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Towards a European Research Area

Science, Technology and Innovation

Key Figures 2002

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PREFACE

The challenges facing Europe at the beginning of the 21st century are manifold. Europe's transition towards a knowledge-based economy will be accompanied by structural changes in industry, as well as a shifting profile of its human capital due to a rapidly ageing population. Moreover, the goals of the European Union of ensuring sustainable economic growth, employment and social cohesion are soon to be extended to a number of candidate countries.

One of the main engines for attaining these socio-economic objectives is technological change, induced primarily by research and development (R&D). This has been acknowledged already at the Lisbon Council in 2000, which set the goal to make Europe «*the most competitive and dynamic knowledge-based economy in the world*» by 2010. Strategies to achieve this goal are now being implemented. In terms of research and development, a major step forward has been the strengthening of measures to create a European Research Area (ERA), which has provided a framework for research policy in Europe since 2000, and will help to improve the overall efficiency of European research efforts.

Several instruments have been established for this purpose. Policy makers in the Member States have already been actively involved in successful instruments such as the 'Benchmarking of national research policies', while the Community's 6^{th} Framework Programme for Research and Technological Development will also provide a strong tool for integrating, structuring and strengthening the European Research Area.

The Barcelona European Council in March 2002 was another step forward, with European governments deciding to increase the EU's overall spending on R&D to 3% of GDP by the year 2010. The decision to increase R&D spending, coupled with a restructuring of the European research landscape towards a true internal research market characterised by high levels of mobility, competition, and research excellence will provide a strong base for our future.

Against this challenging policy background, it is all the more important to know where Europe stands in terms of science and technology, and how its position is evolving. I am therefore very happy to present the 2002 edition of Key Figures, which provides a profile of European S&T in the form of key indicators. This year's report not only contains a carefully selected set of data that describes the main dimensions of European S&T, but also includes the updated data for the research benchmarking exercise. I hope it will be welcomed as a useful tool for policy makers and the interested public.

Philippe Busquin

CONTENTS

Introduction

Science, Technology and Innovation at the Crossroads

Since the development and achievement of the Single Market, Europe has made many steps towards achieving its goals of sustainable growth, social cohesion and international competitiveness. However, these goals remain, and there are many challenges in sustaining prosperity, stability and growth in an ever-changing world.

During the 1980s and 1990s, great structural changes in industry have had significant impact on employment patterns and growth. Such changes include the rise of information and communication technologies (ICTs), and of multinational firms, the decline in manufacturing industry and the increased importance of the service sector, as well as changing supply and production processes. While some industries seem to manage the structural changes better than others, the effects on growth and employment at the country level is becoming far more unequally distributed.

Coping with these structural changes is inevitable for industrialised countries such as the EU-15 Member States. However, the EU-15 is facing other socio-economic challenges at the same time. While the transition to a knowledge-based economy already requires a lot from firms and individuals, it offers a range of opportunities for substantial institutional change. However, the rapid ageing of populations in European countries poses additional challenges.

Policy developments

During the Lisbon European Council in 2000, the European Council expressed the will to make Europe «*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*". In assessing progress towards this ambitious and multifaceted objective it is important to obtain a global overview of efforts and performance on a number of different policy axes: not just research and development, but also innovation, education, e-society and other fields. With this in mind, the European Commission services have started work on two composite indicators for the knowledge-based economy in the framework of the Structural Indicators exercise and the Spring Report. In the first section of Key Figures 2002 the first results from using these indicators are presented.

Of course research and development (R&D) is one of the key means to achieve the Lisbon goal. The key role of R&D, from investment to execution, diffusion and innovation can certainly not solve all structural difficulties but might prove to be vital for economic success. The importance of R&D is however not matched by national investments. A comparison of the investments made by EU-15 countries, the US and Japan in R&D in the previous decade reveals great differences. The crucial role of R&D for European competitiveness has been underlined repeatedly at successive Council meetings, a high point being the Barcelona Council in 2002, where Heads of State and Government committed themselves to investing 3% of GDP in R&D by 2010.

The Commission has adopted a strategic communication to help start the process of achieving the goal set by the Barcelona Council. The communication is intended to launch a debate on ways of reaching the objectives for R&D investment. In order to help identify areas where policy needs to be mobilised in a coherent way, relevant statistical data and analysis are presented here.

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 co-ordinate European research and facilitate the research policies of the individual Member States. The intention is that the combination of national research and Community-level collaborative work should improve European research capabilities and overall make research more strategic.

Benchmarking update

A key instrument for attaining coherent research and innovation policies is the benchmarking of existing ones. Benchmarking was the focus of the 2001 Key Figures publication; the 15 indicators chosen were explained there in greater detail. Some Member States have released detailed methodological reports as well, for example the *Wissenschafts- und Technologieindikatoren* (2001) by the German Statistisches Bundesamt.

Now, as the first cycle of data collection and analysis is coming to an end, this Key Figures 2002 edition includes updated data for the 15 indicators where data are available. Qualitative improvements suggested by the Statistical Offices of the Member States have been taken into account where possible.

The national statistical offices of the Member States have validated most of the data used for the benchmarking update, while private sources were used to obtain data that are not collected at national level (such as data on venture capital, publications, and patents).

Range of indicators

The benchmarking indicators, which have been chosen as the basis for policy analyses, fit well under the chosen subject headings. However, there is a shortcoming relating to differences in definitions and calculation methods. In some cases, such as human resources, the definitions chosen for the benchmarking exercise differ from those in general use; in others missing data lead to differences in estimates, possibly leading to slight differences in macroeconomic outcomes.

The range of indicators gives insight into many of the important issues influencing the innovation process, and the presentation of data also gives valuable information about the investment and performance of a range of countries or regions.

However, it should be emphasised that data are only one important contribution in understanding complex subject matters. In addition, qualitative information is needed to analyse, understand and learn from comparing the performance of science, technology and innovation in different countries.

An Overview of Europe's Investment and Performance in the Knowledge-Based Economy

The Lisbon European Council in 2000 set the ten-year goal of making the EU the most competitive and dynamic knowledge-based economy in the world. Subsequent Council meetings in Stockholm and Barcelona have served to review and add further impetus to these objectives. This chapter gives a first overview of the progress made in the transition to a knowledge-based economy.

However, monitoring the progress made by the Member States towards this goal is not an easy task. The knowledge-based economy is a complex, multidimensional phenomenon that cannot be captured by any single indicator. The number of different aspects that need to be included in any assessment of the knowledge-based economy makes it extremely difficult to distil the "big picture".

Composite indicators provide a way of addressing this problem. By aggregating a number of different variables, composite indicators are able to summarise the big picture in relation to a complex issue with many dimensions. In this section two composite indicators are presented: a composite indicator of investment in the knowledge-based economy, and a composite indicator of performance in the knowledge-based economy (for details of these indicators see Annex IV).

Composite indicator of investment in the knowledge-based economy

In order to advance effectively towards the knowledge-based economy, countries need to invest in both the creation and the dissemination 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 A shows the sub-indicators of this composite indicator.

Table A. 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

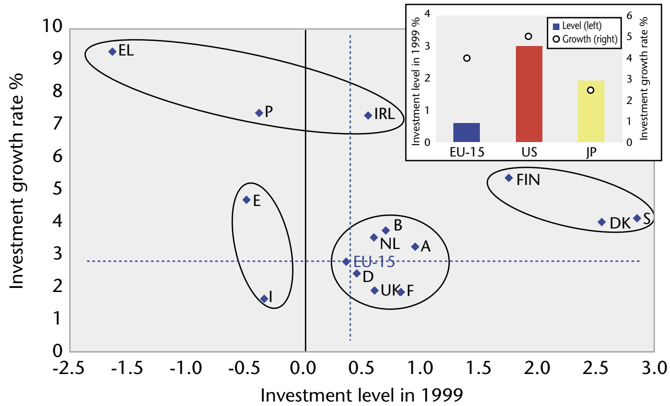
Figure A shows on the horizontal axis the position of each country compared with the other Member States in terms of its investment level in 1999. On the vertical axis, it measures the extent to which each country progressed over the years 1995-1999.

First, this figure confirms that the EU is lagging behind the US in terms of both investment level and growth (even if the European rate of growth is rather similar to that of the US and above Japan's). However, some Member States (Finland, Sweden and Denmark) have levels of investment and growth patterns comparable to or better than the US and Japan.

Beyond this first observation, the composite indicator also allows an interesting comparison between the Member States. Obviously, there are different strategies to achieve the transition towards a knowledge-based economy. Some countries or regions might focus on the creation of new knowledge, whereas others put more emphasis on the diffusion and acquisition of competitive, new knowledge from abroad. Within the Union, a distinction can be made between four groups of countries, based on the efforts made during the period 1995-1999 to fit into a knowledge-based economy.

- The Nordic countries Finland, Sweden, and Denmark are best prepared and are rapidly turning their economies into knowledge-based economies. The rate of growth of their investment is also clearly above the European average.
- A group of six countries – Austria, Belgium, France, Germany, The Netherlands and the United Kingdom – are close to, but slightly above, the European average as regards their investment level. France, Germany and the UK have a rate of growth of investment slightly below the European average, whereas Austria, Belgium and The Netherlands are above.

Figure A. Composite indicator of investment in the knowledge-based economy. Relative country positions in 1999 and annual growth rate 1995-1999[1]



Source: DG Research Key Figures 2002
Data: Eurostat, DG Information Society
Note: For details about the calculations and methodology, see Annex IV

- A third group of three countries – Greece, Portugal and Ireland – have very high growth of investment, which is even above that of the Nordic countries. Greece and Portugal are still below average in terms of investment level, but are catching up at a very

(1) Due to non availability of data for US and Japan, three sub-indicators (education spending, e-government and life-long learning) were not included in the comparison between EU, US and Japan. This explains why the two values for EU-15 are slightly different in Figure A. For more details see Annex IV.

rapid pace. Ireland, on the other hand, was already slightly above the European average level in 1999.

- A fourth group consists of two big southern European countries, Spain and Italy. They are both significantly below the EU average as concerns investment levels, although Spain's investment growth is above the EU average. These countries need to invest significantly more in their knowledge economy to converge towards the other European countries.

Composite indicator of performance in the knowledge-based economy

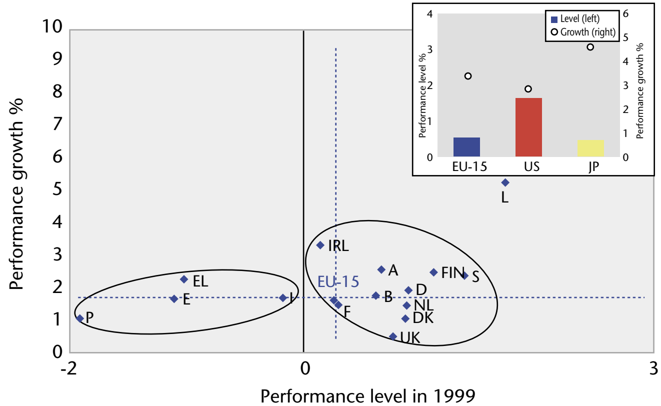
Investment in the knowledge-based economy is only one half of the story. The various elements of investment in knowledge, described above, need to yield successful outcomes if Europe's goals are to be reached. Productivity needs to be maintained and improved but for this to happen, and to be sustainable, there needs to be good performance in science and technology, effective use of the information infrastructure and successful implementation of the education system.

Table B. 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

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

Figure B. Composite indicator of performance in the knowledge-based economy. Relative country positions in 1999 and annual growth rate 1995-1999[2]



Source: DG Research Key Figures 2002
Data: Eurostat, EPO, USPTO, ISI/CWTS, DG Information Society
Notes: For details about the calculations and methodology, cf. Annex IV

(2) Due to non availability of data for US and Japan, two sub-indicators (e-commerce and schooling success rate) were not included in the comparison between EU, US and Japan. This explains why the two values for EU-15 are slightly different in Figure B. For more details see Annex IV.

Figure B shows on the horizontal axis the position of each country with regard to its performance level in 1999. On the vertical axis, it gives the progress made in this area over the years 1995-1999.

Taken as a whole, the EU is lagging behind the US in terms of performance level. However, in the second half of the nineties the majority of European countries managed to improve their performance level at a more rapid pace than the USA. Nevertheless, this higher growth is still not sufficient to eliminate the existing gap between the EU and the US in the short-term, and certainly not by 2010. To avoid this it is necessary not only to increase the volume of investment made in the knowledge-based economy, but also to improve the way it is allocated and implemented.

Within the European Union, the indicator again shows that it is possible to follow different strategies. Luxembourg, for instance, has the highest performance level and growth, although it invests much less than others in knowledge creation. Thanks to a successful specialisation in some sectors of the economy (especially banking and general business services), it apparently succeeds in attracting highly skilled manpower and generates activities with high value added. Apart from the case of Luxembourg, a distinction can be made within the Union between two large groups of countries in terms of their performance in moving towards the knowledge-based economy. However, the differences here are much less marked than they were for investment.

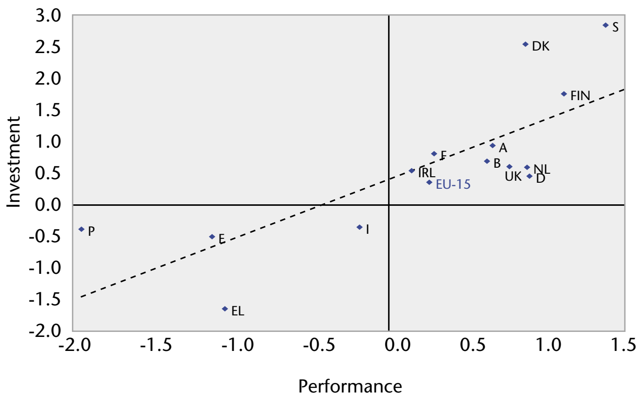
- A broad group of 10 countries consisting of Austria, Belgium, Denmark, Finland, France, Germany, Ireland, the Netherlands, UK and Sweden are quite close to the European average in terms of performance level and growth. Ireland had a much greater rate of growth during the second half of the nineties, which allowed it to approach the EU average by the end of the decade.
- The second group consists of four countries: Greece, Italy, Portugal and Spain. This group was lagging behind the EU average in terms of performance level at the end of the nineties, with a rate of growth around the EU average. The somewhat higher growth of Greece might be a positive consequence of the strong efforts and investments made by this country during the 1990s. However, Portugal's significant increase in investment has not yet been converted into clear effects. It is important to recognise that there is always a time-lag between making the investment and observing improvements in performance.

On the relation between investment and performance

The relationship between what countries invest in knowledge and how this translates into technological and economic performance is highly complex, and is the subject of ongoing research. For one thing, there is clearly a time-lag between the injection of investment and the resulting performance effects. Moreover, just as important as the volume of knowledge investment is where and how the investment is made, in terms of the fields targeted and the instruments chosen. Countries can enhance their performance by exploiting knowledge produced elsewhere and by making their economy more attractive to foreign capital and highly skilled human capital from abroad.

Nevertheless, Figure C suggests that there is an observable relationship between investment and performance in the knowledge-based economy. By and large, those countries that invest more in research, education and innovation are also those that have the best performance. At the same time, at EU level, there is a need for further concertation and co-ordination of Member States' efforts in order to avoid duplication and to attain critical mass.

Figure C. Performance vs. Investment of the Member States in 1999



Source: DG Research Key Figures 2002
Data: Cf. Figures A and B
Note: For details about the calculations and assumptions, cf. Annex IV

Moreover, at recent European Summits, EU Member States have insisted that, in parallel with targeting overall improvements in macro-economic conditions, employment and cohesion, Europe needs to reinforce its efforts in building knowledge infrastructures and enhancing innovation. This involves the sound management of structural change in policy areas relating to research, education, innovation and the information society.

While the composite indicators attempt to integrate some key components of these policy fields, the following sections will narrow the focus somewhat to those indicators relating to R&D investment, human resources, the scientific and technological performance and the technological competitiveness of the Member States.

Part 1: R&D Investment for the Knowledge-Based Economy

Scientific and technological knowledge and its wide dissemination play a vital role in the knowledge-based economy. It is widely agreed that research and development (R&D), along with the availability of a highly skilled workforce, the creation of an intense interplay between the stakeholders of national innovation systems, and the effective use of information and communication technologies, are the key conditions for successful innovation and the competitiveness of advanced economies.

The capacity to create and apply knowledge has become more important in the production of goods and services. On the one hand, production is more research-intensive, drawing on the utilisation of research findings; on the other hand, it is technology-intensive, drawing on the exploitation of new technology, and on the command of the knowledge base of advanced and tailored services and complex production processes.

This part of the document first examines the investments that various countries are making in R&D, and the main sectors making those investments. Secondly, some key figures on Community funding of research by means of the Framework Programmes are presented. Thirdly, since in most countries the business sector plays the most important role in terms of R&D spending, private investment will be examined in more detail. As venture capital (VC) investment – from private as well as public sources – becomes more and more important for the creation of new firms and employment, key data on VC investment will conclude this part.

Key findings

- Since the mid-1990s, the gap in R&D financing between the EU and the US has almost doubled in volume terms. The gap is mostly because the growth in R&D activities in the main EU economies has been low by comparison to that in the US, especially in France, the UK and Italy.
- There are substantial differences between Europe and its main competitors in the structure of their R&D funding. In the EU, while governments account for a much larger share of R&D investment than in the US and Japan, the situation is the reverse in the case of business R&D. The absolute volume and the growth of R&D investments being made by European companies are substantially below the levels found in the US.
- The EU countries have converged in terms of the development of their R&D system. On the one hand, most of the small EU economies, and those that are catching up, have recorded the highest growth rates for R&D investment and R&D intensity (the amount of R&D investment per unit of GDP). On the other hand, the major EU economies have registered either comparatively moderate or negative rates for growth of R&D investment and R&D intensity.
- The business sector finances and executes a high share of R&D in several EU countries. However, comparing the EU average to the US and Japanese shares respectively, the EU's business sector is lagging far behind.

