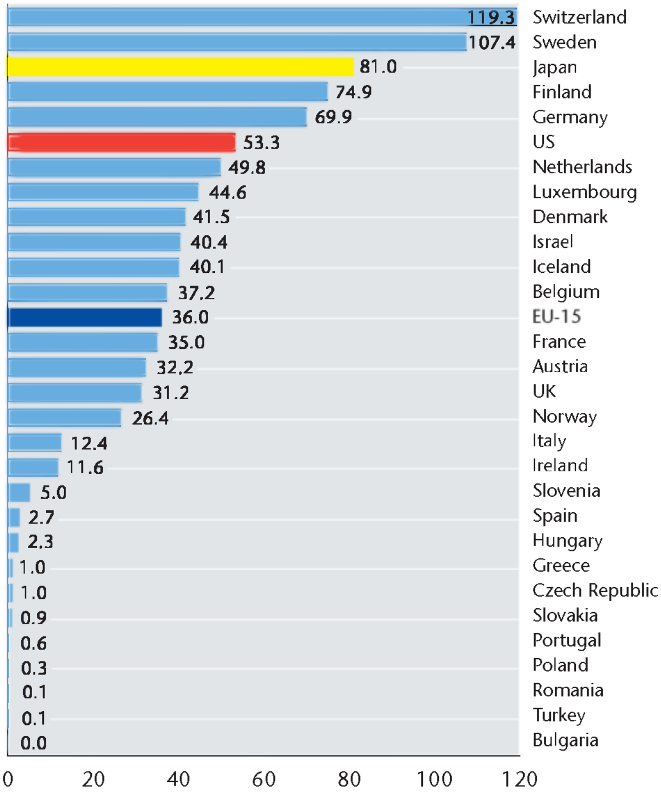
ICT and biotech patents: EU lagging behind

Countries' shares of patenting in two key technologies areas – information and communications technologies (ICT) and biotechnology[1] – are shown in Table II-2b. If one compares this table with the data on shares of all patents given in Table II-2a, it is clear that the EU has a lower share of ICT and biotech patents than it does of patents as a whole, indicating a relative lack of specialisation in these areas. By contrast, the US has 28% of all EPO patents (Table II-2a), but boasts 32% of EPO ICT patents, and a massive 45% of EPO biotech patents. The EU itself has only 34% of biotech patents at the EPO. The EU's patenting in these two technologies is very low at the USPTO. It has just 11% of patents in ICT (compared with 53% held by the US, and 25% by Japan), and just 13% of biotech patents (as opposed to the US's 72%).

In terms of triadic patents (those inventions patented at all three major patent offices: EPO, USPTO and JPO), the EU is well behind the US and Japan in its share of ICT patents, and also trails the US in biotech patents (25% share versus 54% for the US). Of the EU countries, only Finland shows any significant specialisation in ICT patenting. Belgium, Denmark and UK (the latter at the EPO) have a larger share of biotech patents than their share of total patents: for example, Denmark has 0.3% of USPTO patents as a whole, but 1.2% of USPTO biotech patents. The contribution of the Acceding countries to European inventive activity in these two areas would appear to be very low in relation to their GDP and the human resources of these countries.

[1] The data for biotech patents use the latest revised definition of the OECD (for details see OECD website www.oecd.org). For this reason they may differ from data presented in previous reports.

Figure II-2c Triadic patents (1) per million population, 1998



Source: DG Research
Data: OECD, Eurostat
Note : (1) Data relate to year of priority.

Key Figures 2003-2004

Table II-2b ICT and biotech patents - country shares (%) (1)

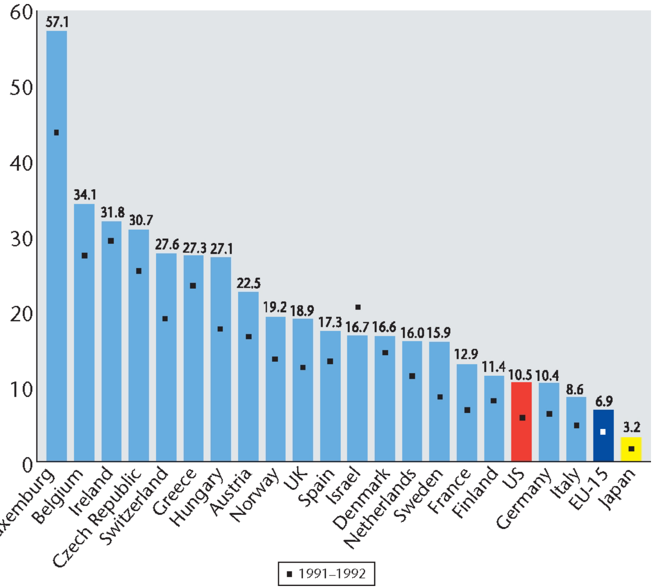
	Share of ICT patents (%)			Share of biotech patents (%)		
	EPO	USPTO	Triadic	EPO	USPTO	Triadic
Belgium	0.8	0.2	0.6	2.3	0.7	0.8
Denmark	0.6	0.1	0.2	1.6	1.2	1.9
Germany	14.1	3.6	8.5	11.0	3.3	7.5
Greece	0.0	0.0	0.0	0.0	0.0	0.0
Spain	0.4	0.1	0.1	0.6	0.2	0.6
France	5.9	1.8	4.4	5.1	1.6	4.0
Ireland	0.3	0.1	0.1	0.2	0.1	0.1
Italy	1.6	0.6	1.1	1.0	0.5	0.7
Luxembourg	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	3.7	0.7	2.6	2.4	1.1	1.9
Austria	0.6	0.1	0.2	0.7	0.3	0.4
Portugal	0.0	0.0	0.0	0.1	0.0	0.0
Finland	2.4	0.5	1.1	0.6	0.3	0.5
Sweden	2.3	1.0	2.6	1.1	0.5	1.3
UK	5.6	1.7	4.6	7.4	2.6	5.4
EU-15	38.2	10.6	26.1	34.2	12.6	25.1
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0
Czech Rep.	0.0	0.0	0.0	0.1	0.0	0.0
Estonia	0.0	0.0	0.0	0.0	0.0	0.0
Hungary	0.1	0.0	0.0	0.1	0.1	0.0
Lithuania	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	0.0	0.0	0.0	0.0	0.0	0.0
Malta	0.0	0.0	0.0	0.0	0.0	0.0
Poland	0.0	0.0	0.0	0.0	0.0	0.0
Slovenia	0.0	0.0	0.0	0.0	0.0	0.0
Slovakia	0.0	0.0	0.0	0.0	0.0	0.0
EU-25	38.3	10.6	26.1	34.5	12.8	25.2
Bulgaria	0.0	0.0	0.0	0.0	0.0	0.0
Romania	0.0	0.0	0.0	0.0	0.0	0.0
Turkey	0.0	0.0	0.0	0.0	0.0	0.0
Switzerland	1.5	0.4	1.0	1.6	0.9	1.5
Iceland	0.1	0.0	0.0	0.1	0.0	0.0
Liechtenstein	0.0	0.0	0.0	0.0	0.0	0.0
Norway	0.2	0.1	0.1	0.4	0.1	0.1
Israel	1.1	0.6	0.6	1.2	0.7	0.8
US	31.7	53.1	35.9	45.3	71.8	53.5
Japan	22.0	25.4	33.0	10.1	7.0	13.2

Source: DG Research Key Figures 2003-2004
Data: OECD
Note: (1) Data relate to priority years (EPO 1999. USPTO 1997, triadic 1996). Triadic patents relate to inventions patented at all three major offices (EPO. USPTO and JPO). EPO data are applications, USPTO data are granted patents.

International co-invention

Data on patents with foreign co-inventors provide an indication of the extent to which countries co-operate internationally in inventive activities (Figure II-2d). To some extent such co-operation is a function of country size, with smaller countries tending to engage more often in foreign collaboration. Thus one sees Luxembourg with 57% of its patents involving foreign co-inventors, followed by Belgium and Ireland with over 30%. The Czech Republic and Hungary also have quite high rates (31% and 27%). The larger countries tend to have lower rates of overseas collaboration – for example, France has 13% and Germany 10% – although the UK with nearly 20% foreign co-inventors shows a comparatively high degree of internationalisation for its size. Taken as a whole, and excluding intra-EU collaborations, the EU-15 has a slightly lower proportion of foreign co-inventors than the US (7% versus 11%), but is higher than Japan (3%). For most countries the trend since the early 1990s has been towards an increase in foreign co-invention.