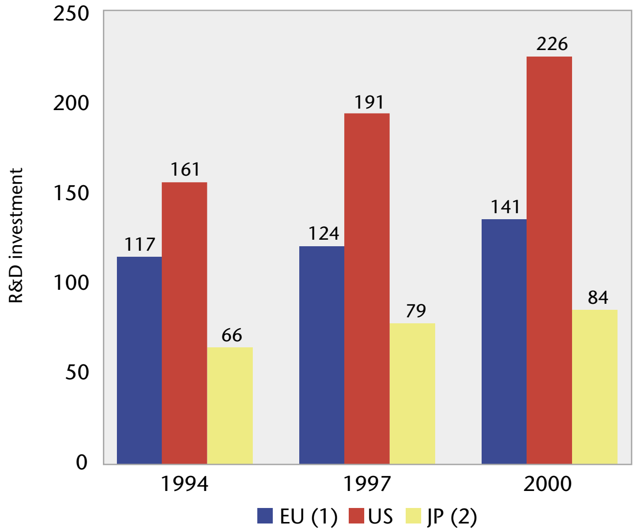
- European Community research funding is complementary to national funding. The new Sixth Framework Programme will amount to over €17 billion for the period 2002-2006 and will be used as the main instrument for establishing the European Research Area.

1.1 Total investment in R&D

The volume of financial resources devoted to R&D is an indicator of the level of commitment to the production and exploitation of new knowledge. It is also an indirect measure of a country's innovation capacity, and reflects the magnitude of accumulation of new knowledge, which is so essential to modern economies. Total R&D investment by main sources of financing provides information on the structure of R&D funding and on the weight of different funding sources in the R&D enterprise as a whole. The 'R&D intensity' indicator, which describes a country's total R&D expenditure in relation to its gross domestic product (GDP), is useful in facilitating comparisons of the R&D activities in countries of different sizes. These indicators are now explored.

As illustrated in Figure 1.1.1, in the year 2000 the EU countries allocated PPS 141bn to R&D, which in current terms is €164bn. This figure was almost 14% higher than in 1997 and some 20% higher than in 1994. As such, the recent trend in R&D investment in the EU has been slighly more favourable, after several years of rather slow growth. In 2000, the equivalent figures for the US and Japan were PPS 226bn (€288bn) and 84bn (€154bn) respectively.

Figure 1.1.1. R&D investment in the EU, the US and Japan - 1994, 1997 and 2000 (PPS[3] billion, at 1995 prices)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) EU average does not include L.
(2) Japan: data for 1994 adjusted by OECD.

The EU clearly invests less in R&D than the US; the investment gap between the EU and the US was some PPS 86bn (€124bn) in 2000. However, of particular significance here is that the gap has doubled

(3) Purchasing Power Standards at 1995 prices, the standard used throughout the report.

in volume terms since the mid-1990s. In 2000, the gap was PPS 7.8bn larger than the previous year. In volume terms, this was the biggest year-to-year change since 1995. The EU does well when compared to Japan: in 2000, the difference was a record PPS 56bn in favour of the EU.

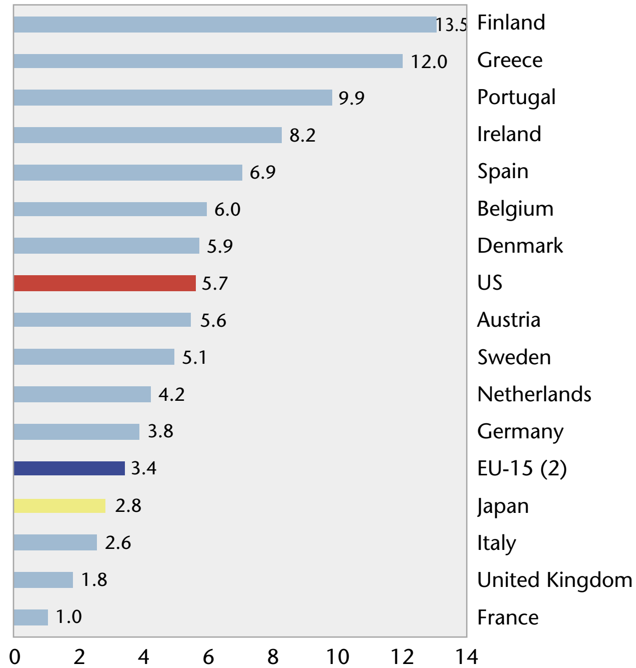
Figure 1.1.2 moves on to examine the growth in R&D investments by country. Since 1995, the growth in R&D investments has been highest among smaller economies (Finland, Belgium, and Denmark) and catching-up countries – those with relatively low absolute volumes of R&D activities and/or R&D intensity. The highest growth rates were recorded for Finland (14% per year), Greece (12%) and Portugal (10%).

Compared to the US (6%), the growth rate was lower in all the major EU economies: in Germany, the UK, France and Italy, real growth in R&D was from 1% to 4% per year. However Germany, with the highest R&D growth rate of the larger EU countries, on its own accounted for over a third of the EU-level increase of absolute volume of R&D between 1995 and 2000. Germany, together with three smaller EU economies (Spain, Finland, and Sweden), accounted for almost 57% of the total increase of R&D activities in the EU.

Financing by sector

Table 1.1.1 shows the share of R&D funding provided by government, the business sector, other national sources and foreign sources by country. In Japan, the business share of R&D financing was, at 72%, the highest among the three economic blocks. In the US, the business sector financed over 68% of all research. These figures stand out clearly when compared to the EU figure of 56%.

Figure 1.1.2. R&D investment - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) B,DK,EL,IRL,I,NL,S: 1995-1999; JP: 1996-2000; All other countries and EU: 1995-2000.
(2) EU average is estimated and does not include L.

By contrast, the government share of R&D funding was the highest in the EU, at 34%. In the US, the figure was 27%, while it was lowest in Japan at less than 20%.

The business sector plays the leading role in R&D financing in most EU countries. However, Finland was the only EU country where the business share of total funding was higher than in the US. The other EU Member States that recorded comparatively high shares for the business sector were Sweden, Germany, Belgium and Ireland, at 64%–68%. Of the major EU economies, the business shares for Italy and the UK were far below the EU average. In Greece and Portugal, the business shares were exceptionally low – less than a quarter of total R&D funding.

Most of the countries that show the highest business sector shares of R&D investment also record the lowest shares for government financing. Public funding accounted for less than 30% of the total in the UK, Finland, Sweden, Belgium and Ireland. At the other end of the scale, in Portugal (70%), Italy (51%) and Greece (49%), the R&D system is mostly dependent on government contributions.

In the EU, the share of funding from abroad was 7.4% of the total. The share of foreign R&D funding was highest in Greece, accounting for almost 25% of the total. The share of foreign funding is also strikingly high in Austria, the UK, Ireland and the Netherlands. The situation is the opposite in Germany, Finland and Sweden, with funding from abroad being very low, below 4%.

Table 1.1.1. R&D financing by main sources of funds (%), latest available year.

	Business enterprise	Government	Other national sources	Abroad	Total
Belgium	66.2	23.2	3.3	7.3	100
Denmark	58.0	32.6	3.5	5.3	100
Germany (1)	66.9	30.7	0.4	2.1	100
Greece	24.2	48.7	2.5	24.7	100
Spain (2)	49.7	38.6	6.8	4.9	100
France	54.1	36.9	1.9	7.0	100
Ireland	64.1	21.8	1.6	12.4	100
Italy (3)	43.0	50.8	-	6.2	100
Netherlands	49.7	35.8	3.4	11.2	100
Austria	40.1	40.3	0.3	19.3	100
Portugal	21.3	69.7	3.7	5.3	100
Finland (2)	70.3	26.2	0.9	2.7	100
Sweden	67.8	24.5	4.2	3.5	100
UK (2)	49.3	28.9	5.5	16.3	100
EU-15 (4)	56.3	34.2	2.1	7.4	100
US (2) (5)	68.2	27.3	4.4	-	100
Japan (2)	72.4	19.6	7.6	0.4	100

Source: DG Research Key Figures 2002
Data: OECD
Notes: (1) 2001 (2) 2000 (3) 1996 (4) EU average does not include L.
(5) excludes most or all capital expenditure.

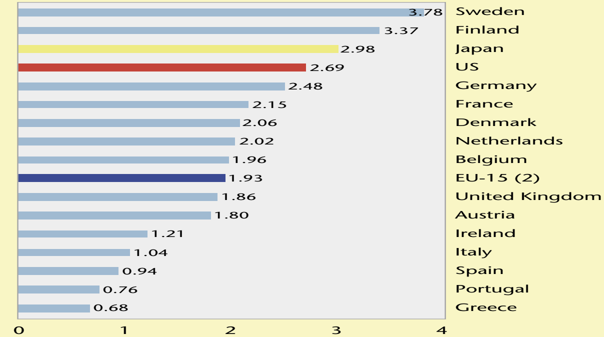
Benchmarking Indicator

R&D intensity: percentage of GDP spent on R&D

As shown in Figure 1.1.3, the EU's R&D intensity in 2000 was 1.93%. The EU average was 0.8 percentage points below the figure for the US and over 1 percentage point behind Japan. Within the EU there is great diversity. The highest R&D intensity is found in Sweden (3.8%) and Finland (3.4%), followed by Germany (2.5%) and France (2.1%). With 0.7%-1.2%, the lowest levels were recorded for Greece, Portugal, Spain, Italy and Ireland. However, as can be seen in Figure 1.1.4, Greece, Portugal and Spain have scored growth rates for R&D intensity far above EU-average since 1995.

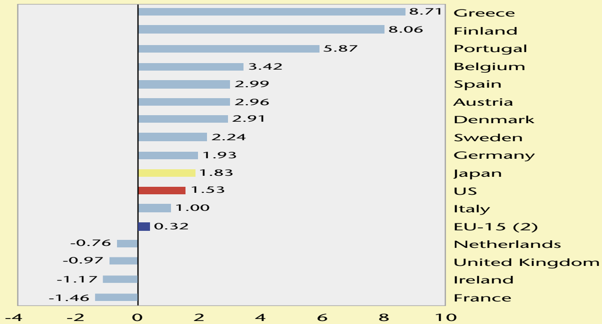
Since 1995, the growth of R&D intensity in the EU has been moderate compared to that of the US and Japan, as shown in Figure 1.1.4. As a result, the EU is currently lagging even more behind the US and Japan than it did in the early 1990s. The recent poor overall development of R&D intensity in the EU is mainly because of the negative trend seen in France, the UK, Ireland and the Netherlands, and the very slow growth experienced in Italy.

Figure 1.1.3. R&D intensity (GERD as % of GDP), latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) EL,IRL,I,B,NL,DK,S: 1999; All other countries and EU: 2000.
(2) EU average is estimated and does not include L.

Figure 1.1.4. R&D intensity (GERD as % of GDP) – average annual growth (%) 1995 to the latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) NL,B,S,DK,I,IRL,EL: 1995-1999; JP: 1996-2000;
All other countries and EU: 1995-2000.
(2) EU average does not include L.

Benchmarking Indicator

Government budget allocated to R&D

The data on government budget appropriations on R&D (GBAORD) are based on information collected from government budget statistics. They involve all the budget items concerning research, and reflect governments' intentions regarding spending.

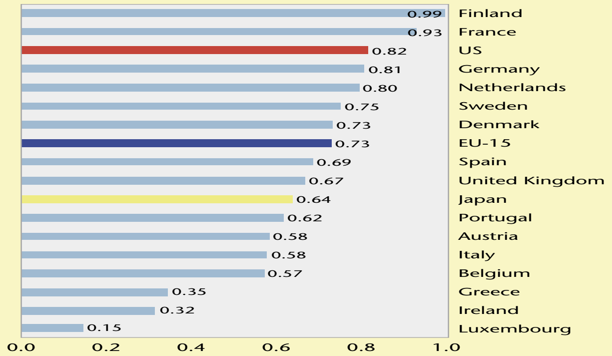
As a proportion of GDP, in 2000 the US government (0.8%) allocated more funds to research than the corresponding authorities in the EU (0.7%) and in Japan (0.6%). Finland (1%) and France (0.9%) were the countries with the highest relative volumes, both even higher than the US (cf. Figure 1.1.5).

In the period 1995-2000, the highest rate of growth in GBAORD in the major economic blocs has been achieved in Japan (over 6%), while in the US and the EU, growth rates were modest, the latter being below 1% per year, as seen in Figure 1.1.6.

There are large differences within the EU. Since the mid-1990s, annual growth has been highest in Luxembourg (16%), Spain (11%), Portugal (11%) and Ireland (9%). Comparatively high growth rates were also recorded for Greece and Finland.

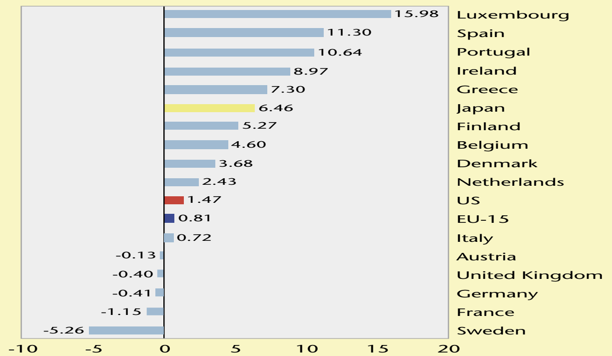
Sweden, France, the UK, Germany and Austria recorded negative annual growth rates. In the first three countries, the development is mostly due to cutbacks in defence R&D. Overall, the slow growth of budget-based R&D funding in the EU is a result of the poor performance of the largest EU economies.

Figure 1.1.5. Government budget allocated to R&D as % of GDP, latest available year (1)



Source: DG Research
Data: Eurostat, Member States
Notes: (1) All countries and EU: 2000.
Key Figures 2002

Figure 1.1.6. Government R&D budget - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research
Data: Eurostat, Member States
Notes: (1) All countries and EU: 1995-2000.
Key Figures 2002

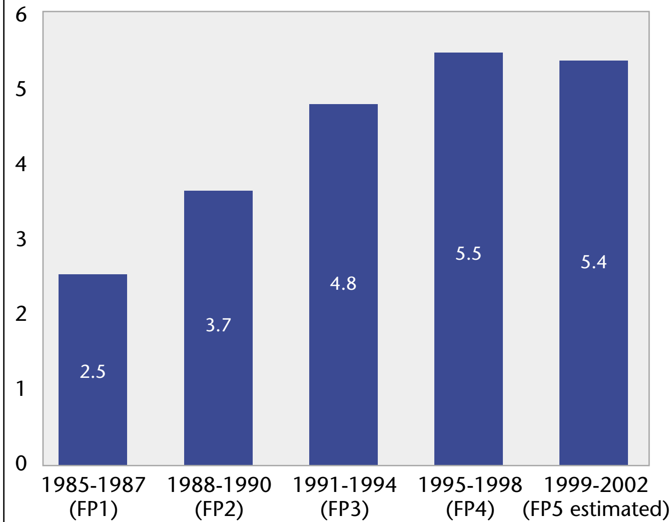
1.2 Community Funded Research

The previous section analysed the funding of R&D by the individual EU Member States in comparison with the US and Japan. This section gives an overview of the additional European investment in R&D, over and above that of Member States, made through the Framework Programmes for Research and Technological Development (FPs) of the European Commission.

Prior to the First Framework Programme (FP1) the European Community primarily invested in R&D related to nuclear energy, coal and steel. However, from the mid 1980s onwards, the European Communities also addressed other European research needs through the FPs and their specific programmes.

Figure 1.2.1 shows how between FP1 and FP5 (1985-2002) the European Communities' contribution to European R&D has risen from the equivalent of 2.5% of the civil part (GBAORD) to stabilise at around 5.5%. In order to be able to make a proper comparison of expenditure under the Framework Programmes with that of the Member States, only that part of the FPs' budgets that would be classified strictly as R&D expenditure is taken into consideration. The actual total budgets of the FPs are some 20% higher than this with the additional money being spent primarily on training, dissemination and innovation activities together with administration.

Figure 1.2.1. European Commission R&D appropriations as % of total (civil) EU government appropriations for R&D



Source: DG Research Key Figures 2002
Data: European Commission, Eurostat, Member States
Notes: (1) EU refers to EU-12 (not including L) from 1985-1994 and to EU-15 (not including L) from 1995 onwards
(2) European Commission R&D appropriations include appropriations in respect of the JRC and the ECSC.

The aim of FP6 is to contribute to the creation of a European Research Area consolidating the experience of previous FPs (S&T excellence, transnational partnerships, equal access) and using the leverage of FP6 to enhance coherence and increase impact of the European Research and Innovation community. The overall budget for FP6 (2002-2006) is €17.5bn, representing approximately 3.9% of the EU's budget (based on the year 2001). There is a nominal increase in budget between FP5 and FP6 of 17% and a real increase of 8.8%. 93% (€16.27bn) of this budget comes from the European Community funding and the remaining 7% (€1.23bn), from the Euratom treaty. Table 1.2.1 gives the breakdown of total funding including administration within these two parts that make up FP6 (see also Figure 1.2.2 which compares in percentage terms the different priorities from FP1 through to FP6).

European Commission funded research and technological development has always aimed to complement Member States' investment in R&D. This is reflected in the way that it emphasises multi-annual pre-competitive co-operative research bringing together partners from different sectors of the economy (industry, government and higher education). Within the individual projects, it targets key domains often of a multidisciplinary nature, it trains researchers by encouraging international mobility and tries to create added value by carrying out R&D at the European level. Figure 1.2.2 gives an indication of how priorities of Community funded research and technological development have changed over the last 20 years.

Table 1.2.1 Sixth framework programme for research, technological development and demonstration, mio euro

COMMUNITY FRAMEWORK PROGRAMME				**16 270**
Focusing and integrating Community research				13 345
Priority 1	Life Sciences, genomics and biotechnology for health		2 255	
	Advanced genomics and applications for health	1 100		
	Combating major diseases	1 155		
Priority 2	Information society technologie		3 625	
Priority 3	Nanotechnologies, nano-sciences, knowledge based multifunctional materials, new production processes and devices		1 300	
Priority 4	Aeronautics and space		1 075	
Priority 5	Food quality and safety		685	
Priority 6	Sustainable development, global change and ecosystems		2 120	
	Sustainable energy systems	810		
	Sustainable surface transport	610		
	Global change and ecosystems	700		
Priority 7	Citizens and governance in a knowledge-based society		225	
	Specific actions covering a wider field of research		1 300	
	Policy support and anticipating scientific and technological needs	555		
	Horizontal research activities involving SMEs	430		
	Specific measures in support of international co-operation	315		
Structuring the European Research Area				**2 605**
	Research and innovation		290	
	Human resources		1 580	
	Research infrastructures		655	
	Science and society		80	
Strengthening the foundations of the European Research Area				**320**
	Support for co-ordination of activities		270	
	Support for coherent development of policies		50	
EURATOM FRAMEWORK PROGRAMME				**1 230**
	Management of radioactive waste		90	
	Controlled thermonuclear fusion		750	
	Radiation protection		50	
	Other activties		50	
	Activities of the Joint research Centre		290	
GRAND TOTAL				**17 500**

Source: DG Research — Key Figures 2002
Data: European Commission

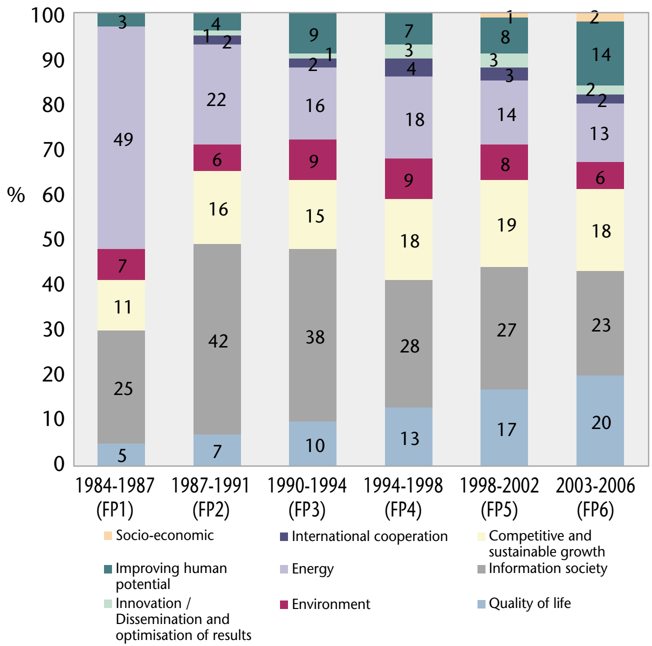
New priorities and instruments to implement the European Research Area

Each new Framework Programme for Research and Technological Development brings with it both new ideas and changes in the priorities attributed to established activities. The Sixth Framework Programme (FP6) is no different from its predecessors in this respect.

For the implementation of FP6 three major new instruments have been introduced: *networks of excellence*, *integrated projects* and *programmes implemented jointly with the Member States*. New subject areas being addressed in depth in FP6 are *Nanotechnologies and Nano-sciences*, *Citizens and Governance in a Knowledge Based Society* and *Policy Support and Anticipating Scientific and Technological Needs*.

Figure 1.2.2 presents FP6 activities broken down as much as possible along the main lines of FP5 in an attempt to illustrate how the relative priorities of FP activities have changed over the last twenty years. The three types of activities that were the most important in the early years: *Energy*, *Information Society* and *Competitive and Sustainable Growth* still represent three of the four most important elements of FP6. Over the years the importance of two activities *Quality of Life* and *Improving Human Research Potential* have consistently increased representing respectively 20% and 16% of funding under FP6. Relative to FP5 the share going *to Quality of Life* has risen from 17% to 20% and *Improving Human Research Potentia*l from 9% to 16%. For *Information Society* it has decreased from 27% to 23%, for *Environment* from 8% to 6%. Minor changes have been recorded for *Competitive and Sustainable Growth* (from 19% to 18%), *Energy* (14% to 13%), *International co-operation* (3% to 2%) and for *Innovation and Dissemination* (3% to 2%).

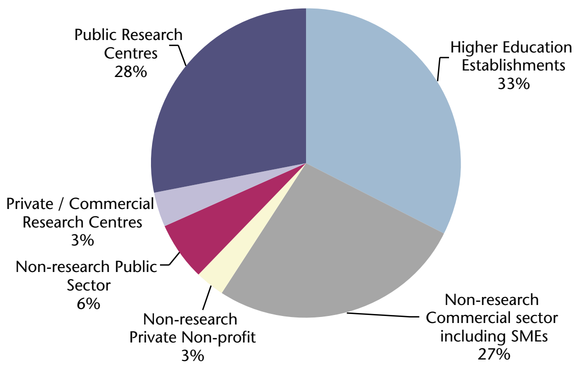
Figure 1.2.2. Evolution of priorities of the RTD Framework Programmes



Source: DG Research Key Figures 2002
Data: European Commission
Notes: In preparing this graph as many elements as possible of the FP6 budget have been decomposed and regrouped along the main lines of FP5. For certain activities of a horizontal nature it has not been possible to perform this exercise, therefore the equivalent budget elements have not been taken into account.

The new Framework Programme devotes the highest ever budget to SMEs. Over 12% of the budget for the thematic priorities of the Specific programme "Focusing and Integrating community research" will be allocated to SMEs (€1.7bn). A further €0.43bn will go to SMEs through Specific Support Schemes. With a total of over €2.1bn over the next four years, the 6th Framework Programme represents a powerful commitment to support research and innovation for SMEs.

Figure 1.2.3. Participation in FP5 by type of organisation (%)

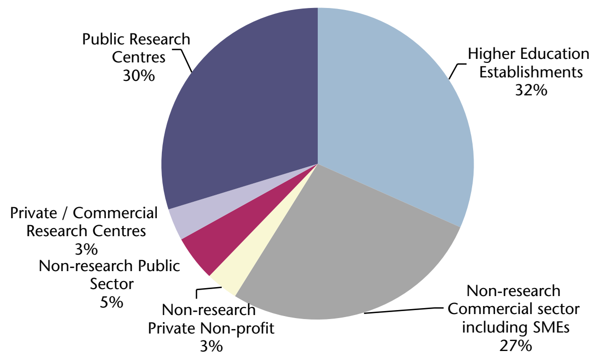


Source: DG Research Key Figures 2002
Data: European Commission
Notes: Coverage: all contracts signed before 1/12/2001. Percentages calculated without taking into account participants that could not be definitively attributed to one of these categories.

As already mentioned one of the aims of the FPs is to encourage different sectors of the economy to undertake joint R&D activities.

Figure 1.2.3 shows the level of participation in FP5 by type of organisation. Figure 1.2.4 shows the breakdown of Community funding by type of participating organisation.

Figure 1.2.4. Allocation of FP5 funding by type of organisation (%)



Source: DG Research Key Figures 2002
Data: European Commission
Notes: As for figure 1.2.3

Table 1.2.2 illustrates the patterns of co-operation between the different Member States measured by counting the number of co-operation links created within individual FP5 projects. These are expressed in terms of percentage relative to the total number of links involving partners from the country. In order to give an idea of the volume of links created under FP5, the last row of the table gives the total number of links for each Member State.

Table 1.2.2. Co-operative links created by FP5 projects: percentages between Member States and totals for Member States

	B	DK	D	E	EL	F	FIN	I	IRL	L	NL	A	P	S	UK
Belgium	3.8	4.1	4.5	4.2	4.1	5.3	3.8	4.1	4.4	6.2	5.2	3.8	3.6	3.9	4.5
Denmark	2.8	4.1	2.6	2.6	2.3	2.4	3.8	2.4	4.5	2.4	3.6	2.8	2.5	3.7	3.3
Germany	15.5	13.1	10.8	14.7	13.5	17.5	15.1	15.6	12.2	11.7	16.3	19.4	13.9	16.1	16.6
Greece	3.8	3.1	3.7	4.4	6.9	3.6	4.1	4.9	4.0	6.2	3.3	3.6	5.2	2.8	3.9
Spain	7.0	6.5	7.2	7.6	7.9	8.0	6.8	9.3	7.3	3.8	6.2	5.9	8.4	6.6	7.1
France	15.0	10.2	14.5	13.6	11.0	10.8	9.5	13.0	10.0	12.8	12.4	10.1	11.3	11.8	13.5
Ireland	1.6	2.4	1.3	1.6	1.6	1.3	1.4	1.4	2.4	1.7	1.7	1.3	1.8	1.5	2.1
Italy	9.8	8.6	10.9	13.2	12.7	10.9	9.6	10.5	9.2	10.5	9.1	8.9	10.7	9.5	10.7
Luxembourg	0.2	0.1	0.1	0.1	0.3	0.2	0.1	0.2	0.2	0.9	0.1	0.2	0.2	0.1	0.1
Netherlands	7.5	7.7	6.9	5.3	5.1	6.3	5.9	5.5	6.6	5.5	5.5	6.2	6.3	6.2	7.0
Austria	2.1	2.2	3.1	1.9	2.1	1.9	2.3	2.0	2.0	2.6	2.4	6.5	2.3	2.1	1.9
Portugal	1.8	1.8	2.0	2.5	2.8	2.0	2.1	2.2	2.5	3.1	2.2	2.1	3.5	1.7	2.2
Finland	2.7	3.9	3.1	2.8	3.1	2.3	4.5	2.8	2.7	2.6	2.9	2.9	2.9	4.9	2.9
Sweden	4.0	5.6	4.8	4.1	3.1	4.3	7.2	4.1	4.2	3.3	4.4	3.9	3.6	4.7	4.9
United Kingdom	15.1	16.4	16.2	14.2	14.0	15.9	13.7	15.0	18.7	12.1	16.4	11.4	14.8	15.9	10.7
Others	7.3	10.2	8.1	7.2	9.6	7.4	10.0	6.9	9.3	14.7	8.4	10.9	8.8	8.5	8.5
Total %	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total links	14 968	10 193	51 162	25 113	13 892	42 602	10 477	35 798	5 508	580	21 540	8 182	7 480	15 401	50 073

Source: DG Research Key Figures 2002
Data: European Commission
Note: Coverage: all contracts signed before 1/12/2001.

1.3 Private investment in R&D

Business sector R&D activities stand at the very core of the interactive model of innovation, where the process of innovation can be considered as new combinations of existing and/or new knowledge. The level and dynamics of business sector R&D activities reflect firms' production and utilisation of knowledge as well as absorption of knowledge from other sectors. Ultimately, the resulting innovations create competitiveness, employment and the economic change that happens in a knowledge-based economy. Consequently, Europe's efforts to move towards a competitive knowledge-based economy are strongly reflected in the level and dynamics of its business sector R&D activities.

Business sector research activities are conducted by a diversity of firms whether classified by size, sector, turnover, technological specialisation, or whatever. Traditionally, a firm's size is expected to influence its level of knowledge investment and its involvement in R&D activities.

Among others, venture capital providers are involved in financing the seed, start-up and expansion phases of new firms, thus contributing to the creation of new R&D performers that are conducting additional profit oriented R&D. Start-ups in high-tech and knowledge-intensive sectors commercialise knowledge assets.

National performances

In particular, the efforts of business sector R&D activities in relation to a country's or a region's overall R&D activities inform us about the relative importance of profit-oriented knowledge creation and absorption in the total R&D activities of an economy and society.

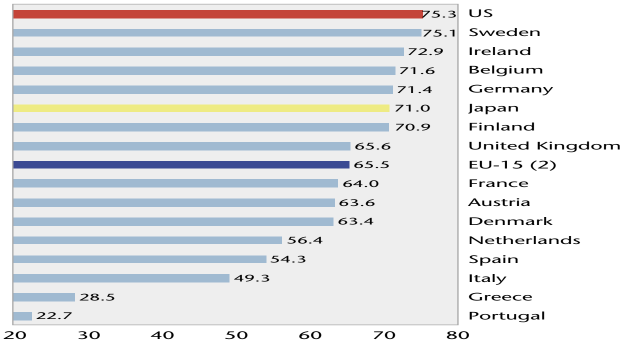
Business expenditure on R&D

Figure 1.3.1 shows that in 2000, business expenditure on R&D (BERD) made up the bulk of total domestic R&D expenditure (GERD) in the EU with 65.5%, in the US with 75.3% (a growing trend since 1990), and in Japan with 71% (which saw a contraction over the period). However, in Member States such as Portugal and Greece, the shares are only 22.7% and 28.5%, reflecting relatively weak business sector knowledge investment in comparison to those in the public and higher education sectors.

Level of business sector expenditure on R&D

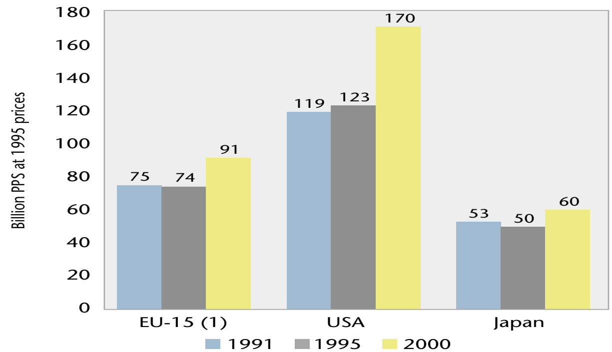
The absolute level of business expenditure on R&D informs us about the efforts of the business sector to create new scientific and technological knowledge as well as to absorb knowledge from other sectors. The information brought together in Figure 1.3.2 shows a huge difference in business sector knowledge creation and absorption between the EU and the US. In 2000, the EU, with 91bn PPS, was still spending far less on business sector R&D than the US, with PPS 170bn, but more than Japan with PPS 60bn. In addition to this, the evolution of BERD between 1991 and 2000 shows that the EU is not catching up with the US, which not only started at a higher level but also increased its business sector R&D expenditure much faster than the EU.

Figure 1.3.1. Business Expenditure on R&D (BERD) as % of GERD, 2000 or latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) A: 1998; B,DK,EL,IRL,I,NL,P,S: 1999; D,E,: 2001.
(2) EU average does not include L.

Figure 1.3.2. Evolution of Business Expenditure on R&D (BERD) for EU, US and Japan



Source: DG Research Key Figures 2002
Data: Eurostat, OECD
Notes: (1) EU average does not include L.

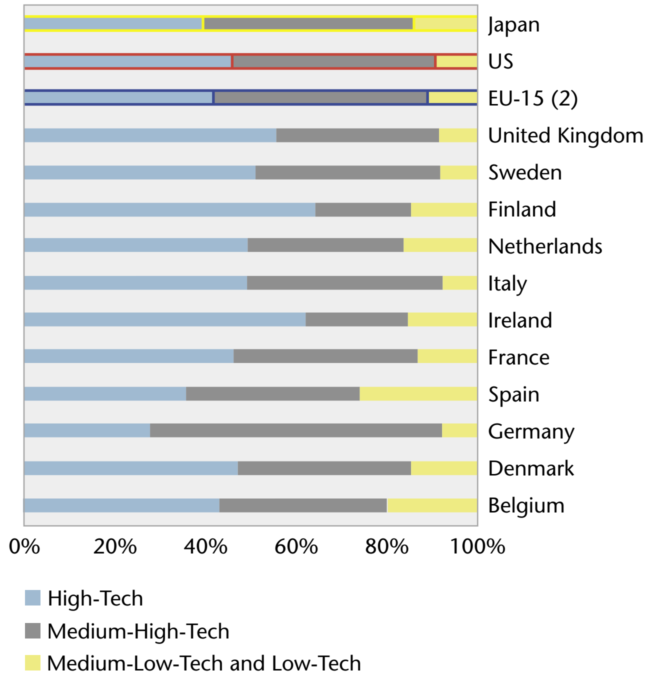
Business sector R&D in high, medium and low-tech industries

The development of the knowledge-based economy is expected to result in a larger share of high-tech industries in the business sector. Scientific and technological knowledge production and absorption will be especially significant in the high-tech industry, but will also become increasingly important for medium-tech and even low-tech industries. The distribution of business R&D expenditure among different types of industry shows whether scientific and technological knowledge is being produced and used in the high-tech, medium to high-tech or medium to low-tech and low-tech industries.