Figure II-2d Patents with foreign co-inventors (%) - average for priority years (1), 1998-1999



Source: DG Research Key Figures 2003-2004
Data: OECD
Note : (1) Data represent the share of patent applications to the EPO with at least one foreign co-inventor, according to the residence of the inventors, in total patents invented domestically. Cut-off point: countries with more than 100 EPO applications over the period 1998-99. EU total excludes intra-EU co-operation.

II-3 Innovation and competitiveness

The overall economic slowdown that the EU-15 has been experiencing since the beginning of this century may be casting doubts on its ability to sustain growth in the long run and its ambition to soon become the world's most dynamic and competitive economy. But despite the overall stagnation (or even decline) during the last few years, the high-tech and knowledge intensive sectors of the economy have continued to grow. According to the recent report "Employment in Europe" 2003, the countries recording positive trends in indicators on high-technology and knowledge intensive activities are also by and large the countries that have recently experienced the fastest growth in overall employment levels (e.g. Ireland, Sweden, Finland) (European Commission, 2003c). This confirms that even high labour cost countries are able to compete in the increasingly globalised economy as long as they specialise in industries that require a high content of knowledge, high qualification levels and expertise in the labour force.

The share of so-called 'knowledge workers' in a country's total employment and its ability to produce high-tech products and sell them on international markets thus constitute important indications of international economic success. The relationship between high-tech, knowledge intensive activities and competitiveness is in no way straightforward and should not be interpreted in a mechanistic way. However, it is clear that increasing the qualification level of the labour force, while at the same time creating and applying new knowledge, represents a precondition for future sustained growth in Europe, and for its ability to compete internationally and to keep unemployment down. The indicators in this section represent an indirect reflection of countries' various degrees of success in making the transition to a new form of competition based on knowledge.

Trade in high technology products

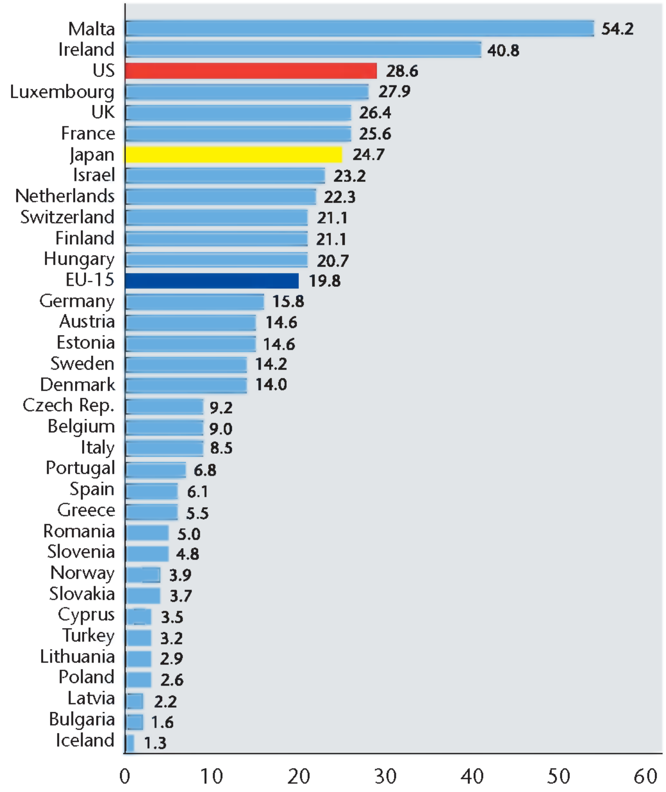
Exports of high-tech products reflect a country's ability to commercialise the results of research and technological innovation in international markets. The extent to which countries' exports are more or less focussed on high-tech products can be seen from Figure II-3a. Of the goods exported by the EU-15, 20% are high-tech products, compared with 25% in Japan and 29% in the US.

However, there is considerable variation between Member States. Ireland is above the US, with 41% of its goods sold overseas being in the high-tech category. Luxembourg, the UK and France come between Japan and the US in their high-tech export intensity, while the Netherlands and Finland are above the EU average. Nevertheless, 14 Member States are below the US, and 11 are lower than Japan. Malta has an especially high concentration of high-tech products in its exports, due to its sales of electronic components which have increased dramatically since the 1980s.

Figure II-3b, showing the share of countries in world high-tech exports, gives an indication of their competitiveness in the global high-tech market.

If one includes trade between EU countries, the EU-15 represents 37.5% of total world exports of high-tech products.

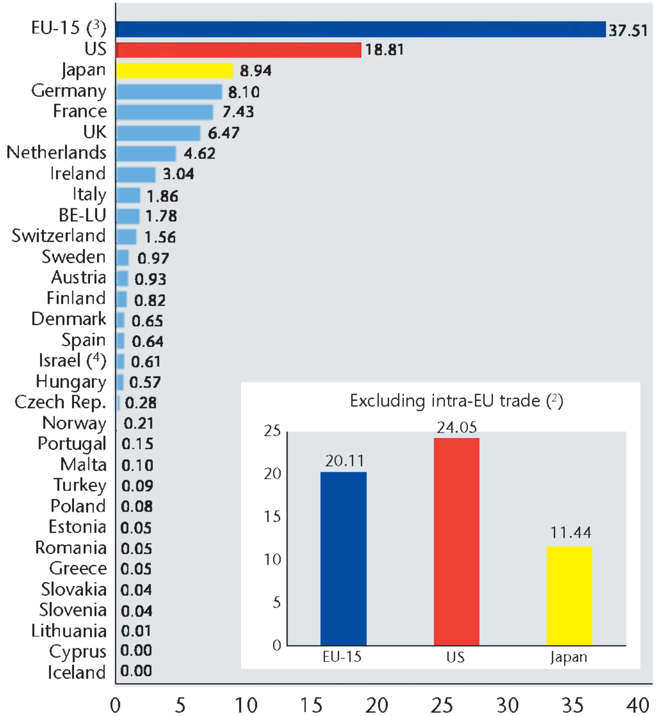
Figure II-3a High-tech exports as a % of total exports, 2001



Source: DG Research
Data: Eurostat (Comext), UN (Comtrade)
Note : EU-15 value excludes intra-EU exports.

Key Figures 2003-2004

Figure II-3b World market share of exports of high-tech products (%), 2001 (1)



Source: DG Research Key Figures 2003-2004

Data: Eurostat (Comext), UN (Comtrade)

Notes: (1) In the larger figure all data include intra-EU exports, and the world market refers to total world high-tech exports including intra-EU exports. (2) In the smaller figure, EU-15 excludes intra-EU exports. World market refers to total high tech exports excluding intra-EU exports. (3) Includes intra-EU exports (4). Israel data for 2000

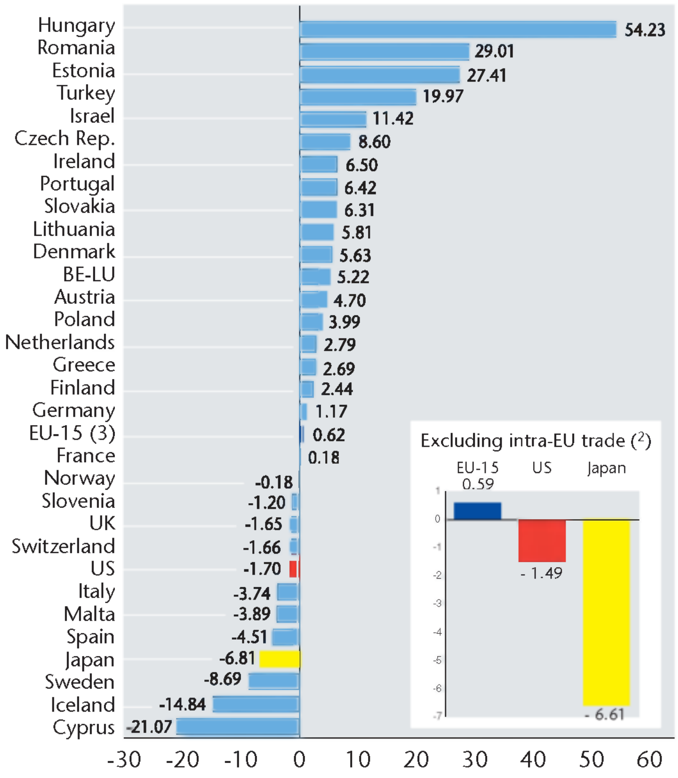
To make meaningful comparisons with the US and Japan, one should, however, exclude intra-EU trade, and the effect of doing this is shown in the smaller graph in Figure II-3b. Here we see that the EU's exports to non-EU countries account for 20.1% of the global market in high-tech goods, compared with 24.1% for the US and 11.4% for Japan. The EU's market share (measured in current euro) has increased slightly in the period 1996-2001 (Figure II-3c), in contrast to the US and Japan whose shares declined over the same period. However, some of this increase is due to the appreciation of the euro in relation to the dollar since 2000. Japan's trade has been particularly hit by declining sales of electronics goods which registered a significant drop in 2001.

The countries with the strongest growth in market share of high-tech exports are Hungary, Romania and Estonia, closely followed by Turkey, Israel and the Czech Republic. The rapid growth seen in the four Acceding countries in this group reflects the restructuring process which has been taking place in recent years. Of the countries with declining high tech market shares, Sweden has experienced a particularly sudden drop due largely to a sharp fall in exports of electronics products in 2001.

Selling knowledge: the technology balance of payments

As well as high-tech products, countries can also buy and sell intangible knowledge. These transactions are measured by the technology balance of payments (TBP), which records a country's exports and imports of technical knowledge and services. The indicator examined here relates to a country's

Figure II-3c World market share of exports of high-tech products - average annual growth rate (%), 1996-2001 (1)



Source: DG Research
Data: Eurostat (Comext), UN (Comtrade)
Notes (1) - (3): See notes for Figure II-3b. Israel data for 1996-2000.

Key Figures 2003-2004

exports of technology (TBP receipts), which reflects its competitiveness on the international market for knowledge. Such trade in technology is also an important vehicle for international technology transfer.

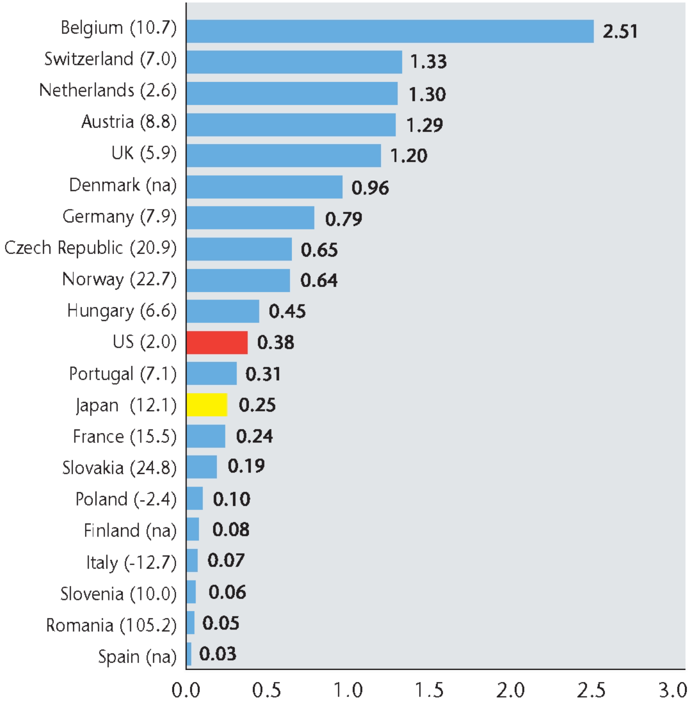
Belgium has the highest level of TBP receipts in relation to GDP (2.5%), with Switzerland, the Netherlands and Austria following at around 1.3%. Hungary and the Czech Republic record higher levels of TBP receipts as % of GDP than the US and Japan (Figure II-3d).

TBP flows are highly internationalised, and, as for a number of other indicators, multinational companies are involved in a significant proportion of these transactions. Some of these receipts may therefore be going to foreign affiliates based in the country in question.

Labour productivity: widening gap after decades of catching-up

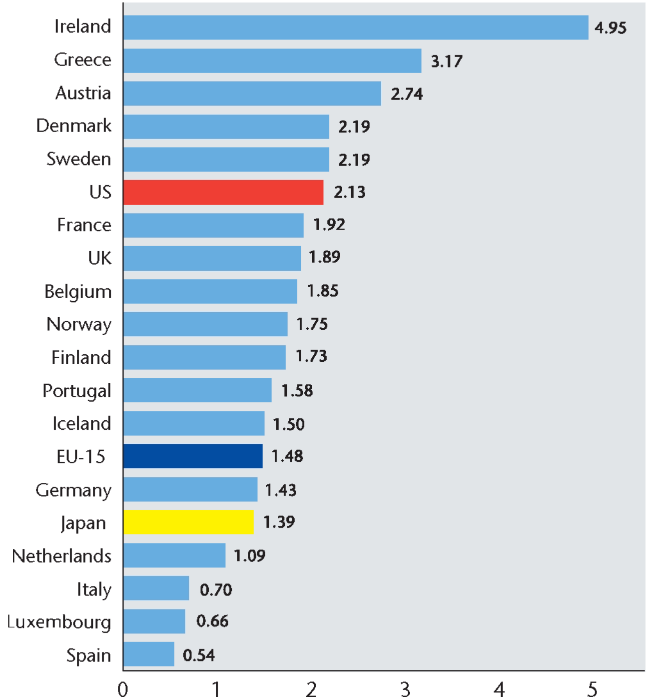
In the long run, increasing labour productivity constitutes the surest way to increase the standard of living of a population in a sustainable manner. Moreover, labour productivity is heavily impacted upon by innovation performance, as measured by total factor productivity. Since the middle of the 1990s, the EU has stopped catching up with the US in terms of labour productivity, reflecting a relatively weaker innovation performance. The EU 1997-2002 labour productivity growth rate is much lower than that for the US (Figure II-3e). While the US labour productivity growth rate is at a relatively high level (2.13%), EU-15 labour productivity growth is considerably lower (1.48%), and closer to that of Japan (1.39%).

Figure II-3d Technology Balance of Payments Receipts as % of GDP, 2001 (1); in brackets: average annual real growth rate (%) of TBP, 1997-2001 (2)



Source: DG Research Key Figures 2003-2004
Data: Eurostat, OECD, National sources
Notes: (1) or latest available year: ES, FI: 1998; DK, HU: 1999; NO, SI: 2000; DE, NL, AT, PT, CZ, SK: 2002 (2) or nearest available years: HU: 1997-99; NO, SI : 1997-2000; DE, AT, PT : 1997-2002.

Figure II-3e Labour productivity (GDP per hour worked) - average annual real growth (%), 1997-2002 (1)



Source: DG Research Key Figures 2003-2004
Data: OECD, Eurostat
Notes: (1) NO: 1997-2001.

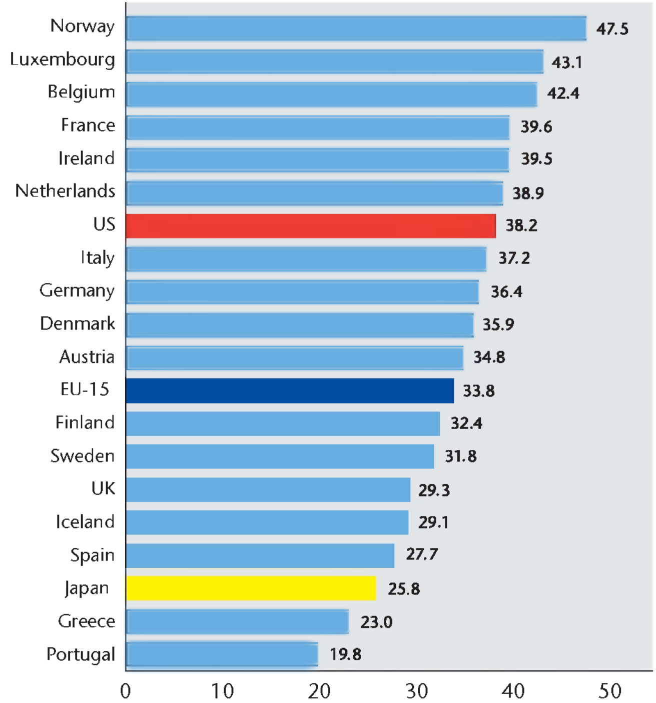
Countries like Ireland and Greece, have very high growth rates (4.95% and 3.17% respectively), and are clearly catching up. Labour productivity growth in other countries such as Spain, Italy, Netherlands and Germany is rather meagre.

The fact that the EU had not quite caught up with the US in terms of labour productivity by the mid-1990s, combined with a lower labour productivity growth rate since that time, has resulted in large absolute differences in labour productivity between the EU and the US. Labour productivity is highest in the US (38.2 current PPS per hour worked) and lowest in Japan (25.8), with the EU-15 taking a middle position (33.8) (Figure II-3f). No traditional distinctions can be made between different groupings of countries. Labour productivity is low in Southern European countries such as Portugal (19.8), Greece (23.0) and Spain (27.7). But it is rather high in Italy (37.2). On the other hand, labour productivity is very high in Norway (47.5), at a medium level in Denmark (35.9), and at rather low levels in Finland (32.4) and Sweden (31.8). The Benelux countries, together with France and Ireland have relatively high levels.