Figure 1.3.3 shows that the share of high-tech industries in business sector knowledge investment is noticeably higher in the US with 45.8% than in EU-15 (not including EL, L, A, P) with 41.5%, while Japan ranks even lower at 39.3%. However, the EU share of medium to high-tech industries (47.5%) exceeds that of the US (44.7%). The share of medium to low-tech and low-tech industries is slightly higher in Europe (11.0%) than in the US (9.4%) while its share in Japan is considerably higher (14.1%).

The high-tech industry's share of manufacturing BERD of some Member States such as Ireland (62.1%) and Finland (64.0%) substantially exceeds that of the US. While in Germany the shares of high-tech and the low to medium-tech industry are relatively low, the medium to high-tech sector's share of BERD investment (64.3%) is very significant, and far above the EU average (47.5%) as well as that of the US (44.7%). The share of medium to low-tech and low-tech industry is the highest in Spain, followed by Ireland.

Figure 1.3.3. Share of manufacturing BERD by industry type, latest available year (1)



Source: DG Research Key Figures 2002
Data: OECD
Notes: (1) I: 2001; DK,F,IRL,NL,S,EU-11: 1999; All other countries: 2000.
(2) EU average does not include EL, L, A, P.

Benchmarking Indicator

Industry financed R&D as percentage of industrial output

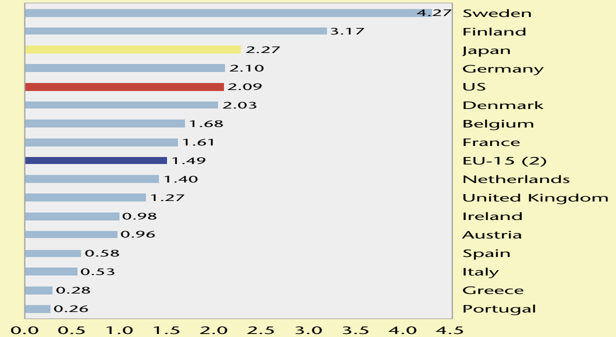
The objective of business-financed research activities is to increase firms' future profitability and competitiveness. The relative efforts of business sector financing of R&D activities and its dynamics are important indicators for the profit-oriented creation of new scientific and technological knowledge and for efforts in absorbing existing knowledge from other sources – from the government sector, higher education and from abroad.

As shown in Figure 1.3.4, the US business sector allocates considerably more to R&D than the business sector of the EU – 2.09% of industrial output compared to the European rate of 1.49%.

However, Sweden and Finland are way ahead followed by Japan and Germany. In all four countries the effort is higher than in the US. Some other Member states – Denmark, Belgium and France rank above the EU average while all others stay below.

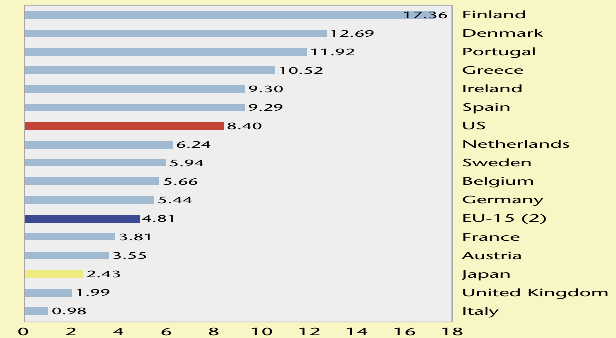
The growth of business sector financed R&D indicates the efforts being invested in future competitiveness. As can be seen in Figure 1.3.5, in the late 1990s business R&D investments in the US grew faster (8.40%) than those in the EU (4.81%). Finland is a special case, as both the level and the growth of industry financed R&D are very strong. Usually, countries starting at a low level of effort, such as Ireland, Portugal, Greece and Spain, experience stronger growth. However, the Netherlands, Sweden, Belgium and Germany also show stronger growth than the EU average.

Figure 1.3.4. Business financed R&D as % of industrial output (1), latest available year



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) D,FIN: 2000; All other countries and EU: 1999.
(2) EU average does not include L.

Figure 1.3.5. Industry financed R&D - average annual real growth 1995 to latest available year (1) (%)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) JP: 1996-2000; A,D,E,P,FIN,US: 1995-2000;
All other countries and EU: 1995-1999.
(2) EU average does not include L.

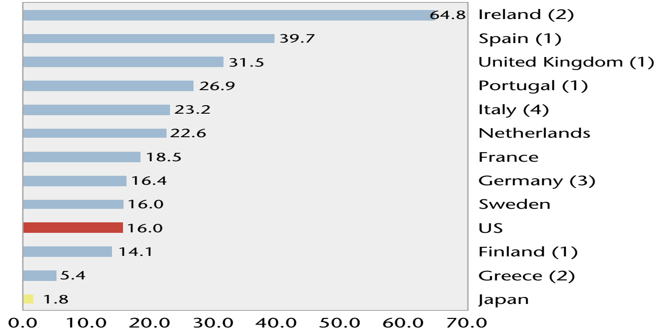
Internationalisation of R&D activities

The internationalisation of business sector R&D activities is reflected in the increased role of foreign investment in knowledge creation, and also offers the potential for international knowledge spill-overs. A first indicator of the extent of any foreign contribution to domestic investment in knowledge is the share of foreign R&D expenditure in a country.

It is obvious that the internationalisation of industrial R&D activities varies considerably across countries (cf. Figure 1.3.6). In particular, its importance is high in Ireland – 64.8% in 1997– reflecting the country's overall development strategy based on the attraction of foreign direct investment (FDI). Ireland has followed the example of the UK, which has traditionally attracted significant amounts of FDI. The low share of foreign R&D activities in Japanese manufacturing R&D implies that the country's innovation system is less open to outside involvement, and as such is less exposed to international knowledge spill-overs via FDI. It should be noted that restricted availability of data limits the analysis of the degree of internationalisation in R&D.

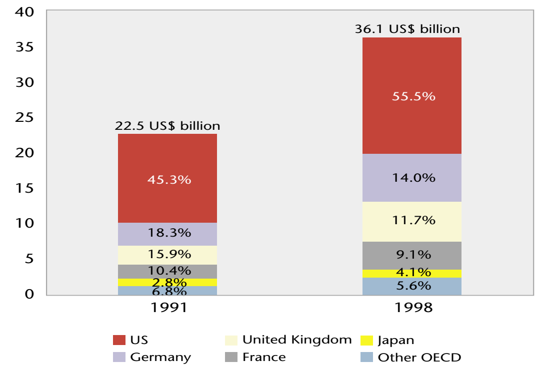
Figure 1.3.7 shows the spending by foreign affiliates in the manufacturing industry of various OECD countries. Between 1991 and 1998, R&D expenditure of these affiliates rose from $22.5bn to $36.1bn. The US continues to attract the largest share of foreign R&D investment (55.5% of the OECD total, compared to 45.3% in 1991).

Figure 1.3.6. Share of foreign affiliates in manufacturing BERD, 1998 or latest available year (1)



Source: DG Research
Data: OECD, Activities of Foreign Affiliates Database
Notes: (1) 1999 (2) 1997 (3) 1995 (4) 1992.
Key Figures 2002

Figure 1.3.7. Relative importance of R&D expenditure under foreign control in the manufacturing industry of selected OECD countries



Source: DG Research
Data: OECD
Key Figures 2002

Benchmarking indicator

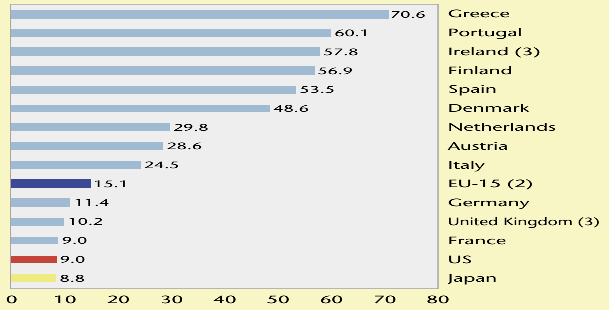
SME share of publicly funded R&D executed by the business sector

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 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 can be hampered by lack of resources and by the relatively high information and administrative costs of participating in research programmes.

Figure 1.3.8 reveals that the share of SMEs in publicly funded R&D executed by the business sector is considerably higher in the EU (15.1%) than in the US (9%) and Japan (8.8%) which are the countries with the lowest shares. In the EU, small countries tend to show a high share, with Greece leading with 70.6%. The lowest shares within the EU Member States are to be found in the larger countries – Germany, the UK and France. The latter manages only 9.0%.

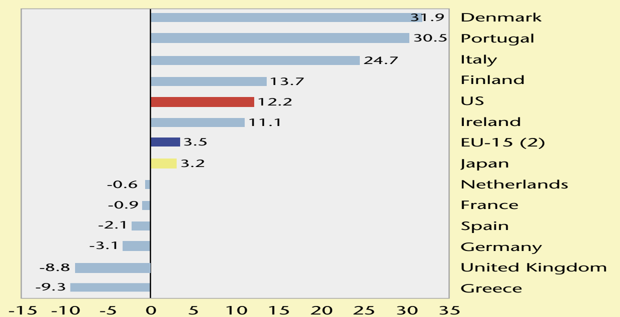
Figure 1.3.9 shows that publicly funded R&D executed in the SME sector is growing considerably faster in the US (12.2%) than in the EU (3.5%) and Japan (3.2%). By contrast, the small countries – Denmark, Portugal, Finland and Ireland – and also Italy show stronger growth than the EU average. All other Member states have negative growth rates.

Figure 1.3.8. Share of SMEs in publicly funded R&D executed by the business sector (%), latest available year (1)



Source: DG Research   Key Figures 2002
Data: Eurostat, Member States
Notes: (1) JP,I,E,FIN,P: 2000; A: 1998; IRL: 1997; All other countries and EU: 1999.
(2) EU average does not include B,L,S.
(3) Only independent SMEs.

Figure 1.3.9. Publicly funded R&D executed in the SME sector - average annual real growth (%), 1995 to the latest available year (1)



Source: DG Research   Key Figures 2002
Data: Eurostat, Member States
Notes: (1) JP,I,FIN,P: 1995-2000; E: 1999-2000; IRL: 1995-1997; D,DK,EU,US: 1997-1999; All other countries: 1995-1999.
(2) EU average does not include B, E, IRL, L, A, S.

1.4 Venture Capital Investment

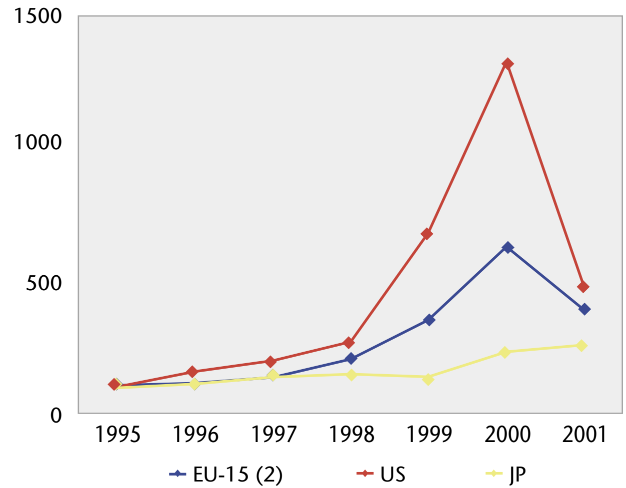
Venture capital financing of seed, start-up and expansion phases of a firm's life cycle creates and expands new business activities. The venture capital industry provides equity capital for high risk, promising new companies, particularly to high-tech and knowledge intensive start-ups. Yet venture capital companies provide not only equity capital, but also managerial skills that are critical for the success of firms in the early stages.

In comparison with the US, European venture capital financing of seed, start-up and expansion phases of new business activities has been lagging behind dramatically in the late 1990s and the early 2000s, as shown in Figure 1.4.1. This reflects a far weaker thrust of venture capital financing in the creation and expansion of new business activities. Both in the EU and in the US, VC investment has accelerated since 1998 but in the US the growth rate was dramatic between 1998 and 2000.

However, Table 1.4.1 shows that the present crisis of the new economy has broken the trend abruptly with VC investment declining by 62% in the US and by 37.9% in the EU.

In the US the VC industry traditionally plays a more prominent role than in the EU where other sources and forms of financing might be relatively more important. In 2001, the crisis of the new economy is clearly recognised in the abrupt decline of venture capital financing in seed, start-up and expansion phases of new businesses. It is obvious that the US VC industry has reacted much more strongly to the crisis.

Figure 1.4.1. Venture Capital in EU, US and Japan, 1995=100 (1)



Source: DG Research — Key Figures 2002
Data: EVCA 1996-2002, NVCA 2001, NISTEP
Notes: (1) Venture Capital includes investment in seed, start-up and expansion stages.
(2) EU average does not include L.

Table 1.4.1 : Venture Capital Investment

Countries	Venture Capital Investment mio euro 2000				Relative change % 2000-2001			
	Seed	Start-up	Expansion	Total	Seed	Start-up	Expansion	Total
Belgium	80	185	261	526	-65.7	-61.3	-23.0	-42.9
Denmark	1	33	126	160	4 554.3	181.6	16.7	86.6
Germany (1)	392	1 261	2 143	3 795	-56.1	-22.1	-27.4	-28.6
Greece	–	9	110	120	–	232.7	-45.7	-23.5
Spain	3	197	569	769	61.4	-46.1	34.2	13.7
France	70	1 085	1 884	3 039	-57.2	-51.0	-61.8	-57.8
Irland	1	110	100	212	-26.4	-66.8	-13.9	-41.5
Italy	132	408	966	1 506	-83.7	-33.8	-22.9	-31.2
Netherlands	0	372	1045	1 418	174.6	-50.9	-28.7	-34.5
Austria	12	49	88	149	-34.4	-30.2	-2.9	-14.3
Portugal	–	31	104	135	–	-48.0	-45.1	-45.8
Finland	23	113	113	248	10.2	2.4	-35.8	-14.2
Sweden	28	199	334	562	-17.0	7.8	98.8	60.7
United Kingdom	64	1 548	4 487	6 099	94.3	-48.1	-61.3	-56.3
EU-15 (2)	807	5 598	12 330	18 735	-38.0	-37.7	-38.1	-37.9
US (3)	3 357[a]	28 019[b]	66 037	97 412	-72.5	-63.1	-61.1	-62.0
Japan (4)	:	5 096	1 224	6 321	:	0.7	-4.0	-0.2

Source: DG Research   Key Figures 2002
Data: EVCA 1996-2002, NVCA 2002, NISTEP
Notes: 1) D: expansion includes € 102.6m Bridge and € 75.6m Turnaround
2) EU does not include L 3) US: a) seed corresponds to start-up/seed b) start-up corresponds to early stage 4) JP: seed is included in start-up. The definition of venture capital differs between the EU-15, USA and Japan.

Benchmarking Indicator

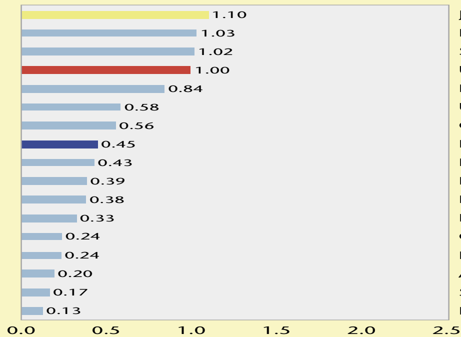
Volume of venture capital investment in early stages (seed and start-up)

Venture capital financing of the seed and start-up phases of new firms which, even if quantitatively only a small fraction of GDP, creates new business activities, and plays therefore a critical role in economic progression. In particular, financing of new businesses in the high-tech and knowledge intensive sectors creates additional business sector R&D and new R&D performers and also commercialises scientific research results from the public and private sector.

The share of venture capital in seed and start-up phases per thousand GDP is, as can be seen from Figure 1.4.2, quantitatively very low. However, it has immense qualitative importance in the creation of new innovative business activities. VC financing plays a more prominent role in the US (1.0 per thousand GDP) while the EU lags far behind with 0.45 per thousand GDP. This reflects of course also the use of alternative instruments of financing. At around 1.0 per thousand GDP, Finland and Sweden rely more strongly on VC financing, while in Portugal, Spain and Austria its role is much more limited (between 0.1 and 0.2 per thousand GDP).

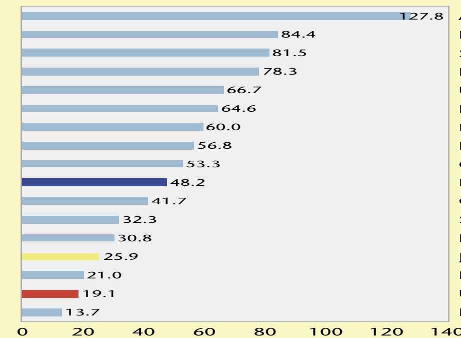
As Figure 1.4.3 shows, the growth of venture capital investment in seed and start-up phases in the late 1990s was also stronger in the US (19.1%) than in the EU (48.2%). This low US value, however, results from the very strong reaction to the present crisis in new economy. Among the Member States, Austria shows a particularly strong rate of growth (127.8%) followed by Denmark, Sweden and Ireland with growth rates of over 70%. By contrast, in the Netherlands and Portugal VC financing is growing relatively slowly (respectively 13.7% and 21%).