The importance of knowledge in Europe's economies: high-tech industries and knowledge intensive services

The increasing importance of knowledge in the economy is likely to produce new winners and losers on the economic map of the world. The remainder of this section looks at indicators of the share of value added or employment accounted for by high-tech and medium high-tech manufacturing or knowledge intensive services. Such indicators show the relative weight in

Figure II-3f Labour productivity (GDP per hour worked, in current PPS), 2002 (1)



Source: DG Research
Data: OECD, Eurostat
Notes: (1) NO: 2001.

Key Figures 2003-2004

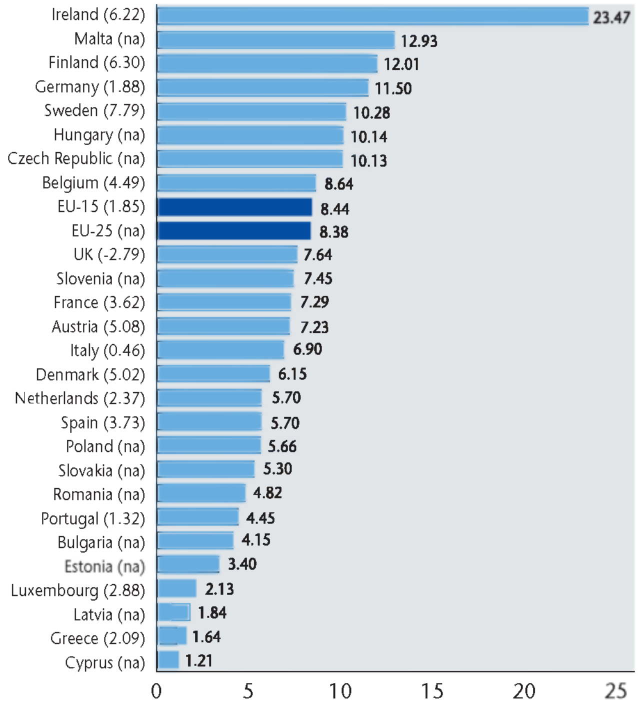
an economy of those activities that require both higher R&D input and qualification levels of employees. However, each country has a unique economic structure. In some (e.g. Portugal, Germany, and especially the Czech Republic, Slovakia and Slovenia) manufacturing traditionally represents a very significant proportion of all economic activities. Other countries are dominated by service activities (e.g. Luxembourg, Netherlands, Sweden and the UK). The overall economic structure of countries should therefore be borne in mind when interpreting the following indicators.

Value added of high-tech and medium high-tech industries

The value added of high-tech and medium high-tech manufacturing as a percentage of total value added gives an indication of the overall importance of high-tech sectors in the economy. It would be expected that with a gradual shift to the knowledge-based economy the value added of those industries with a higher component of R&D should grow at the cost of other, more traditional industries.

In 2001, 8.4% of the EU-15's value added originated from high-tech and medium high-tech industries (Figure II-3g), while for the EU-25 the figure was marginally lower. Ireland is at the top of the group, with almost twice the level of the next country – Malta. It is also interesting to note that among the top performing countries there are both countries with a high overall share of manufacturing in their economic base (Germany, Hungary, Czech Republic), as well as some countries which are mainly service-based but have an

Figure II-3g Value added of high-tech and medium high-tech industries as % of total gross value added, 2001 ([1]); in brackets: average real annual growth rates of value added, %, 1996-2001



Source: DG Research Key Figures 2003-2004
Data: Eurostat
Note: EU-25 data do not include LT. ([1]) or latest available year: BG, CY, CZ, HU, PL, RO, SK, EE, SI, LV, MT: 2000.

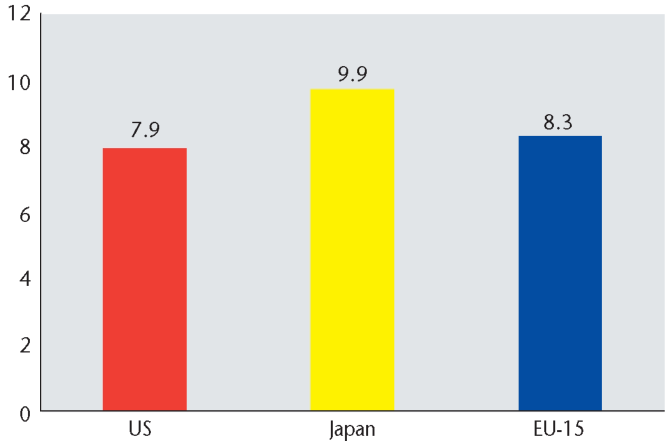
important element of high-tech and medium high-tech activities in their manufacturing (e.g. Ireland, Malta, Sweden, Finland). At the opposite end of the scale, the lowest scoring countries have very low shares of manufacturing activity overall (Greece, Luxembourg, Cyprus), or, as in the case of the Baltic republics of Latvia and Estonia, have relatively important manufacturing sectors but with a low proportion of high-tech activities.

The differences between Acceding countries are very substantial in this respect with some of them with relatively high values, and others with relatively low values. The Acceding countries of Hungary, the Czech Republic and Malta all score rather highly mainly due to traditionally high levels of activity in high-tech and medium high-tech manufacturing branches, such as automotive and electronics in the first two, and due to recent FDI in all three, while Cyprus is the last of all the 26 countries.

Unfortunately, data on more recent trends in relative importance of high-tech and medium high-tech industries are only available for the EU Member States. The average real annual growth of value added in these industries for the EU-15 during the period 1996-2001 was 1.9%. Remarkably, only the UK recorded negative growth, which demonstrates the increasingly important role of high-tech industries in Europe. Nonetheless, the countries that experienced the most dynamic growth are those that are the top investors in R&D and top performers in industry financed R&D (all three Nordic Member States) plus Ireland which has recently been the most important recipient of high-tech manufacturing FDI in the EU.

Moving to the comparison between the EU, the US and Japan (Figure II-3h), one can clearly see that Japan is ahead of its two rivals in terms of value added by high-tech and medium high-tech sectors, largely due to its traditionally strong position in the manufacturing of electrical and optical equipment. The third place of the US, on the other hand, reflects the traditionally more important role of its service industries compared with manufacturing.

Figure II-3h Value added of high-tech and medium high-tech manufacturing as % of total gross value added, 2001



Source: DG Research Key Figures 2003-2004
Data: OECD, STAN database

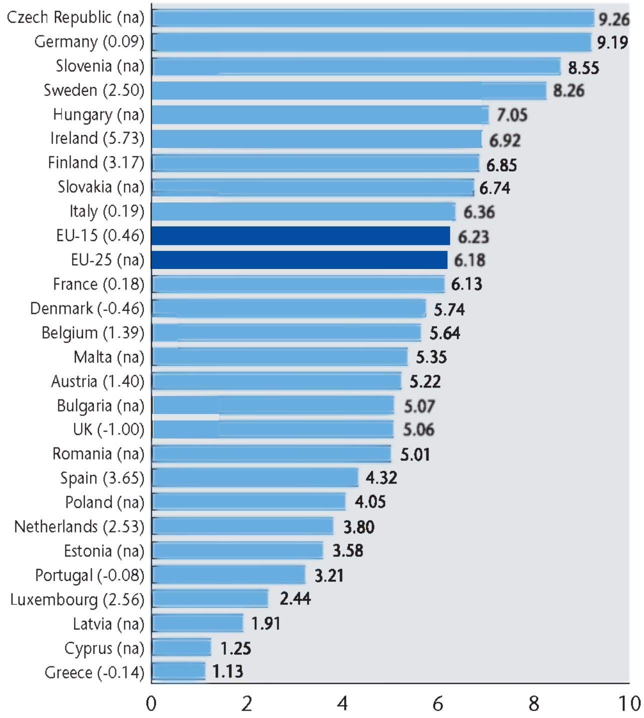
Employment in high-tech and medium high-tech industries

Indicators of employment are presented separately from value added because they reflect a slightly different feature of high-tech and knowledge intensive activity. A high share of employment in a given high-tech or knowledge intensive sector may not necessarily be accompanied by high levels of value added and vice versa – e.g. in some cases a large number of employees (even in a high-tech branch) may account for only limited value added. Thus the labour productivity of these sectors may vary from one country to another.

Nevertheless, employment in high-tech and medium high-tech industries reflects an important aspect of an economy, namely the part of the working population that is actually applying new, improved knowledge in the workplace, or mastering modern technology to be able to carry out a job. However, one should bear in mind that even in the industries classified as high-tech or medium high-tech there exists a great diversity of jobs and that not all people employed in these industries are necessarily so-called 'knowledge workers'.

Nevertheless, high-tech industries tend to have a higher average spending on R&D. Equally, employment in high-tech manufacturing sectors has been growing substantially faster than in manufacturing branches as a whole. High-tech employment in 2002 was 4.5% higher than in 1997 in EU-15 as opposed to an increase of only 2% in total manufacturing, (European Commission, 2003c), suggesting a strong link between R&D intensity, job creation and competitiveness.

Figure II-3i Employment in high-tech and medium high-tech industries as % of total employment, 2001 (1); in brackets: average annual growth rate of employment, %, 1996-2001



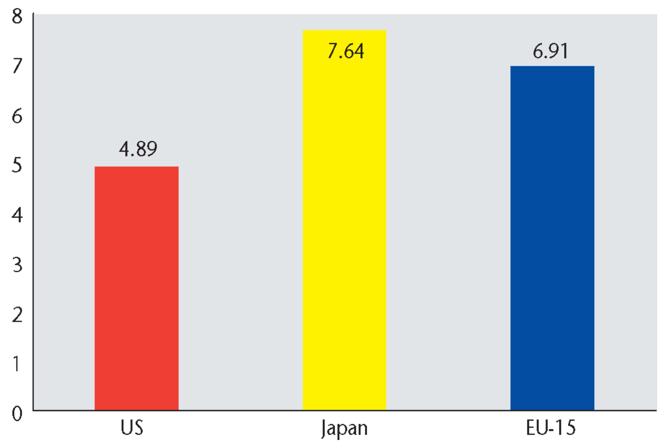
Source: DG Research Key Figures 2003-2004
Data: Eurostat
Note: EU-25 data do not include LT. (1) or latest available year: EU-25, BG, CY, CZ, HU, PL, RO, SK, EE, SI, LV and MT: 2000.

In 2000, average employment in high-tech and medium high-tech manufacturing in EU-15 was 6.2%, virtually the same as for the EU-25 (Figure II-3i). There are, however, some important differences among both the EU-15 and the Acceding countries. The top of the ranking consists of the traditional high-tech manufacturing countries which includes some existing Member States such as Germany, Sweden, Ireland and Finland, but also a number of Acceding countries such as the Czech Republic, Slovenia and Hungary. The lowest rankings are occupied by countries with either a smaller share of manufacturing in the economy, or countries with more traditional, less high-tech manufacturing sectors. Again, they are both existing Member States (Greece, Luxembourg and Portugal) as well as some Acceding countries (Cyprus, Latvia).

Trends in terms of growth of employment in high-tech and medium high-tech industries are also presented in Figure II-3i for the existing Member States. The growth in the EU-15 as a whole is nearly 0.5% - substantially less than the growth in value added of these industries for the same period, thus indicating important overall productivity gains in European high-tech manufacturing. The most dramatic growth rate was recorded in Ireland, whose average annual growth is approaching 6%, or approximately half the growth rate recorded for value added of Irish high- and medium high-tech industries. Ireland is followed by Spain and Finland. By contrast, the UK and Denmark registered the highest decline of high-tech manufacturing employment suggesting a further trend towards de-industrialisation in these economies.

The comparison between the Triad (Figure II-3j) shows a similar picture to that for value added: Japan comes first, trailed by the EU-15[8] and the US. What is interesting though are the differences in the gaps between the shares of employment and shares of value added (see Figure II-3h) which suggest the greater efficiency of the US high- and medium high-tech manufacturing industries.

Figure II-3j Employment in high-tech and medium high-tech manufacturing as % of total employment, 2001 (1)



Source: DG Research — Key Figures 2003-2004
Data: OECD, STAN database
Notes: EU-15 data do not include EL, IE, LU, NL. (1) or latest available year: EU-15: 1999.

[8] The data for EU-15 presented in Figures II-3j and II-3k differ by 0.68 percentage point because of the differences between methods used by Eurostat and OECD.

Value added of knowledge intensive services (KIS)

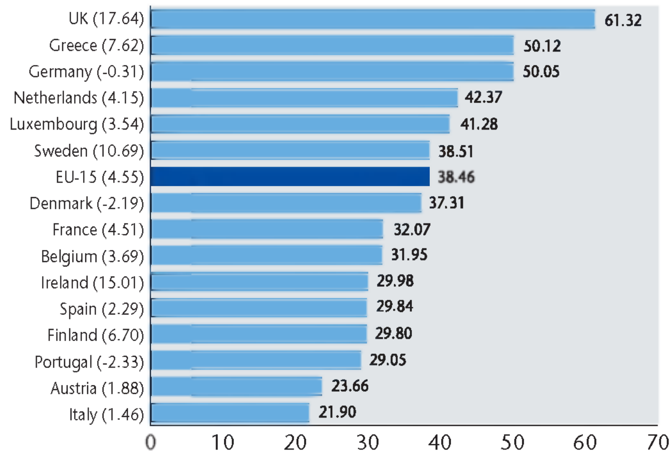
Knowledge intensive services (KIS) play an increasingly important role in all developed economies. They cover a sector with high requirements for qualifications and the application of knowledge, which gives them a special importance for economic growth. The development of KIS is closely linked to the growing specialisation of industries and the need for even more specialised services emanating from other service and manufacturing sectors. Very often, specialisation is conditioned by a more sophisticated demand and, as a consequence, may lead to increases in productivity.

The value added created by KIS is an important indicator of the overall knowledge intensity of a given economy. Moreover, the share of value added accounted for by KIS has been constantly growing in the EU in recent years, even when some other sectors have been declining. In 2001, KIS accounted for nearly 39% of EU's total value added (Figure II-3k).

However, there were quite substantial differences among individual Member States with the UK being the top performing country, followed by Greece and Germany while the lowest scoring countries were Italy and Austria. Neither those countries with high levels of employment in services (Luxembourg, Netherlands, Sweden), nor those with low levels (Portugal, Greece, Spain) scored at either of the extremes for this indicator.

The value added produced by KIS shows positive growth over the period 1996-2001. On average the annual real growth rate has been 4.5% for the EU-15 as a whole. The top performers

Figure II-3k Value added of knowledge intensive services as % of total gross value added, 2001 (1); in brackets: average real annual growth rate (%) of value added, 1996-2001



Source: DG Research Key Figures 2003-2004
Data: Eurostat
Note: (1) or latest available years: SE, LU, GR, EU-15: 2000

were the UK and Ireland, both of which posted growth rates well above the other EU-15 countries. Germany, Denmark and Portugal, on the other hand, were the only EU countries that experienced an average real annual decrease of value added by KIS. Unlike high-tech manufacturing, no comparable data for the Triad exist for KIS. The data for the Acceding countries are also insufficiently harmonised to allow comparisons to be made. However, one would expect that the overall weight of

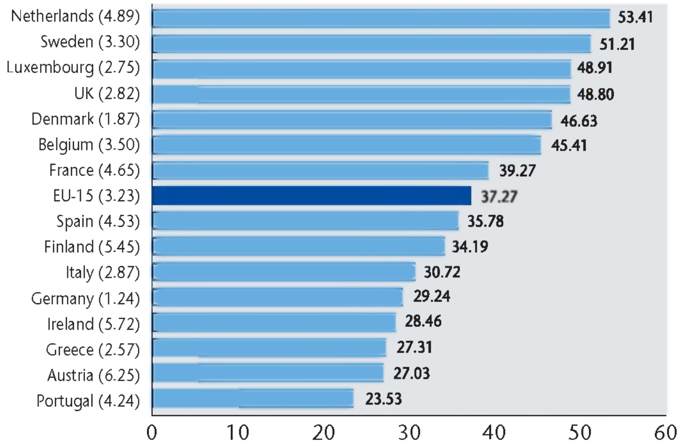
KIS in the European economy will decrease with enlargement since most Acceding countries still have underdeveloped service sectors.

Employment in knowledge intensive services

The share of employment in the knowledge intensive services is another indicator of the extent to which the economy employs highly qualified personnel in jobs characterised by high knowledge requirements. As in the case of high-tech manufacturing employment, employment in KIS says nothing about the productivity of those employed. However, some inference can be made by comparing the KIS value added and KIS employment indicators for individual countries (Figure II-3l). In 2001, 37.3% of people employed in the EU-15 worked in KIS, the top performers being those countries with the highest share of employment in the service sector as a whole (Luxembourg, Netherlands, Sweden). Portugal, Austria and Greece were the last in the ranking, two of which – Portugal and Greece – also happen to have the lowest overall share of service employment in the EU. This is not very surprising given that in most EU countries the KIS account for more than half of all service employment.