Figure 1.4.2. Venture capital investment in early stages (seed and start-up) per thousand GDP, latest available year (1)



Source: DG Research
Data: EVCA, NVCA, Nistep
Notes: (1) All countries: 2001.
(2) EU average does not include L.
Key Figures 2002

Figure 1.4.3. Seed and start-up venture capital investment - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research
Data: EVCA, NVCA, Nistep
Notes: (1) All countries: 1995-2001.
(2) EU average does not include L.
Key Figures 2002

Perspectives

In order to meet the objective set at the Lisbon Summit in March 2000 to make the EU the most competitive and dynamic knowledge-based economy in the world by 2010, the EU has a major challenge ahead. While both the private and the public sectors need to invest more in R&D, these investments should be made in an effective way, with special focus on mechanisms to stimulate efficiency throughout the whole R&D system. During the past few years, growth in R&D financing has been insufficient, but more progress has been made in the way the funds are allocated. For instance, public funds are increasingly awarded on a competitive basis, often through intermediary public funding organisations and via public-private co-financing programmes.

Aiming at achieving the 3% objective by the year 2010, much attention is being paid to enhancing private sector efforts in research. In particular, as Europe lags significantly behind the US in venture capital financing, additional efforts have been made to support venture capital financing in seed, start-up and expansion phases of new business activities; these are expected to generate new business sector R&D activities and R&D performers. Also, public sector R&D should be strengthened with new resources for research along with increases in public funding for private sector R&D.

Because of the potential systemic failures of national innovation systems (mismatches, inefficiencies, lack of collaboration), an increase in funding is not enough on its own. Other factors affecting the volume of R&D and the level of R&D intensity should be taken into account as well. These include, for example: the regulatory environment for R&D; the stock of human resources in research; and the capacity of the innovation system to absorb any increases in funding; and the capability of R&D financiers and performers to co-operate and use funding in a productive way.

The role of governments is increasingly seen to be to act as a facilitator, creating a favourable regulatory framework and environment for the various players in the innovation system to conduct research and to collaborate with each other. The key issue is stimulating public–private partnerships in both financing and in research and development. In this regard, Community funding through Framework Programmes has opened up new avenues for more intensive collaboration and participation in multi-annual pre-competitive R&D bringing together partners from various countries and from different sectors of the economy. This trend is enhanced by the implementation of the Sixth Framework Programme with the introduction of new instruments, and by the favourable development of Community funding for co-operative R&D activities.

Part 2: Human Resources in S&T

Human resources are an important element of the knowledge-based economy. The role of human resources in economic processes is being re-defined – from the creator of knowledge in S&T processes to the applicant of knowledge within broader the economy. Human resources in S&T are measured by the numbers of people in S&T related occupations, and the level of formal educational qualifications in the labour force.

This section analyses key indicators on human resources in S&T, including numbers of researchers, graduates in S&T (especially new PhDs), investment in tertiary education, international mobility of students and researchers and women in S&T.

Key findings

- In the EU Member States, the proportion of researchers in the labour force is low compared to the US and Japan; only Finland and Sweden are at the same high level.
- The EU produces more S&T graduates than the US or Japan, both in absolute terms and in relation to population size.
- EU Member States invest less of their national resources in tertiary education than the US, but more than Japan.
- The main foreign destinations of EU students are the US and Canada. The main regions of origin of foreign researchers in the EU are other European countries, Asia and Oceania.
- In the EU, women are less well represented than men in S&T and the situation is even worse among researchers.

2.1 Researchers

Traditionally, researchers[4] are responsible for knowledge production and exploitation in the R&D process. In the knowledge-based economy, other knowledge workers in management, production and services are of growing importance. But still, researchers are the most relevant group for measuring human resources in S&T.

National performances

In 1999, 920 000 researchers were employed in the EU, (cf. Table 2.1.1). This is nearly 300 000 less than in the US, but about 260 000 more than in Japan. Germany, the UK and France have the most researchers, accounting for two thirds of the EU total.

Huge differences can be seen regarding the sectors. On average in the EU, the higher education sector employs about one third of researchers, while only one half are employed by the private sector. In Japan and in the US the latter's share is much higher. But Member States vary greatly in this respect, from Ireland, and Austria at 64% to Portugal at 13%.

(4) 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 1993).

Table 2.1.1. Total number of researchers (1) and in % by sector, 1999.

	Total number	Business Enterprise	Governmental	Higher Education
Belgium	30 219	54.5	4.0	40.4
Denmark	18 438	46.5	21.2	31.0
Germany	255 260	58.8	15.0	26.1
Greece	14 828	15.6	13.5	70.6
Spain	61 568	24.7	19.4	55.0
France	160 424	47.0	15.7	35.4
Ireland	8 217	64.4	3.7	32.0
Italy	64 886	40.4	21.1	38.5
Netherlands	40 623	47.7	19.8	31.4
Austria	20 222	64.4	4.8	30.7
Portugal	15 752	12.7	21.9	52.3
Finland	25 398	41.6	16.2	40.9
Sweden	39 921	57.2	6.1	36.6
UK	164 040	56.2	9.1	30.3
EU-15 (2)	919 796	50.0	14.2	34.3
US	1 219 407	83.3	3.8	11.2
Japan	658 910	65.8	4.7	27.1

Source: DG Research — Key Figures 2002
Data: Eurostat, Member States, OECD
Notes: (1) Researchers in full-time equivalents (FTE).
(2) EU average does not include L.

Benchmarking Indicator

Number of researchers per thousand labour force

This indicator reflects the share of scientific work in overall employment. It is therefore an indicator that is frequently used to show the knowledge base of an economy in terms of involvement of human resources in knowledge production in a classical sense.

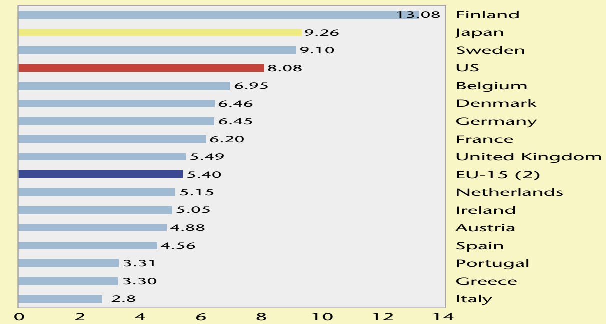
Finland leads with 13 researchers per thousand labour force, followed by Japan and Sweden, as seen in Figure 2.1.1. At roughly 8 per thousand, the US also has a high proportion. Most European Member States have shares of between 4.6 and 7 per thousand in the labour force, while the average is at 5.4.

The southern European countries of Portugal, Greece and Italy are far behind, with low shares of around 3 researchers per thousand in the labour force.

How did this change in the 1990s? Greece, Finland, Ireland and Spain have growth rates greater than 10%, followed by Portugal and Belgium – see Figure 2.1.2. These countries have higher growth rates than the US with 6.2%. It is especially interesting that Finland, already the best performer, is still increasing considerably.

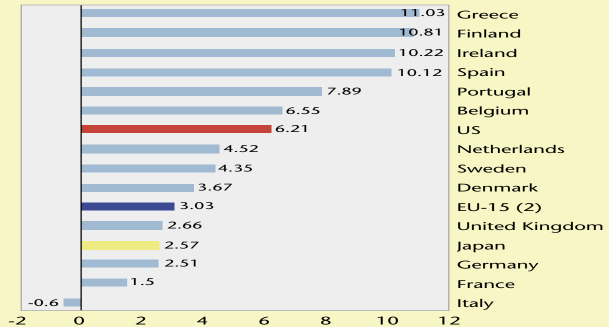
The EU average growth rate is about 3% and is thus higher than that of the four largest EU Member States and Japan. It should be noted that Italy suffered an annual decrease of 0.6%.

Figure 2.1.1. Researchers per thousand labour force: latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States, OECD
Notes: (1) FIN,JP,E,P: 2000; UK,A: 1998; US: 1997. All other countries: 1999.
(2) EU average does not include L.
Researchers are full-time equivalents (FTE); labour force are headcounts (HC).

Figure 2.1.2. Researchers per thousand labour force: average annual growth 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) cf. Figure 2.1.1.
(2) EU average does not include L and A.

2.2 S&T graduates and PhD recipients

The numbers of graduates[5] in S&T fields of study[6] reflect two features of the role of human resources within the knowledge-based economy: first the output of the higher education system, and second the supply of human resources with higher qualifications.

National performances

Regarding the numbers of S&T graduates, the EU is far ahead of the US and Japan, as shown in Table 2.2.1. In the EU-15 Member States in 1998, a total of two million students earned their tertiary degrees across all disciplines, including 523 000 in science and engineering (S&E). The highest numbers of graduates in S&E, and indeed in all disciplines, are "produced" in France, the UK and Germany; these countries account for about two thirds of all EU graduates and of S&T graduates.

The profiles of the EU Member States vary. S&E is relatively strong in Ireland, France and Germany. Within S&E, science is strong in Ireland and the UK; engineering dominates in all other Member States. Compared to the S&E disciplines, health and food sciences are more important in Denmark, Belgium and the Netherlands. Social sciences are above average in Luxembourg, Austria, and Spain. Compared to the EU, the dominance of engineering in Japan is remarkable, as well as the social sciences in the US.

(5) Graduates are defined by the levels of education classified in ISCED 1997. In the following analyses, graduates include all tertiary degrees (ISCED 5a and 5b) and PhDs (ISCED 6).

(6) The Canberra Manual (OECD 1994) defines S&T relevant fields of study as follows: It includes 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).

Table 2.2.1. Graduates by field of study 1998 (1)

	Science	Engineering	Science & Engineering (S&E)	Health & Food	Soc/Hum/ Educ.	All fields of study
Belgium (2)	2 216	5 105	7 321	9 002	20 639	37 169
Denmark	2 266	3 773	6 039	9 445	14 563	31 048
Germany	31 925	59 880	91 805	91 686	128 485	322 487
Spain	22 241	30 530	52 771	34 576	142 796	240 881
France	66 691	82 407	149 098	37 069	288 365	497 188
Ireland	7 579	5 439	13 018	3 982	22 134	40 719
Italy	15 785	27 816	43 601	30 488	104 918	179 431
Luxembourg	24	54	78	32	261	371
Netherlands	4 392	9 211	13 603	17 595	46 544	80 111
Austria	2 348	2 454	4 802	2 786	13 023	20 987
Finland	2 452	7 506	9 958	9 647	15 729	38 959
Sweden	3 027	6 018	9 045	8 058	17 598	34 822
UK	64 850	57 092	121 942	81 766	253 421	465 895
EU-15 (3)	225 796	297 285	523 081	336 132	1 068 476	1 990 068
US	169 311	179 238	348 549	322 758	1 301 199	2 066 595
Japan	25 021	209 808	234 829	128 157	541 431	1 107 332

Source: DG-Research Key Figures 2002
Data: Eurostat, Member States, OECD
Notes: (1) Graduates are composed by ISCED 1997, levels 5 and 6.
(2) Flemish Community only.
(3) EU totals do not include EL and P.

These data give the impression that the production of graduates, especially in the S&E fields of study is sufficient in the EU Member States. However, it should be noted that what is not shown in the table is that the number of S&E graduates in the EU is declining.

One significant sub-section of S&T graduates, recipients of PhDs, is now presented in further detail in the following benchmarking indicator.

Benchmarking Indicator

New PhDs per thousand population aged 25 to 34

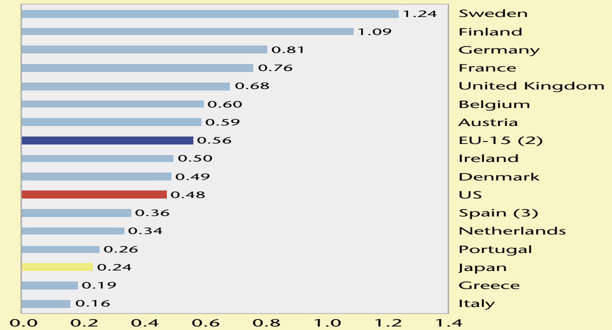
This indicator shows the number of new doctorates for the given year per thousand of the population aged between 25 and 34. The PhD level is chosen so that the analysis focuses on those people who are following the traditional S&T career path. A PhD is often mandatory for further scientific employment in the higher education sector. In addition, for research-related careers in government and the business sector, a PhD is helpful for reaching posts with broad scientific and management responsibilities.[7]

In 2000, as a proportion of the younger population the highest number of new PhDs were "produced" in Sweden (1.2) and Finland (1.1), followed at some distance by Germany, France and the UK (between 0.8 and 0.7) – see Figure 2.2.1. With an average of 0.56, EU countries are slightly ahead of the US (0.48) and far head of Japan (0.24). Greece and Italy produce even lower numbers – less than 0.2.

Figure 2.2.2 shows that the largest increase from 1999 to 2000, was in Portugal with 14%, followed by Finland and Greece. On average in the EU, numbers of PhDs grew by 1.5% between 1999 and 2000, which is higher than in Japan (0.7%) and the US (0.1%). Ireland and especially the Netherlands experienced a decrease of 2.8 and 4.8% respectively.

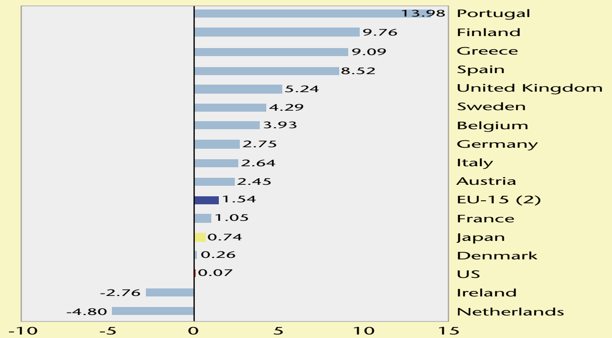
(7) The Frascati manual (OECD 1993) relates the researchers to the university degree levels of education, the technicians on lower, mostly secondary education levels. But the borders are ill defined.

Figure 2.2.1. New S&T PhDs per thousand population (aged 25-34), latest available year (1)



Source: DG Research — Key Figures 2002
Data: Eurostat, Member States, OECD
Notes: (1) I, EL: 1999; All other countries 2000.
(2) EU average does not include L.
(3) E is provisional.

Figure 2.2.2. New PhDs per thousand population (aged 25-34): growth in % 1999-2000 (1)

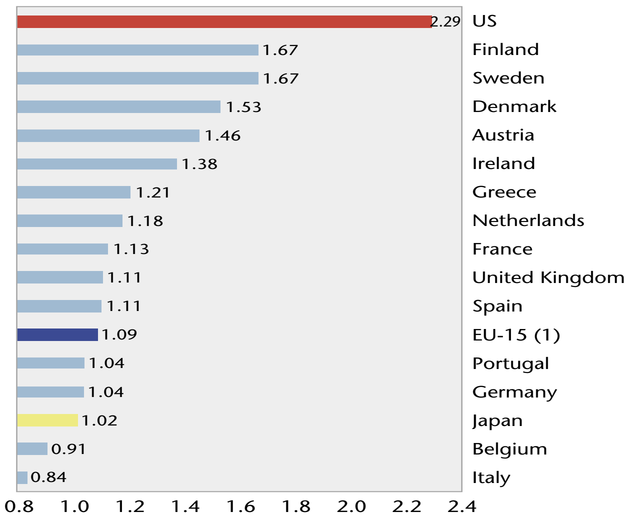


Source: DG Research — Key Figures 2002
Data: Eurostat, Member States, OECD
Notes: (1) I,EL: 1998-1999.
(2) EU average does not include L.

2.3 Investment in tertiary education

In Figure 2.3.1, huge differences between the EU and the US can be observed. EU Member States are spending between 1.7% (Finland and Sweden) and 0.8% (Italy) of their GDP on tertiary education while the US is spending more than 2% of its GDP. The EU average is far behind at about 1.1%, which in turn is marginally higher than the expenditure in Japan (1%).

Figure 2.3.1. Private and public expenditure on tertiary education: % of GDP 1998



Source: DG Research Key Figures 2002
Data: OECD
Notes: (1) EU average does not include L.

These results are a combination of the EU's relatively low expenditure on total education (both as percentage of GDP and per capita), the low share of tertiary education in the overall education expenditure, and the small share of private expenditure on tertiary education in the EU average – see Table 2.3.1. This lower private involvement is one of the main differences between Europe, Japan and the US. However, the share of private expenditure on tertiary education has been increasing significantly during the 1990s.

Table 2.3.1. Investment in education: data for 1998.

	Total expenditure on educational institutions, 1998 (% of GDP)	Total expenditure on educational institutions, 1998 (€ per capita)	Share of expenditure at tertiary level, 1998 (in % of total educational expenditure)	Share of private expenditure, tertiary education, 1998 (% of total education expenditure)	Index of change between 1995 and 1998 of educational expenditure at tertiary level (PPS 1995, 1995=100)	Share of private expenditure, primary + secondary education, 1998 (% of total education expenditure)
Belgium	5.0	1 105	18.3	:	:	:
Denmark	7.2	2 016	21.4	2.8	473	2.1
Germany	5.6	1 325	18.8	7.9	107	24.1
Greece	4.8	446	25.4	:	:	:
Spain	5.3	669	20.9	27.9	130	10.8
France	6.2	1 352	18.1	14.5	97	7.3
Ireland	4.7	838	29.2	27.4	121	3.1
Italy	5.0	766	16.8	25.3	170	1
Netherlands	4.6	1 040	25.6	12.5	113	5.7
Austria	6.4	1 519	22.9	1.1	46	5.2
Portugal	5.7	528	18.5	7.7	273	0.1
Finland	5.7	1 278	29.1	:	:	:
Sweden	6.8	1 501	24.6	10.7	:	0.2
UK	4.9	788	22.6	37.3	105	:
EU-15 (1)	5.5	1 038	20.0	13.8	164	6
US	6.4	1 493	35.6	53.2	:	9.2
Japan	4.7	1 573	21.7	58.3	:	8.3

Source: DG-Research Key Figures 2002
Data: Eurostat, Member States, OECD
Notes: (1) EU average does not include L.