The trends in KIS employment show the increasing importance of knowledge-intensive occupations in all European countries without exception. The EU-15 as a whole witnessed an average annual growth of 3.2% in the period 1996 – 2001. The countries that experienced the slowest growth were Germany and Denmark. The highest ranks were taken by Austria, Ireland and Finland. Interestingly, Austria, which scored the lowest in terms of its share of KIS employment, also recorded the highest average annual growth of KIS employment over the past five years (6.2%) - nearly double the EU average - suggesting a catching-up in KIS employment.

Figure II-3l Employment in knowledge intensive services as % of total employment, 2001; in brackets: average annual growth rate (%) of KIS, 1996-2001



Source: DG Research Key Figures 2003-2004
Data: Eurostat

Comparable data for the Triad and the Acceding countries are not available. However, since several of the Acceding countries have the highest shares of manufacturing activity in Europe, their entry into the EU is likely to reduce somewhat the overall importance of the service sector, including the KIS, in Europe's economy.

Key findings

- In terms of scientific publications Europe's strong growth seems to have halted. Actual numbers are still rising, but the EU share of world publications is declining, whereas the US share is recovering.
- Per head of population, the EU generates fewer patents with a high economic value (so-called 'Triadic patents') than the US and Japan.
- The EU is lagging behind the US in its share of patents in biotechnology and information and communications technology.
- There has been a slight increase in the EU share of global exports of high-tech products in value terms between 1996 and 2001. Japan's share fell sharply in 2001 hit by falling sales of electronic goods.
- Since the middle of the 1990s, the EU has stopped catching up with the US in terms of labour productivity, reflecting a relatively weaker innovation performance.
- Large disparities persist among EU countries in both high-tech manufacturing and KIS.
- Japan outperforms the EU in high-tech manufacturing indicators while the Central European Acceding countries perform better than the EU average.

Perspectives

This Part presented the situation of the EU present and future members from the perspective of indicators, showing their relative position in respect of the knowledge-based economy as well as their competitive position. It has been argued that in order to make Europe more competitive - or even simply maintain its current competitive position, sustained growth and employment levels - Europe needs to invest in production of new knowledge, in applying new technology, and ultimately in the people that will be able to put the new knowledge and technology to use. The current state of affairs has been described using various indicators of scientific and technological output, as well as general competitiveness indicators.

Looking first at scientific and technological output, the EU is still ahead of the US and Japan in its share of scientific publications, but lags behind in most of the other performance indicators, especially patents. There is, nonetheless, a substantial variation within the EU and certain EU Member States often score better than the US and Japan (most notably Sweden and Finland), yet the overall situation in the EU-15 is far from satisfactory. Moreover, one tends to find most of the Acceding countries in a position of catching up from relatively low levels of S&T output. Although there are some noticeable encouraging tendencies in several Acceding countries, one can expect that with the enlargement of the Union the 'European Paradox' will be, at least temporarily, further accentuated. In other words, in relation to its enlarged population, the EU-25's strong performance in science will contrast increasingly with its weaker development and commercialisation of technology.

In this context, the introduction of the Community Patent (agreed by the Council in March 2003) should help to stimulate European inventive activity by reducing the cost of patenting, providing a clear legal framework in case of dispute and ensuring the free movement of goods protected by patents.

However, Europe still needs to exploit better its scientific and technological output, notably in terms of selling its high-tech goods on world markets. While its share of high-tech exports has grown slightly since the mid-1990s, the EU still had a lower market share than the US in 2001. Indeed, 2001 was a difficult year for the high-tech sector, and the ability of industry to withstand this correction will be a crucial factor in a number of countries. Moreover, this is a highly competitive market no longer restricted to the major developed countries. Over the past decade, we have seen developing Asian producers emerge as important players in high-tech market niches. A number of Acceding countries are also growing rapidly in their exports of high-tech, due in part to inflows of foreign investment.

At the same time, an increase in labour productivity, itself dependent on higher levels of innovation, is essential if Europe is to improve its global competitiveness. However, since the middle of the 1990s, the EU has stopped catching up with the US in terms of labour productivity. The EU-US gap is quite large and widening. This reflects weaker human capital formation, capital deepening and innovative performance as reflected in total factor productivity.

The indicators of high-tech manufacturing and knowledge-intensive services (KIS) show continuing and significant disparities within Europe, which are likely to grow with enlargement. Countries in Europe have, and will probably always have, different economic structures, and clearly not all of them can produce luxury cars, become financial centres, or host an internationally recognised university producing large numbers of publications or patents. Yet, even those Member States that have 'inherited' a less high-tech economic structure and less robust research infrastructures will increasingly require policies to improve the exploitation of new technologies and new knowledge.

The challenge of the knowledge-based economy is for Europe as a whole to become more attractive as a location for high-tech activities, capable of producing scientific excellence, and of attracting and retaining top quality researchers. The concrete response to the challenge of the knowledge-based economy will thus require a policy mix that will balance the advancement of research and increased R&D investment, the stimulation of innovation, and the development of human resources. If the Lisbon strategy of making the EU the most competitive economy in the world is to be realised, Europe must make the necessary investments and appropriate policies for it to compete effectively in the knowledge-intensive economy.

Annex I: Basic macroeconomic and demographic data

Table A-1: Basic macroeconomic and demographic data for the European countries, Israel, the US and Japan ([1])

	GDP		Population		Young population (25-34)		Employment		Unemployment	
	in bio € 2002	av. Annual real growth (%) 1997-2002	in 1000 2002	av. annual growth (%) 1997-2002	in 1000 2002 (2)	av. annual growth (%) 1997-2002 (3)	in 1000 2002 (4)	av. annual growth (%) 1997-2002 (5)	in 1000 2002 (4)	av. annual growth (%) 1997-2002 (5)
Belgium	261	2.1	10 310	0.27	1 407	-1.79	4 189	1.22	319	-3.92
Denmark	183	2.2	5 368	0.35	768	-1.14	2 776	0.62	129	-2.64
Germany	2 108	1.5	82 440	0.10	11 171	-4.01	38 610	0.78	3 396	-2.16
Greece	141	3.8	10 988	0.94	1 621	0.79	3 914	0.68	435	0.68
Spain	*694*	3.5	40 409	0.55	6 865	1.36	*16 303*	2.88	2 081	-5.87
France	1 521	2.7	*59 344*	0.42	8 166	-0.93	24 924	1.74	2 308	-4.87
Ireland	*128*	8.3	*3 883*	1.23	*609*	2.93	*1767*	4.69	80	-12.16
Italy	1 258	1.8	*56 332*	-0.40	*9 104*	-0.41	23 345	1.39	2 160	-4.03
Luxembourg	22	5.3	*444*	1.20	68	-0.54	194	2.44	5	2.82
Netherlands	444	2.6	16 105	0.68	2 386	-1.77	8 336	2.05	230	-9.28
Austria	217	2.4	8 139	0.18	1 213	-2.80	4 061	0.69	166	-0.14
Portugal	*129*	2.8	10 336	0.52	1 581	1.02	*5 027*	1.68	271	-3.80
Finland	140	3.2	5 195	0.24	647	-1.89	2 344	1.72	237	-5.47
Sweden	255	3.1	8 909	0.15	1 200	-0.91	4 347	1.64	228	-12.20
UK	1 659	2.5	*58 928*	0.01	*8 915*	-1.29	*27 659*	0.55	1 533	-4.93
EU-15	9 161	2.4	377 131	0.19	*55 410*	-1.36	167 796	1.33	13 579	-4.32
Cyprus	11	4.2	*706*	-0.98	103	-1.42	309	1.70	13	-5.14
Czech Rep.	*74*	1.5	*10 270*	-0.08	*1 602*	2.71	4 796	-0.58	376	10.22
Estonia	*7*	4.4	*1 361*	-1.42	*184*	-2.65	588	-1.12	58	-1.79
Hungary	70	4.3	10 175	-0.25	1 535	2.94	3 871	1.41	229	-8.34
Lithuania	15	4.5	*3 476*	-1.28	*491*	-3.21	1 399	-3.47	215	0.58
Latvia	*9*	5.7	2 346	-1.11	*322*	-1.94	1 065	0.53	144	-4.56
Malta	*4*	2.7	*395*	1.08	*53*	1.90	137	0.44	12	2.36
Poland	200	5.3	38 632	0.00	5 441	1.55	13 782	-1.91	3 445	13.26
Slovenia	23	3.9	1 994	0.07	293	-0.46	902	2.10	59	-2.49
Slovakia	25	3.0	5 379	0.00	804	1.44	*2 127*	-0.62	483	10.54
EU-25	9 599	2.5	451 864	0.13	*66 226*	-0.95	196 772	0.96	18 614	-1.42
Bulgaria	17	4.1	7 891	-1.10	1 129	0.21	2 992	-1.07	617	8.16
Romania	48	1.3	*22 392*	-0.17	3 723	3.48	*7 819*	-2.82	735	3.12
Turkey	192	1.0	68 612	1.59	12 101	3.01	*21 779*	-0.44	*2 535*	32.13
Switzerland	284	1.6	*7 261*	0.50	*1 027*	-2.22	:	:	:	:
Iceland	*9*	3.5	287	1.21	42	0.40	*140*	1.65	*2*	-16.74
Liechtenstein	:	:	34	1.48	5	-0.44	:	:	:	:
Norway	*202*	2.0	4 524	0.59	667	-0.34	*2 318*	0.87	92	-0.15
Israel	109	2.2	6 442	1.91	960	2.65	2 271	2.72	2.33	8.26
US	11 048	3.0	287 676	1.06	39 575	-0.94	*148 729*	1.05	8 378	4.45
Japan	4235	0.5	127 066	0.18	19 148	1.59	*65 492*	-0.66	3 588	9.28