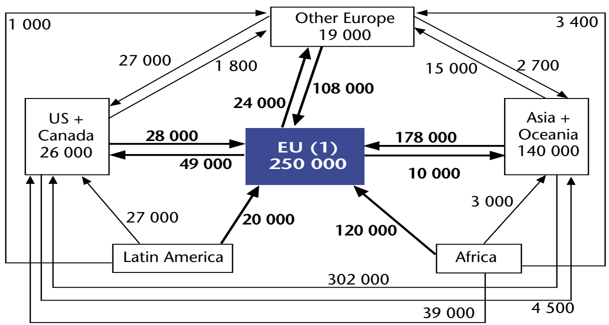
2.4 International Mobility

Indicators on international mobility show the level of movement of human resources between countries and therefore the extent to which the research system is open and attractive for people from abroad. They also indicate the ability to attract new knowledge.

Foreign students by world regions

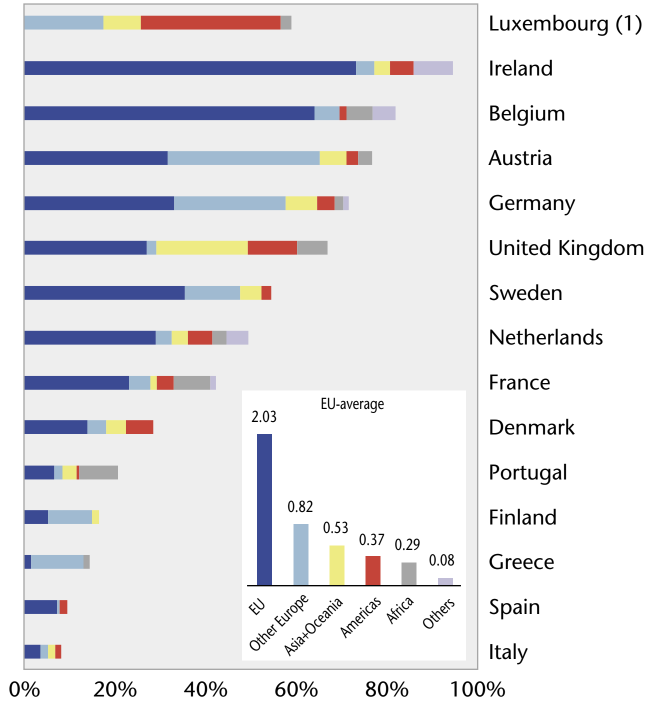
The most complete data on mobility of students between the world regions are provided by the OECD. Figure 2.4.1 gives an overview of the main flows of students between the world regions.

Figure 2.4.1. Migration between the world regions: foreign students enrolled in tertiary education 1999



Source: DG Research — Key Figures 2002
Data: OECD
Notes: (1) EU totals do not include EL and P.
The values inside the boxes show migration within the region. The EU figures do not include EL and P. The host regions only include OECD countries. The regions of origin are complete.

Figure 2.4.2. Foreign S&T employees as % of labour force by region of origin 2000



Source: DG Research — Key Figures 2002
Data: Eurostat NewCronos CLFS
Notes: (1) The high shares of non-native residents from the EU in L (29%) are not included in the figure.

Foreign S&T employees in the EU by regions of origin

The Community Labour Force Survey (CLFS) provides data on the labour force broken down by the international standard classification on occupations (ISCO) and nationality. In Figure 2.4.2, the world regions of origin of people working in the EU as professionals (ISCO-2) are analysed.

Most foreign S&T employees in the EU are from other EU Member States – around 2% of the workforce. The rest of Europe, Asia and Oceania and the Americas follow, supplying decreasing numbers. The largest shares of foreign S&T employees are in Luxembourg and Ireland, followed by Belgium, Austria, Germany and the UK. It is worth noting the relatively large shares of other Europeans in Austria and Germany, Asians in the UK and Africans in Portugal, France and Belgium.

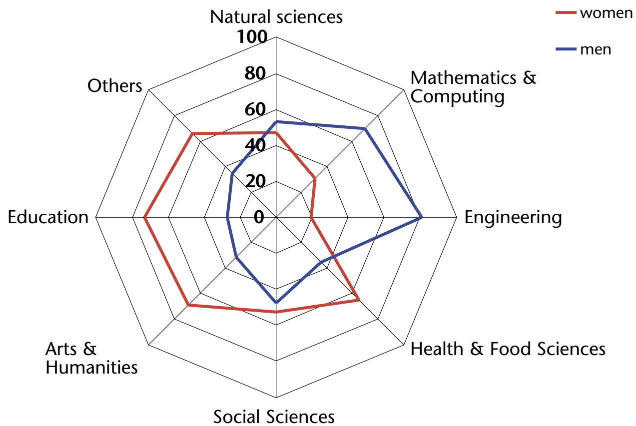
2.5 Women in S&T

The participation of women in the production of knowledge is an important indicator of the extent to which the full potential of human resources is being used in a society. By detecting differences in participation, it is possible to identify starting points for increasing the human resources involved in S&T.

Graduates by gender and discipline

In 1998, as many women as men received a degree. But differences occurred between the disciplines, as Figure 2.5.1 illustrates. While more men are graduating in engineering, mathematics and computing, more women are receiving degrees in educational sciences, arts and humanities. Only the natural and the social sciences are nearly balanced.

Figure 2.5.1. Share of male and female graduates by discipline 1998, EU average (1)



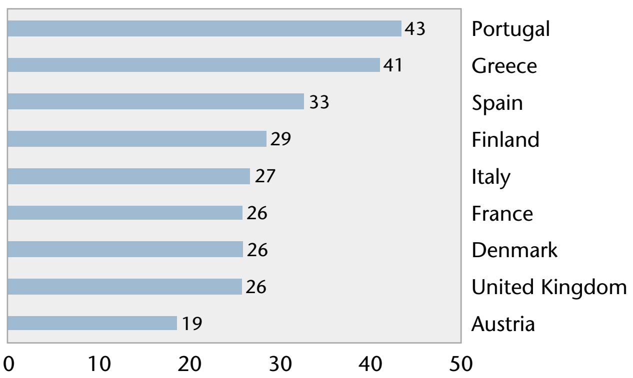
Source: DG Research Key Figures 2002
Data: OECD education database
Notes: (1) EU average does not include EL and P.

Female researchers

The differences in the numbers of men and women employed as researchers are also high. In the EU Member States analysed in Figure 2.5.2, the share of women varies between 43% in Portugal, 41% in Greece and 19% in Austria. In the other countries, between a quarter and one third (Spain) of researchers are women.

These data lead to the conclusion that women represent an enormous potential for human resources in S&T. As S&E are the classic areas of study that are important for the knowledge-based economy, the under-representation of women in these fields is an important place to start in order to unlock more human resources for S&T. Another factor is the attractiveness for women of careers in S&T, which may contribute to achieving the knowledge-based economy faster.

Figure 2.5.2. Female researchers as a share of total in %: latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) UK,FIN,P: 2000; A: 1998. All other countries: 1999.

Perspectives

The indicators discussed in this section represent only a handful of the indicators on human resources in S&T. Nevertheless, they provide interesting information on the performance of the EU and its Member States in connection with the knowledge-based economy. They support major conclusions and aims of the European Research Area such as:

- The relatively low number of researchers in the EU may become a serious restriction for European R&D in the future. Businesses could especially be encouraged to employ researchers. Positive examples within the EU, like Sweden and Finland, should be emulated.
- The high quality of S&T tertiary education in the EU has to be maintained. In this way, a sufficient output of high quality students, especially in science and engineering, can be ensured.
- Investment in tertiary education could be increased. Compared to the US and Japan, the private sector in the EU has huge potential to do so.
- In order to meet short-term demands and to increase the quality and breadth of domestic knowledge production, it makes sense to attract researchers and students from abroad. The provision of favourable conditions within the EU, like improvements to research facilities, are important steps towards attracting the "best brains", which also includes the return of EU nationals from abroad.
- In order to increase the human resources for S&T, more women need to be recruited to S&T related professions. Furthermore, in order to make S&T attractive for women and to exploit their full potential, it has to be ensured that they face equal opportunities to men in a career in S&T. Existing bottlenecks for women should be examined and resolved.

Part 3: Comparing Performance in Science, Technology and Innovation

As Europe is striving to become the most dynamic knowledge-based economy, the production and diffusion of knowledge are key concepts. Scientists, researchers, and engineers are among those highly qualified people involved in creating knowledge. The codification of this knowledge is achieved through publications and patent applications. Publications are the most often used channel to disseminate knowledge and to make it available to third parties for further usage. The information contained in patent applications protects an invention. As this is disclosed after a patent is granted, this codified knowledge serves as restriction.

Performance in publishing and patenting are used as proxy indicators of scientific and technological capacities. However, when it comes to the commercialisation of knowledge, another indicator is more suitable for revealing the knowledge embedded in economic activity: trade in high-tech products.

This section analyses the following key performance indicators:

- Scientific performance indicators (measured by the number of scientific publications and citations),
- Technological performance indicators (such as numbers of patents at the European Patent Office (EPO), the United States patent and Trademark Office (USPTO),
- Innovation performance indicators, which is performance in commercialising technology as measured by the technology balance of payments and market shares in high-tech trade.

Key findings

- In terms of scientific performance, the EU as a whole is doing well. With respect to highly cited publications, some EU countries show outstanding world shares.
- Technological performance expressed in the number of patents is growing, while the share of patents being made by EU countries is decreasing. However, Sweden and Germany still show high numbers in the European as well as US patent offices.
- Innovation performances measured by the technology balance of payments and high-tech trade on the world market gives a rather heterogeneous picture of the EU Member States in terms of numbers of patents and growth rates.
- The aim to be innovative and competitive means that pressure to commercialise scientific and technological knowledge is growing day by day. However, this also brings with it the risk that R&D funding might be focused only on product related research.

3.1 Scientific Performance

Scientific performance in terms of the output of research can be measured at different levels, such as by individual researcher, research unit, institutions such as universities and research institutes, country, or world region. While the performance of a research unit or institute is important for policy-makers at a country level, the comparison made here is between countries.

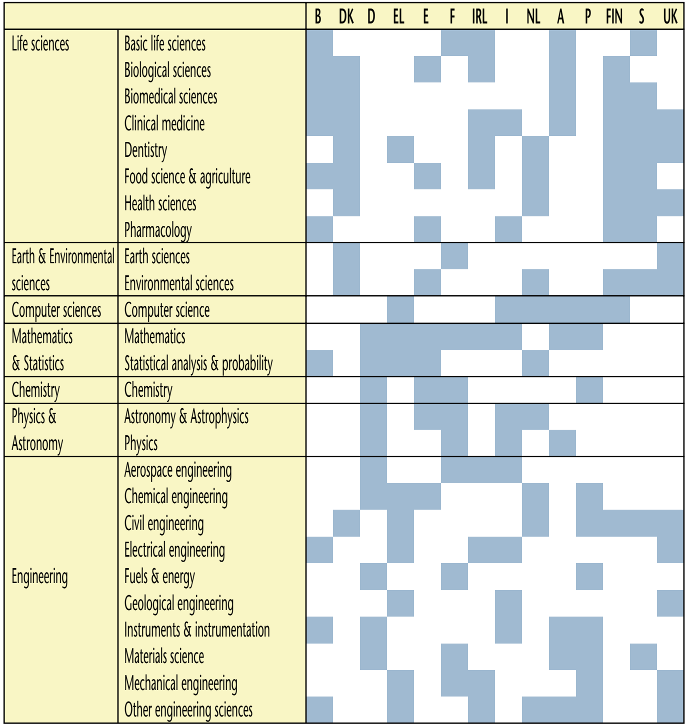
Specialisation profiles matter

Publication numbers tell only one side of the story. In order to be able to analyse performance, data such as the number of researchers in a country or the size of the population are variables that enable comparisons between countries. It can be argued that counting and comparing publication numbers in different countries needs further quantitative and qualitative information than is currently available for a thorough analysis. While several scientific disciplines, such as engineering, biology, mathematics, can be found almost everywhere, many countries display distinctive specialisation patterns, as can be seen from Table 3.1.1. Such specialisation can depend to a certain extent on a country's technological profile.

Such profiles can have an impact on a country's scientific output. In two countries with a comparable population size, the first might be specialised in the life sciences while the second may focus on engineering. Most probably the number of publications from the first will be more than double those of the second simply because in the life sciences publishing is a very core business of scientists, while engineers tend to publish less but might opt for patents.

From Figure 3.1.1 one can see clearly that Sweden, Finland, Denmark, Belgium, and to a certain degree Ireland and the UK are specialised in the life sciences, while Germany, Portugal, and Greece are more specialised in engineering. Other countries like France and the Netherlands display a more balanced profile.

Figure 3.1.1. Relative specialisation profile by field and EU-15 member country



Source: DG Research Key Figures 2002
Data: ISI, CWTS (treatments), DG Research (calculations)
Notes: (1) Publication period: 1996-1999
(2) Blue fields indicate relative specialisation.

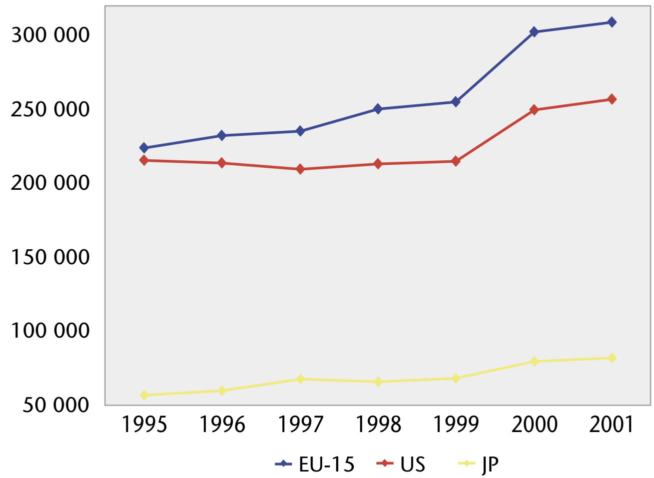
Publication trends – comparing world regions

The number of publications has been growing steadily in recent decades. During the second half of the 1990s, declining growth rates can be calculated for the US, while the EU-15 showed a slightly positive trend and Japan was able to achieve the highest growth rates. At the beginning of the new decade, quite a significant increase is apparent for all three regions. However, annual changes may not only reflect real research activities and capabilities, but also changes in the publications databases, changing publication habits and strategies, and changing propensities of countries to pursue international scientific co-operation. It is impossible to disentangle these often interrelated factors at the macro level in a satisfactory and systemic way.

What can be stated in detail? First, the overall trend of increasing publication numbers was sustained over the whole period (cf. Figure 3.1.2). In terms of absolute numbers, the EU and the US are the prime producers. However, in terms of growth rates, Japan had an average annual growth rate of 9% between 1995 and 1997, whereas the EU achieved 2.5% and the US recorded a decrease of –1.4%. This did not continue in the latter half of the 1990s: the period 1995-99 saw a comparably moderate rate of growth in the number of Japanese publications (4.5%), the EU-15 continued growing steadily (3.9%) while the US ended its negative trend but achieved 0% growth.

Taking the whole period of 1995-2001, Japan achieved the highest growth rate (6.3%), followed by the EU-15 (5.5%), while a moderate increase for the US (3%) can be calculated.

Figure 3.1.2. The number of publications by the EU 15, US, and Japan (1995-2001)



Source: DG Research Key Figures 2002
Data: ISI, CWTS (treatments)

Highly cited publications at the field level

Is it possible to measure the quality of different countries' performances in different disciplines? Strictly speaking, there is no indicator for quality performance using publication data. However, citations are used as a proxy for influence, importance, and thus indirectly also quality. In Table 3.1.1, ratios for the highly cited papers by broad field are shown.

While the US scores high numbers in many fields, many of these can be linked to its size and relative weight in the underlying database. Denmark, Ireland, the Netherlands, the UK, and Belgium are the EU countries with high ratios in some of the fields. Language seems to be an important factor for highly cited papers. It does not come as a surprise that the US and the UK score above 1 in almost all fields. Smaller non-English speaking countries such as Denmark, the Netherlands, Belgium and Sweden which have a high propensity to publish in international journals do very well in a large number of fields.

Table 3.1.1. Countries by highly cited papers by broad field (1)

	B	DK	D	EL	E	F	IRL	I	NL	A	P	FIN	S	UK	US	JP
Basic Life Science	0.99	0.79	0.95	0.41	0.42	0.79	0.95	0.55	1.02	0.81	0.47	0.92	0.78	1.19	1.46	0.57
Biomedical Science & Pharmacology	0.82	0.66	0.81	0.45	0.38	0.74	1.11	0.65	0.81	0.83	0.51	0.78	0.82	1.10	1.30	0.43
Clinical Medecin & Health Science	1.22	1.11	0.82	0.53	0.58	0.88	1.32	0.81	1.18	0.82	0.98	1.23	1.16	1.14	1.40	0.50
Biological Science	0.74	0.98	0.89	0.36	0.42	0.76	1.14	0.40	1.24	0.80	0.49	0.64	1.10	1.34	1.13	0.50
Agriculture & Food Science	0.93	1.15	0.70	0.43	0.48	0.88	1.25	0.60	1.20	0.60	0.74	0.98	1.21	1.15	1.02	0.28
Earth & Environmental Science	0.84	1.00	1.05	0.46	0.32	0.84	0.95	0.45	1.18	0.44	0.49	0.69	0.86	1.12	1.30	0.50
Chemistry	1.09	1.63	1.09	0.75	0.67	0.90	0.93	0.83	1.72	0.93	0.60	0.95	1.44	1.31	1.94	0.73
Engineering	1.16	1.50	0.94	0.40	0.53	0.83	0.81	0.64	1.24	0.71	0.54	0.78	0.96	0.82	1.38	0.60
Computer Science	1.35	1.22	0.97	0.52	0.44	0.81	:	0.69	0.89	1.18	0.43	1.07	0.58	0.84	1.41	0.45
Mathematics & Statistics	0.83	1.40	0.96	0.46	0.51	1.16	0.71	0.83	0.94	0.79	0.85	0.69	0.78	1.18	1.43	0.75
Physics & Astronomy	0.91	1.50	1.25	0.59	0.78	1.04	0.88	0.85	1.38	1.04	0.42	0.87	1.09	1.16	1.79	0.80

Source: DG-Research Key Figures 2002
Data: ISI, CWTS (treatments)
Notes: (1) The index is calculated as the ratio of the number of actual papers divided by the expected papers in the top 5% of most cited papers. Publication years 1996, 1997, 1998; citation years 1996-1999, 1997-2000, 1998-2001. Red signals the highest, blue the lowest scores. Calculation not possible for L and IRL (Computer Sciences) due to too low publication numbers.

Benchmarking Indicator

Number of scientific publications and number of highly cited papers per capita

The indicator 'scientific publications' was chosen as it reflects the research capacity and knowledge pool of a country. The database is very much dominated by internationally authored publications written in English.

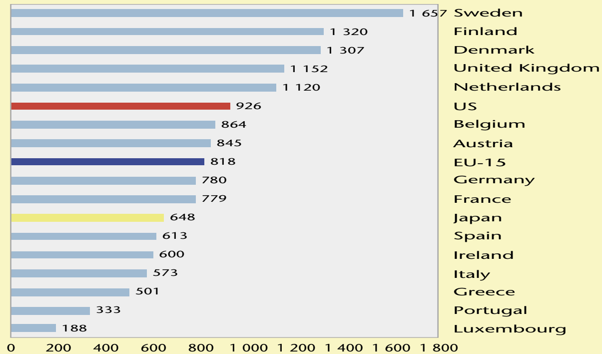
Changes in methodology, slight changes of results

Concerning the 'number of publications', there is a change in retrieving the underlying data from the databases in this Benchmarking update. This change results in the retrieval of more publications and gives higher publication output numbers (for full data see Annex III).

In terms of the number of publications per capita, the US, with 926 per million, scores better than the EU (818) and Japan (648). Five EU countries do better than the US. An explanation for the leading EU countries is that they are research intensive, medium-sized countries with a strong urge to publish internationally. France and Germany, on the other hand, are only in middle ranking positions, as they have large internal markets for publications in French and German.

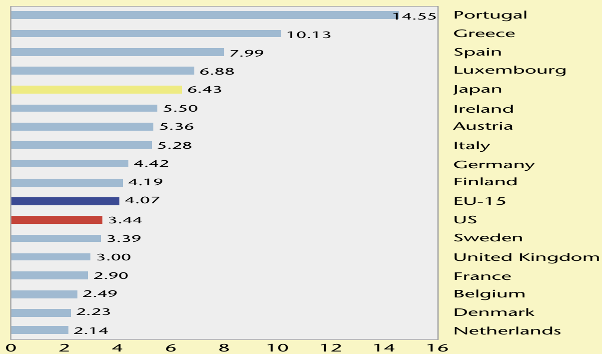
Figure 3.1.4 shows the growth rates since the mid-1990s. This conceals various significant developments, one of the most important being the recent increase in the US growth rate. This signals that after a zero growth period in the mid 1990s, the US was able to increase output at the very end of the 1990s. The highest average growth rate has been maintained by Japan (6.4%), followed by the EU-15 (4.1%) and the US (3.4%).

Figure 3.1.3. Number of scientific publications per millon population, latest available year (1)



Source: DG Research Key Figures 2002
Data: ISI, CWTS (treatments)
Notes: (1) Publications: 2001, Population: 2000.

Figure 3.1.4. Average annual growth (%) of number of scientific publications, 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: ISI, CWTS (treatments)
Notes: (1) 2001

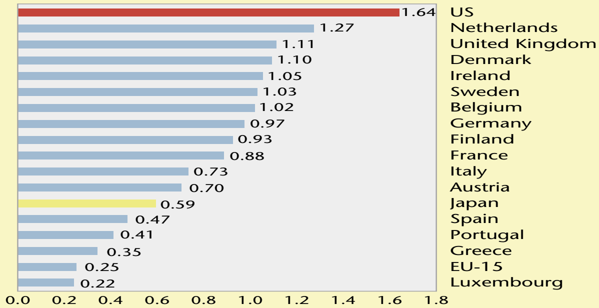
Highly cited papers

High citation rates are used as a proxy of the importance of research. Only a small fraction of the overall scientific output is highly cited. However, the number of papers and the analysis of the particular fields in which these papers occur, give some important information to science policy-makers, and signal important research to scientific communities worldwide.

For Key Figures 2002 the length of the citation window and the retrieving method have been amended (cf. Annex II).

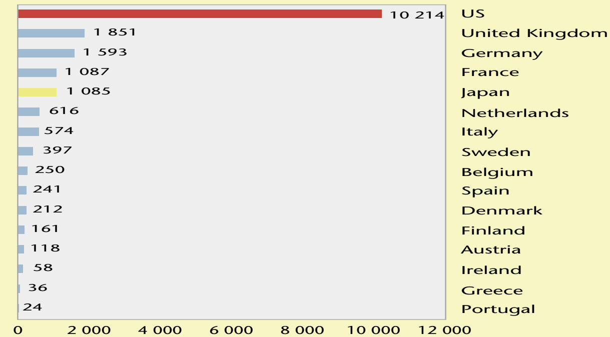
When it comes to highly cited papers, all EU countries lag behind the US. However, there are several countries with shares above the world average. The Netherlands, UK, Denmark, Ireland, Sweden and Belgium do far better than the world average (1.0), while Italy, Austria, Spain, Portugal and Greece achieve only below average shares. The absolute numbers reflect the size of the publishing country. It should be noted that the calculations are based on a full counting method. The number of highly cited papers is not additive but international co-publications are counted fully for two or more countries. It would be interesting to estimate the percentage of European involvement in highly cited US publications and vice versa.

Figure 3.1.5. Highly cited papers as percentage of total number of scientific publications, latest available year (1)



Source: DG Research Key Figures 2002
Data: ISI, CWTS (treatments)
Notes: (1) Publication period is 1996, 1997, 1998. Citation window is a four year fixed period: publication year plus three years, i.e. 1996-99, 1997-2000, 1998-2001.

Figure 3.1.6. Number of highly cited papers, latest available year (1)



Source: DG Research Key Figures 2002
Data: ISI, CWTS (treatments)
Notes: (1) cf. Figure 3.1.5

3.2 Technological Performance

Success in the knowledge-based economy requires a capacity to create technological knowledge that can be commercialised in the form of new and improved products and processes. This also relies on an ability to absorb and exploit knowledge created elsewhere.

Patents represent an important outcome of technologically oriented inventive activity. Since firms invest considerable amounts of time and money to obtain patent protection, the existence of a patent usually signals an expectation that such investments will bring a commercial return to compensate for this investment. Patents may also involve important transfers of knowledge, both in terms of the dissemination of information about the patented invention, and through the use of other scientific and technological knowledge to produce the patented technology.

Two sets of indicators are analysed here as they cover two of the most important international markets where intellectual property rights are of strategic significance: number of European patents and number of US patents.

There tends to be a "home advantage" effect in patenting. For example, US inventors will have a dominance in the US patent system because it is their home market, while European inventors tend to be the dominant players in the European patent system.

National performances

Table 3.2.1 shows that EU countries were responsible for more than 42% of the EPO patents in 1999, while their share at the USPTO was below 17%. The US showed the opposite pattern. The shares of the EU and Japan at both the EPO and USPTO offices have fallen between 1992 and 1999, while the US shares have increased. Amongst the EU countries, Germany leads with 17.6% at the EPO, followed by France (6.3%) and the UK (5.6%). At the USPTO the rankings are the same, but the percentages are lower.

The most dynamic EU countries at the EPO are Portugal, Finland and Ireland, on different absolute levels. The most dynamic EU countries at the USPTO are Denmark, Greece and Belgium. The largest decreases of shares at the EPO were those for Japan and France, and for Luxembourg and Germany at the USPTO.

Table 3.2.1. Patents: Shares 1999 and average annual growth 1992-1999 (%)

	Shares EPO	Growth EPO	Share USPTO	Growth USPTO
Germany	17.6	-1	6.3	-3.3
France	6.3	-3.3	2.7	-2.6
UK	5.6	-1.5	2.6	-1.8
Italy	3	-2.3	1.1	-2.9
Sweden	2.6	6.1	0.9	2
Netherlands	2.5	0.1	0.9	-2.3
Finland	1.2	7.8	0.4	2.7
Belgium	1.1	2.9	0.5	3.9
Austria	0.9	-2.2	0.3	-2.7
Denmark	0.8	5.2	0.3	6.8
Spain	0.6	5.6	0.2	2.9
Ireland	0.2	7.6	0.1	2.5
Greece	0.1	6	0	4.6
Luxembourg	0.1	1.2	0	-6.1
Portugal	0	10.8	0	1.4
EU-15	42.6	-0.7	16.4	-2.1
US	33.7	2.6	53.7	0.3
Japan	14.6	-4.3	20.1	-1.1

Source: DG Research Key Figures 2002
Data: EPO, USPTO; OST and Fraunhofer-ISI (treatments & calculations)

Benchmarking Indicator

Number of patents at the EPO, per million population

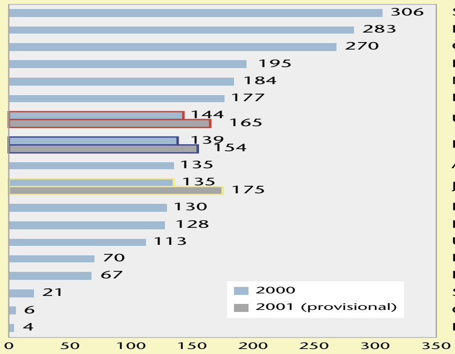
When numbers of patents are expressed in relation to population size it can help to correct for the effect of differences in country size, and thus to gain some insight into the comparative national propensity to patent.

Figure 3.2.1 illustrates that in terms of patents applied for at the EPO, the EU countries are on a similar level to the US and Japan. However, there is much diversity between EU countries. Within a range of four to 300 patents per million population, Sweden, Finland and Germany are at the top, while Spain, Greece and Portugal are at the lower end.

From Figure 3.2.2 shows that the strongest growth in the late 1990s at the EPO was experienced by the more moderately performing countries – Ireland (26%) and Luxembourg (24%). Japan and the US, at 12.5% and 11.6% respectively, had slightly higher growth rates than the EU (10.8%). The other EU countries are in the range between 16.5% (Greece) and 9.3% (Austria); only France is far behind with 7.5%.

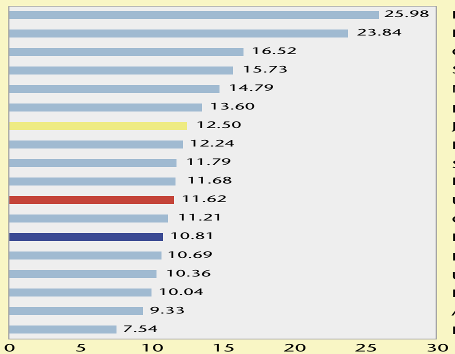
As can be seen in many other indicators, those countries that are performing less well in terms of absolute numbers tend to have higher growth rates and vice versa. In this figure, the Netherlands appears as the exception to the rule; it is an over-average performer in both absolute numbers and growth rates and therefore one candidate for taking the lead in the future.

Figure 3.2.1. Number of patents at the European patent office per million population; latest available year (1)



Source: DG Research Key Figures 2002
Data: EPO, OST (treatments & calculations)
Notes: (1) EU, JP, US: 2000 and 2001 (provisional). All other countries: 2000.

Figure 3.2.2. European patents per million population: Average annual growth, 1995 to latest available year (1), %



Source: DG Research Key Figures 2002
Data: EPO, OST (treatments & calculations)
Note: (1) EU, JP, US: 1995-2001 (provisional). All other countries: 1995-2000.

Benchmarking Indicator

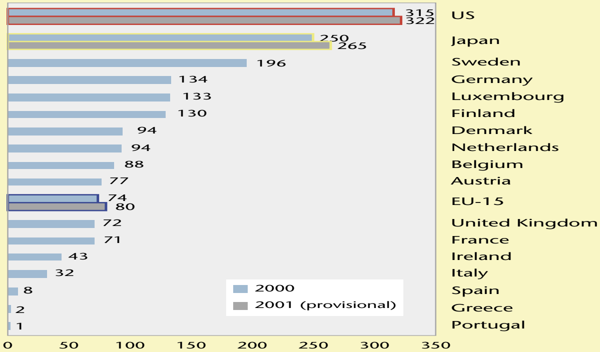
Number of patents at the US Patent and Trademark Office, per million population

Patents granted at the US Patent and Trademark Office tell a similar story. Figure 3.2.3 shows how the US and Japan lead with 315 and 250 patents per million population, while the average for the EU is only 74 in 2000 (In 2001 these number are slightly higher.). Sweden is again the best performing EU country with about 200 patents per million population, followed by Germany, Luxembourg and Finland (all with around 130).

Again, the countries with higher absolute numbers are behind in terms of their growth rate, and vice versa. Thus, the EU has higher growth rates than the US and Japan, as shown in Figure 3.2.4. Among EU Member States, Portugal has, at 37.2%, by far the highest growth rate. France has the lowest growth, with only 7.1%.

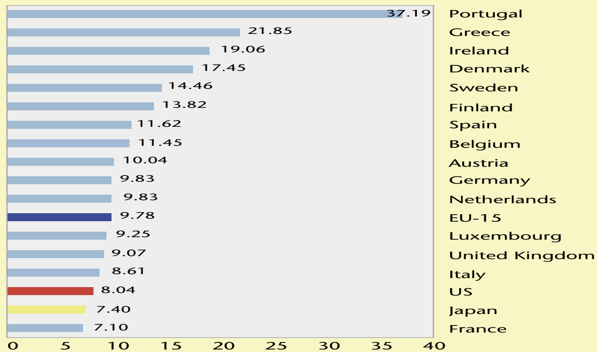
Compared to the EPO patents, Denmark is performing better at the USPTO, especially with respect to growth. This is interesting, because already in Table 3.2.1 this trend was foreseen. Denmark seems to have developed a stronger orientation towards the US market in recent years.

Figure 3.2.3. US patents per million population: Latest available year (1)



Source: DG Research Key Figures 2002
Data: USPTO, Fraunhofer-ISI (treatments & calculations)
Notes: (1) EU, JP, US: 2000 and 2001 (provisional). All other countries: 2000.

Figure 3.2.4. US patents per million population: Average annual growth, 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: USPTO, Fraunhofer-ISI (treatments & calculations)
Notes: (1) E: 1998-2000. All other countries: 1995-2000

Patents by technology area

Table 3.2.2 shows different countries' shares of patents granted in the US by field of technology. These shares give an indication of the fields in which countries tend to specialise. The EU-15 has its highest shares in chemistry, processes and mechanics. The lowest shares are in electricity, consumer goods and instruments. The US profile is one of strength across all fields, but this is partly a result of a home market advantage. Japan's fields of strength are clearly electricity and instruments. Regarding the individual EU countries, Germany's specialisation in mechanics, chemistry and processes stands out. Chemistry (which includes pharmaceuticals) is also an area of active patenting in the US for several other Member States notably France, the UK, Belgium and Denmark. However, shares in electricity and instruments are generally rather low.

The shares of the EU countries at the USPTO are lower than at the EPO, where the profiles are similar but less sharply defined; typically, a country will have a more even distribution of patents across technology fields in its domestic patent system than it will in a foreign system. This can also be observed for the US.