Source: DG Research Key Figures 2003-2004
Data: Eurostat, OECD, Countries.
Notes: ([1]) Data in italics are estimated or provisional. ([2]) EL : 2000; IT, UK, CY, EE, SK : 2001. ([3]) EL : 1997-2000; IT, UK, CY, EE, SK : 1997-2001; ([4]) IL : 2001; ([5]) IL: 1997-2001; TR: 2000-2002.

Annex II: Definitions and Sources

Symbols and abbreviations

Country codes

BE	Belgium
DK	Denmark
DE	Germany
EL	Greece
ES	Spain
FR	France
IE	Ireland
IT	Italy
LU	Luxembourg
NL	Netherlands
AT	Austria
PT	Portugal
FI	Finland
SE	Sweden
UK	United Kingdom
EU-15	European Union (15 Member States)
CY	Cyprus
CZ	Czech Republic
EE	Estonia
HU	Hungary
LT	Lithuania
LV	Latvia
MT	Malta
PL	Poland
SI	Slovenia
SK	Slovakia
ACC	Acceding countries
EU-25	European Union (25 Member States)
BG	Bulgaria
RO	Romania
TR	Turkey
CC-13	Candidate Countries (ACC and 3 Candidates)
IS	Iceland
LI	Liechtenstein
NO	Norway
CH	Switzerland
IL	Israel
US	United States
JP	Japan

Other abbreviations

na not available

General indicators

Gross domestic product (GDP)

Definition: Gross domestic product (GDP) data have been collected according to national accounts definition (ESA 1995 definition).
Source: Eurostat.

Small and medium-sized enterprises

Definition: Small and medium-sized enterprises (SMEs) are defined as enterprises (1) having fewer than 250 employees, and (2) either an annual turnover not exceeding 40 million ecu or an annual balance-sheet total not exceeding 27 million ecu , and (3) conforming to the criterion of independence as defined in paragraph 3 in Commission Recommendation 96/280/EC of 3 April 1996 concerning the definition of small and medium-sized enterprises. However, the data received on SMEs do not always comply with the above definition. The Japanese definition of SMEs refers to companies with less than "300" employees.
Sources: Member States, Japan (Report on the Survey of Research and Development, Statistics Bureau) and the US (NSF).

Purchasing Power Standards (PPS)

Definition: Financial aggregates are sometimes expressed in Purchasing Power Standards (PPS), rather than in ecu/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 1995 PPS.
Source: Eurostat [see e.g. Eurostat (2002a)].

Part I: Investment in the knowledge-based economy

Gross domestic expenditure on R&D

Definition: Gross domestic expenditure on R&D (GERD) is defined according to the OECD Frascati Manual definition, in national currency, and converted to Euro and PPS. The same methodology also applies to data on R&D investment, which relates to financing of total gross domestic expenditure on R&D. *Sources:* Eurostat, Member States. OECD for the US. OECD and national sources for Japan.

Basic research

Definition: The term "basic research" is used in the sense of the OECD Frascati Manual (2002a) definition: "Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view." However, in practical terms, because of the increasing interplay between the different modes of R&D, it is often difficult to draw a line between basic and applied research. In addition to this and the limited availability of the data, in many cases, data may be distorted since countries tend to label basic research according to the institutions where the research is carried out in spite of the fact that these institutions may also perform other types of research. For instance, all the research done by universities could be defined as basic research. Moreover, collecting reliable and comparable data seems very difficult because the distinctions between basic and applied research have blurred in recent years, with more intense collaboration and interaction between various stakeholders within national innovation systems. *Sources:* OECD (2001a, 2002a, 2002b).

Government budget allocated to research

Definition: The government budget allocated to research is defined as government budget appropriations or outlays for R&D (GBAORD) according to the OECD Frascati Manual definition (except in Japan), in national currency, and converted into euro and 1995 Purchasing Power Standards (PPS). The data are based on information obtained from central government or federal budget statistics. They cover government-financed R&D in all sectors of performance carried out either domestically or abroad. The figures reveal an overall picture of governments' investment plans, but not that of their actual spending.

Sources: Eurostat and EU Member States. For the US: NSF.

Publicly funded R&D executed by the business enterprise sector

Definition: Publicly funded R&D executed by the business enterprise sector is defined as Business enterprise expenditure on R&D (BERD) financed by government, according to the OECD Frascati Manual definitions.

Sources: OECD, Member States and national sources for Japan.

Research and development expenditure financed by industry

Definition: Research and development expenditure financed by industry is defined as GERD financed by the Business enterprise sector according to the Frascati Manual definition.

Sources: Member States; OECD for the US; OECD and national sources for Japan.

Venture capital investment

Definition: Venture capital in early stages of a company - i.e. seed and start-up stages – provides financing mainly for the initial business plan, research activities, product development and first marketing. It is part of total venture capital (= equity investments made for the launch, early development or expansion of business). Total venture capital itself is a part of total private equity capital for enterprises not quoted on a stock market (EVCA). Romania is a pilot country in EVCA data collection and the data contains only the activity of private equity companies within country. In the US the definition of seed VC includes also start-up VC and the start-up phase covers early stage financing that corresponds to other early stage financing (NVCA). The Japanese data for early stage and expansion phase financing come from the VEC survey and are based on the following assumptions: firstly, early stages correspond to the period before establishment or less than 5 years of the company's life time. Secondly, the expansion phase covers five years or more and less than ten years after the establishment of companies financed by the VC. Thirdly, the ratio of venture capital in early stage and expansion stages to the new or additional investment is the same as that in total new investment.

Sources: European Venture Capital Association (EVCA) for the Member States, EFTA-countries, Acceding countries and Romania. National Venture Capital Association (NVCA) for the US. NISTEP for Japan from the VEC survey.

Researchers

Definition: Researchers (Research Scientists and Engineers, RSEs) include the occupational groups ISCO-2 (Professional Occupations) and ISCO-1237 (Research and Development Department Managers). See the "Frascati Manual" (OECD 2002a). The data for researchers are generally given in full-time equivalents (FTE). Only for female researchers as shares of all researchers are they given in headcount (HC).

Sources: OECD, MSTI database, 2003, Vol.1. Eurostat/Member States: Benchmarking indicators

Classification: ISCO: International Standard Classification of Occupation (version 1988).

Foreign S&E employees and H-1B beneficiaries in the US

Definition: S&E employees include agricultural scientists / biological scientists, engineers, mathematicians / computer scientists / physical scientists, social scientists and post-secondary teachers. The H-1B visa is a non-immigrant classification, which permits US employers to bring in foreign skilled workers on a temporary basis (maximum 6 years). H-1B visas demand a university degree or equivalent qualifications and include following occupations: computer related; managers and official needs; technical and managerial professionals, administration specialities; architecture, engineering and surveying; education; law; life sciences; maths and physical sciences; medicine and health; social sciences. The country of origin is defined by the place of birth.

Sources: S&E employees: SESTAT, SRS, NSF; H-1B beneficiaries: US Immigration and Naturalization Service, Table 44

S&T graduates

Definition: Graduates are defined by the levels of education classified in ISCED 1997. In these Key Figures graduates include all tertiary degrees (ISCED 5a and 5b) and PhDs (ISCED 6). The Canberra Manual defines S&T relevant fields of study as follows: they include the natural sciences and engineering (which can be understood as the core S&T fields – here labelled S&E) also the medical sciences, agriculture (here labelled health and food sciences), the social sciences, arts and humanities and education (Soc/Hum/Educ) (see OECD 1994).

Particularities in figure I-4a: BE: in 2001 data for the Flemish community exclude second qualification. LU: Luxembourg does not have a complete university system; refers only to ISCED 5B first degree. FI: Data include those who graduated a second time at the same ISCED level. AT: ISCED level 5B refers to previous year. PT: ISCED level 5B excludes second qualification. RO: Data exclude advanced research programmes (ISCED level 6); Data exclude second qualifications. CY: Data exclude tertiary students graduating abroad. The fields of study in Cyprus are limited. PL: Since 2001 ISCED 6 graduates are included.

Sources: Eurostat/Member States: Benchmarking indicators; UOE (UNESCO/OECD/Eurostat) database.

Classification: ISCED: International Standard Classification of Education (1997 version).

Educational attainment

Definition: Percentage of population aged 25-64 with at least upper secondary education (ISCED 3 or higher)

Source: Eurostat NewCronos database

Expenditure per student in tertiary public education

Definition: Expenditure in tertiary public educational institutions (in Euro PPS)

Source: Eurostat NewCronos database

Particularities in figure I-4c: NL, UK, LV: Expenditure on public and private educational institutions. MT: Purchasing power parities (PPP) of 1999.

Participation in lifelong learning

Definition: Percentage of population aged 25-64 having followed any kind of education or training in the 4 preceding weeks.

Foreign students in Europe

Definition: Foreign students in tertiary education (ISCED 5 and 6) by country of citizenship. The table gives the total number of foreign students in the countries under consideration and the ten most frequently occurring countries or regions of origin (in order of descending order of importance).

Sources: Eurostat NewCronos database, US: IIE (www.opendoors.iienetwork.org)

Part II: Performances

(Co-)Publications

Definition: Publications are research articles, reviews, notes and letters that were 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-15 aggregate, double counts of multiple occurrences of EU Member States in the same record were excluded.

Co-publications are publications by two or more authors from two or more countries. Despite the possibility of several authors from one country, each country involved is counted only once.

Source: ISI, Science Citation Index; treatments and calculations: University Leiden, CWTS.

Scientific specialisation

Definition: Relative activity index (RAI) is calculated for 26 fields on the basis of publications from 1995-1999. The field of 'Multidisciplinary' has been left out. RAI = a/b, where a = % of a country in all publications in a field and b = % of publications of that country compared to total publication output of all countries. Normalised score: RAI*=(RAI-1)/(RAI+1). Scores <0.10 signify no specialisation, scores between 0-0.10 and 0.10 are around field average and >0.10 signify a specialisation. The 26 sub-fields have been regrouped into six broad fields by calculating the average RAI for each broad field.

Source: ISI, Science Citation Index; treatments and calculations: University Leiden, CWTS. Calculation of broad fields: DG-Research.

Patent indicators

Definition: European patents are the number of patents applied for at the European Patent Office (EPO). US patents are the number of patents granted at the US Patent and Trademark Office (USPTO). The country of origin is defined as the country of the inventor.

Source: OECD based on data from EPO and USPTO.

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).

Sources: Eurostat (Comext), UN (Comtrade).

Technology balance of payments receipts

Definition: The technology balance of payments (TBP) records a country's exports and imports of technical knowledge and services (including licences, know-how, trademarks, technical services, etc.). TBP statistics are defined according to the Technology Balance of Payments Manual of the OECD.

Sources: OECD, Eurostat, Member States.

Labour productivity

Definition: Labour productivity is defined as GDP per hour worked.

Sources: Eurostat, Member States.

High-tech and medium high-tech industries

Definition: High-tech and medium high-tech industries are defined by the average shares of their expenses dedicated to R&D, or R&D-intensity. According to the Eurostat definition, high-tech and medium high-tech industries consist of the following manufacturing sectors: manufacture of chemicals and chemical products, manufacture of machinery, motor vehicles and of other transport equipment, mechanical and automotive engineering, machinery and transport, and manufacture of office machinery, electrical machinery, radio, television and communication equipment, medical, precision and optical instruments (i.e. NACE 24, 29, 30-33, 34, 35.2, 35.3, 35.4 and 35.5).

Despite the recent progression harmonising the definitions, the OECD data used here for the medium high-tech manufacturing differs slightly from that of Eurostat as it is based on the ISIC Rev. 3 classification. This explains the differences between the data presented in graphs comparing the EU Member States and

Acceding and Candidate countries on the one hand (Eurostat method), and the data presented in the graphs comparing the Triad (OECD method).

Sources: Eurostat (SBS, CLFS, National Accounts) and OECD (Science, Technology and Industry Scoreboard).

Classification: NACE Rev. 1. for Eurostat, ISIC, Rev. 3 for OECD

Knowledge intensive services

Definition: Knowledge intensive services are defined according to the Eurostat definition as: post and telecommunications, computer and related activities, research and development, water transport, air and space transport, financial intermediation, real estate, renting and business activities, education, health and social work and recreational, cultural and sporting activities (i.e. NACE Rev.1 codes 61, 62, 64-67, 70-74, 80, 85, 92).

The output of knowledge intensive 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.

Employment in knowledge intensive services is the number of employed persons (full and part time) in knowledge intensive services according to the Eurostat definition (as above).

Sources: Eurostat (SBS, CLFS and National Accounts), OECD (Science, Technology and Industry Scoreboard).

Annex III: Methodology changes in the indicators of high-tech and medium high-tech industries and knowledge intensive services

In the past years indicators relating to the high-tech and medium high-tech industries (HT/MHT industries) and knowledge intensive services (KIS) have formed part of the set of benchmarking indicators. The data used to construct employment related indicators were derived from the Community Labour Force Survey (CLFS) while data on value added came from Benchmarking sources. For the future, Eurostat proposed a methodological change in favour of using data originating from Structural Business Statistics (SBS). SBS data allow for greater precision in respect of employment figures (unlike CLFS data which are based on questionnaires collected from households, SBS data are based on a survey of employers) and also allow for better matching between the inputs and outputs of the economy. Furthermore, thanks to the ongoing improvement of SBS, the HT/MHT and KIS indicators can in the future be fully and exclusively based on the SBS methodology which will allow the use of the same source for data on both employment and value added thus increasing future comparability.

Generally, the SBS data cover only certain categories of NACE classification, namely the categories C to K excluding J (i.e. omitting a number of service categories). This does not cause any major problems in HT/MHT industries, but causes problems for KIS, a substantial part of which is represented by activities that SBS does not account for (namely health and education).

The indicators on HT/MHT industries and KIS from previous Key Figures' should therefore not be compared with the current indicators, as the former indicators used as their basis data sets constructed with very different methodologies.

High-tech and medium high-tech industries

The data on total gross value added in basic prices for the entire economy, as well as the total employment data applied to calculate the shares of HT/MHT industries have been taken from National Accounts statistics.

The data on value added at basic prices (from National Accounts) are calculated from the production value plus subsidies on products less the purchases of goods and services (other than those purchased for resale in the same condition) plus or minus the change in stocks of raw materials and consumables less other taxes on products which are linked to turnover but not deductible. It represents the value added by the various factor inputs in the operating activities of the unit concerned.

On the other hand, SBS methodology calculates the value added are factor cost, which is the gross income from operating activities after adjusting for operating subsidies and indirect taxes. Broadly speaking, this represents the value added at basic prices, plus subsidies on production, minus taxes on production. In other words, it can be expected that this methodological difference is understating the actual value added accounted for HT/MHT industries.

Also the employment data for HT/MHT industries comes from SBS statistics while the total employment data originates from National Accounts statistics which also produces a certain degree of methodological inconsistency. While the SBS data originate from the survey of employers, the total employment data as per National Accounts statistics represent a compromise between SBS and LFS data. This difference, however, should be of minor importance.

Knowledge intensive services

The data on both value added and employment in KIS have only a limited reliability since the SBS does not account for all KIS categories. It accounts only for the KIS that fall within the category of market economy, i.e. not education, health care, etc. (only NACE 61, 62, 64, 70, 71, 72, 73 and 74 are covered while categories 65, 66, 67, 80, 85 and 92 are not). Because of this, the data from CLFS and Benchmarking data were used to estimate the missing segments of KIS for EU-15. Due to the lack of reliable time series and comparable CLFS data - at the time of writing – similar estimations for Acceding countries were not feasible. Just as in the case of HT/MHT industries, the total value added and the value added of KIS are not strictly compatible. The total employment data and the total value added data used in the denominator of the relevant indicators come from the National Accounts statistics and not from SBS. Therefore the same reservations as in the case of HT/MHT industries also apply in the case of KIS.

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15

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