Table 3.2.2. Share of patents granted in the US by technology field in %, 1999

	Electricity	Instruments	Chemistry	Processes	Mechanics	Consumer goods	All fields
Germany	3.3	5.1	8.5	8.9	10.9	3.9	6.3
France	2.0	2.2	4.1	2.6	3.0	2.0	2.7
UK	1.9	2.5	4.2	2.5	2.3	2.1	2.6
Italy	0.7	0.7	1.5	1.8	1.2	1.2	1.1
Netherlands	0.9	0.9	1.2	1.1	0.4	0.5	0.9
Sweden	0.7	0.9	0.8	1.1	1.2	0.7	0.9
Belgium	0.2	0.6	1.2	0.7	0.3	0.2	0.5
Finland	0.5	0.3	0.3	0.8	0.4	0.3	0.4
Austria	0.1	0.2	0.5	0.6	0.4	0.5	0.3
Denmark	0.1	0.2	0.8	0.4	0.3	0.2	0.3
Spain	0.1	0.1	0.3	0.3	0.2	0.3	0.2
EU-15	10.7	13.8	23.7	20.9	20.8	12.1	16.4
US	50.9	55.4	52.7	53.7	50.7	66.6	53.7
Japan	27.8	23.0	15.0	16.2	19.1	7.0	20.1

Source: DG Research Key Figures 2002
Data: USPTO, Fraunhofer-ISI (treatments & calculations)
Notes: IRL, EL, P and L omitted because of low patent numbers

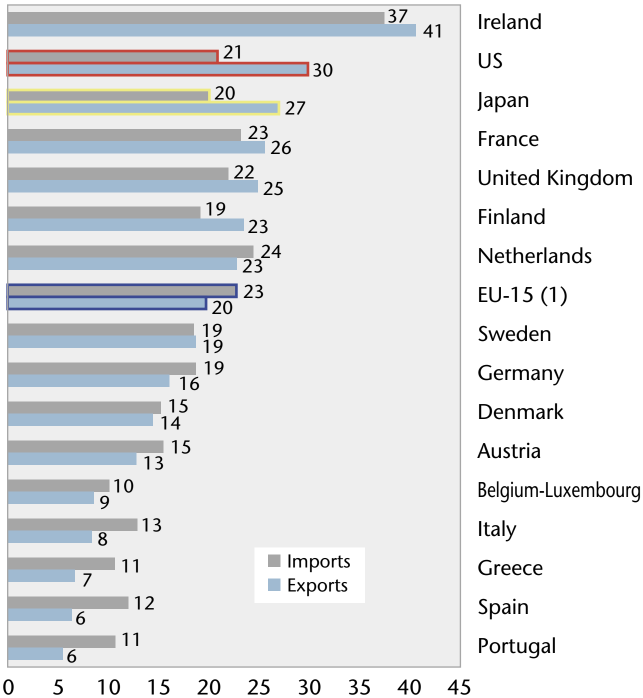
3.3 Performance in commercialising technology

A key factor underlying a country's competitiveness in the modern global economy is its ability to exploit and commercialise new technologies. Two important indicators of this are trade in high-tech products and the technology balance of payments.

National performances in high-tech trade

High-tech exports generally reflect a country's capacity to exploit the results of its R&D in global markets. Moreover, such products embody and disseminate many technologies that have an impact on both the economy and society. Figure 3.3.1 shows that the EU countries have a lower share of high-tech products in their exports and imports (around 20%) than the US and Japan. Only Ireland has a larger share in both categories. The Member States with the lowest shares have a higher share of imports than of exports, which could indicate that few such products are produced domestically. These figures can therefore reflect differences in industrial structure, and some countries can be strongly influenced by the presence of foreign multinationals in the economy.

Figure 3.3.1. High-tech trade as a % of total trade (2000)



Source: DG Research Key Figures 2002
Data: Eurostat (Comext), UN (Comtrade)
Notes: (1) EU-15 values exclude intra-EU trade.

Benchmarking Indicator

World market share of exports of high-tech products

The world market share of exports of high-tech products indicates the strength of an economy in R&D intensive activities and in transforming scientific and technological knowledge into economic activity. A large share is usually associated with high levels of R&D investment, increased productivity, and highly paid jobs for skilled workers.

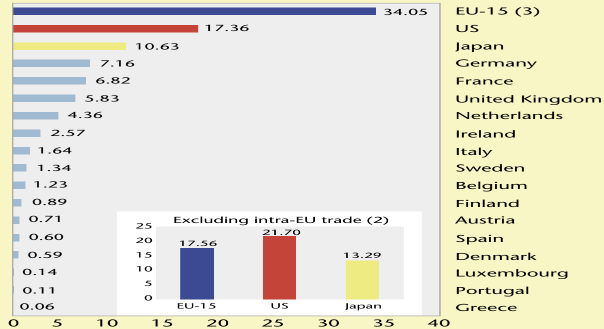
Figure 3.3.2 shows that EU countries together have the largest share of more than one third of global high-tech exports. However, any comparison of the EU as a whole with the US and Japan should exclude intra-EU trade; the effect of this is shown in the box.

When this is taken into account, the EU's exports to non-EU countries only account for a share of 17.6% of world exports, which is below the US, at 21.7%, but ahead of Japan (13.3%).

Among the EU Member States, Germany leads with 7.2%, followed by France, the UK, and the Netherlands. Ireland's share of 2.6% is high relative to its size, due to its expanding high-tech sector and the strong presence of foreign high-tech multinationals.

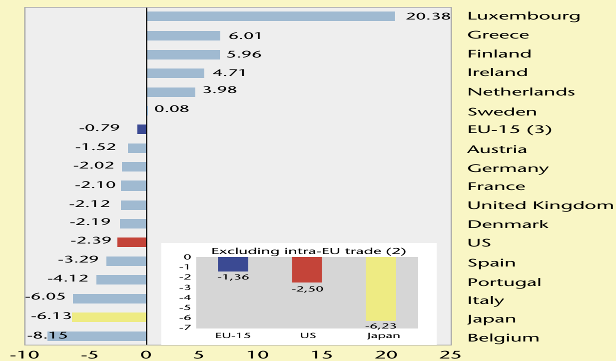
High-tech export growth rates in the late 1990s were negative for the EU (-1.4%), the US (-2.5%) and Japan (-6.2%), as seen in Figure 3.3.3 (excluding intra-EU trade – smaller box). The largest decreases were in Japan, Belgium and Italy. Luxembourg, Greece and Finland posted the strongest increases, followed closely by Ireland and the Netherlands.

Figure 3.3.2. World market share of exports of high-tech products: 2000 (1) %



Source: DG Research   Key Figures 2002
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 share refers to total high-tech exports excluding intra-EU exports.
(3) Includes intra-EU exports.

Figure 3.3.3. World market share of exports of high-tech products: Average annual growth 1995-2000 (1) %



Source: DG Research   Key Figures 2002
Data: Eurostat (Comext), UN (Comtrade)
Note: (1) Cf. note to Figure 3.3.2

Benchmarking Indicator

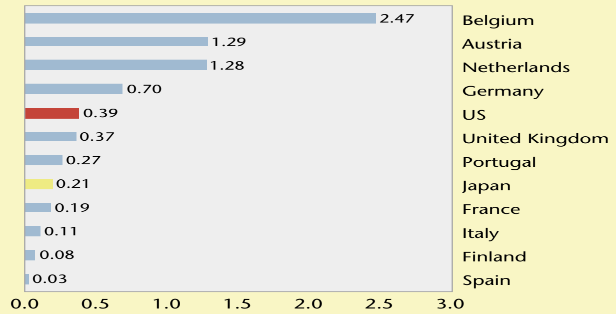
Technology balance of payments receipts as a percentage of GDP

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 (including licences, know-how, trademarks, technical services, etc.). The indicator examined here relates to a country's 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.

Figure 3.3.4 shows significant differences between the EU countries. Belgium has the highest percentage of TBP receipts in relation to GDP (2.5%), followed by Austria and the Netherlands (1.3%). Germany is also ahead of the US, while the UK and Portugal are above Japan. With between 0.03 and 0.19%, Spain, Finland, Italy and France have the lowest percentages.

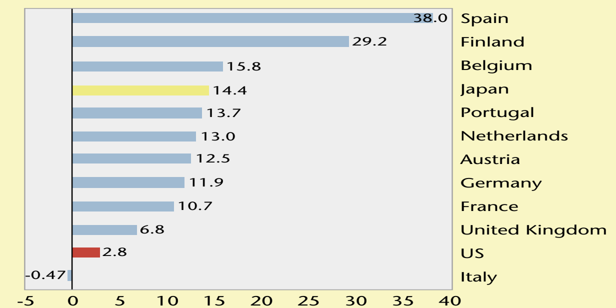
Regarding growth rates – Figure 3.3.5 – the two countries with the lowest levels of TBP receipts, Spain and Finland, made the largest advances in the late 1990s; 38% and 29% respectively. The top-performing country Belgium is still on a remarkable growth path of 16% per year. The other EU countries, except Italy, are behind Japan, but in front of the US.

Figure 3.3.4. Technology balance of payments receipts as % of GDP: most recent year (1)



Source: DG Research Key Figures 2002
Data: OECD, Eurostat, Member States
Notes: (1) E,FIN: 1998; F,US: 1999. All other countries: 2000.
EU average cannot be calculated.

Figure 3.3.5. Average annual real growth (%) of technology balance of payments receipts: most recent years (1)



Source: DG Research Key Figures 2002
Data: OECD, Eurostat, Member States
Notes: (1) calculated in PPS at 1995 prices.
E,FIN: 1995-1998; US,F: 1995-1999; P,UK: 1996-2000.
All other countries: 1995 to 2000. EU average cannot be calculated.

Partner countries of EU high-tech trade

Which are the EU's most important partner countries in high-tech trade? Table 3.3.1 shows that the highest share, around one-quarter of EU high-tech exports, go to the US, followed some way behind by Switzerland and Japan. Turkey and Canada are also in the top ten (with the largest growth rates between 1995 and 2000) as well as a number of fast-growing Asian countries including China.

Table 3.3.1. EU exports and imports of high-tech products: Top ten lists

EU-15 exports: target country				EU-15 imports: country of origin			
Rank	Country	Share of EU exports (2000) %	Average annual growth (1995-2000) %	Rank	Country	Share of EU imports (2000) %	Average annual growth (1995-2000) %
1.	US	27.7	19.6	1.	US	35.6	18.1
2.	Switzerland	7.3	15.2	2.	Japan	11.8	11.4
3.	Japan	4.6	10.8	3.	China	6.2	36.4
4.	China	3.4	15.9	4.	Taiwan	6.1	23.0
5.	Turkey	2.8	27.0	5.	Switzerland	5.0	15.0
6.	Singapore	2.8	16.4	6.	Singapore	4.6	13.9
7.	HongKong	2.6	8.1	7.	Korea Rep	4.5	27.6
8.	Canada	2.5	24.5	8.	Malaysia	3.7	16.5
9.	Taiwan	2.3	22.2	9.	Canada	2.4	20.5
10.	Korea Rep	2.1	17.9	10.	Philippines	2.0	42.7

Source: DG Research Key Figures 2002
Data: Eurostat, Comext

The most important country of origin of EU high-tech imports is the US with around one third, followed by Japan and China. Taiwan is in fourth position with 6.1%. China's large increase between 1995 and 2000 of 36.4% is remarkable; only the Philippines tops this with 42.7%.

Perspectives

The indicators given in this chapter on scientific, technological and innovation performance draw a varied picture. They do not always show the same countries in the lead or the same countries behind. This results from the very different scientific and technological specialisation profiles of EU countries, reflecting long-standing industrial and scientific traditions that are persistent and slow to change.

In general, the EU countries performs well in science but generally less well than their competitors in technology. This mismatch suggests that the EU is suffering from an insufficient exploitation of its scientific and technological potential; this is much less apparent in the US and Japan.

An explanation might be the large presence of high-tech industry in the US, while in Europe medium and medium high-tech industries still tend to dominate. These industries are generally less knowledge intensive and have difficulties in becoming more so. As a consequence, they make less usage of the scientific knowledge available. The opposite can be stated for the US, where knowledge-intensive industries have a higher share of the industrial structure, and they exploit the available scientific knowledge to a greater extent.

The economic development of Ireland suggests that foreign direct investment and high-tech imports can help to speed up the necessary domestic industrial change.

In the next chapter, this issue will be further analysed through the examination of indicators on the impact of the knowledge-based economy on competitiveness.

Part 4: Impacts of the Knowledge-Based Economy on Competitiveness

Education, scientific progress and innovation have always been crucial ingredients of economic activity and important sources of competitiveness. The transition to the knowledge-based economy is enhancing the level of competitiveness of our economies. On the one hand, the sectors and industries that are most involved in the production and exploitation of knowledge are gaining weight and have to compete globally. On the other hand, the integration of knowledge into the day-to-day processes of all parts of the economy is influencing the way economic production is performed and is thus having an impact on overall economic output and competitiveness.

This section analyses, with the help of relevant benchmarking indicators, the impact of the knowledge-based economy on economic features such as labour productivity, and value added and employment in high-tech and medium high-tech industries and in knowledge intensive services.

Key findings

- In terms of labour productivity, the EU competes with the US and is better than Japan. This is valid for the EU average and for most of the EU Member States. The existing gap in output per capita between the EU and the US is principally due to lower employment rates in the EU and to the smaller number of working hours per worker per year.
- The high-tech and medium high-tech industries in the EU have a lower share of value added in overall industrial output than in the US and Japan, but their share of employment is higher.
- The value added of knowledge intensive services varies a lot between EU countries, but are of great significance in all of them.
- Compared to the EU average, the employment in knowledge intensive services is relatively high in the northern EU countries Sweden and Denmark and relatively low in the southern EU countries Portugal, Spain, Italy, and Greece.

4.1 Labour productivity

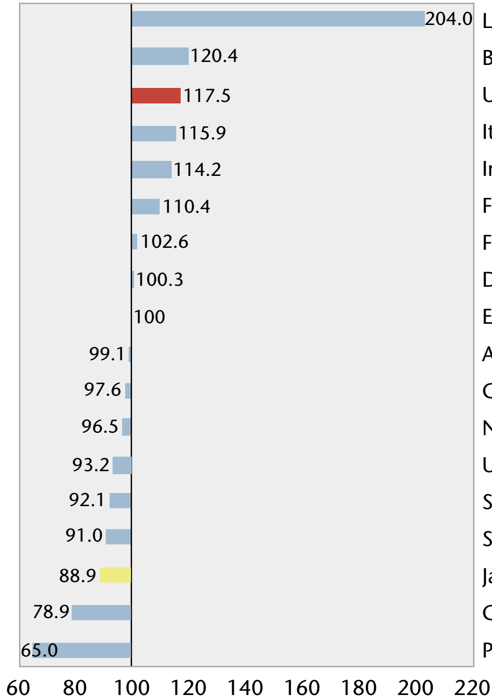
Labour productivity is related to two main features: the level of technology that is integrated in the work and the knowledge of the worker. The absorptive capacity of the worker – their ability to take on new information and apply it in their work – plays an important role in exploiting the benefits of technological progress. Labour productivity is therefore a useful indicator for showing the extent to which knowledge and technology are being used in economic processes.

One way to measure labour productivity is in terms of GDP per person employed. The values for the EU countries, the US and Japan are presented in Figure 4.1.1, normalised to the EU average.

Luxembourg in on top with a ratio of more than 200%, mainly due to its special economic structure. All other countries are in the range of between 120 and 80, with the exception of Portugal at 65. The US is above the EU average, Japan below.

This concept has some disadvantages; for example, it does not take part-time work into account. To try to complete the picture, therefore, another concept is used in the following benchmarking indicators.

Figure 4.1.1. GDP (in PPS 2000) per person employed: 2000 (EU 15=100)



Source: DG Research Key Figures 2002
Data: Eurostat, NewCronos
Notes: Data for P and JP are estimated.

Benchmarking Indicator

Labour productivity – GDP per hour worked

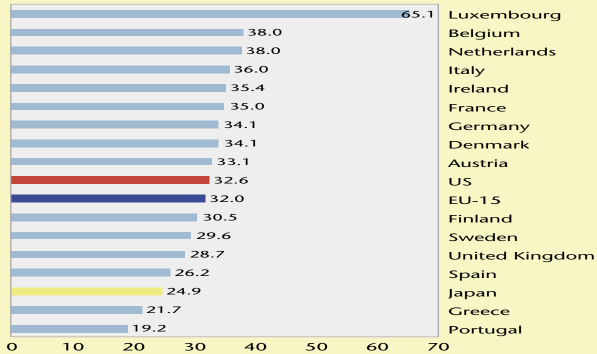
This benchmarking indicator shows the relationship between economic input in units of labour and the economic output in terms of GDP. It is measured by the GDP per hour worked, in year 2000 expressed in purchasing power standards.

Figure 4.1.2 illustrates that the EU has a similar labour productivity to the US – around 32 – and both are much higher than Japan, at 25. Within the EU, by far the highest labour productivity can be observed for Luxembourg (65), although its small size and special economic structure probably create some distortions. Greece and Portugal are the only two EU countries below Japan.

The rest of the EU countries are within the range of 38 (Belgium and the Netherlands) and 26 (Spain).

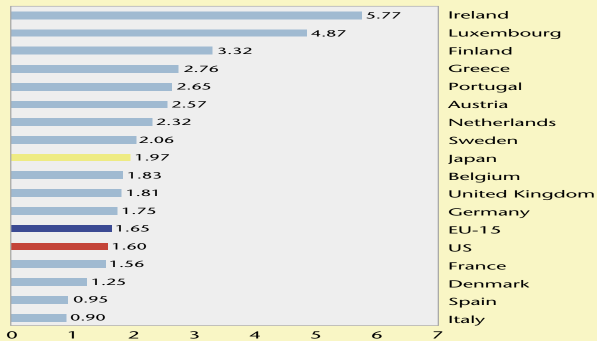
Figure 4.1.3 looks at productivity growth rates. In the late 1990s, the EU had an average annual growth rate of 1.6%, which is again similar to that in the US (1.6%), but this time behind Japan (2%). The most dynamic EU country is Ireland, which had a growth rate of almost 6% per year in the late 1990s. Luxembourg (4.9%) and Finland (3.3%) are also well above average. The smallest growth rates were with 0.9 in Italy and Spain.

Figure 4.1.2. Labour productivity (GDP per hour worked, PPS 2000), latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) US: 1999. All other countries: 2000.

Figure 4.1.3. Labour productivity (GDP per hour worked, PPS 2000): annual average growth rates in % 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Note: (1) US: 1999. All other countries 2000.

4.2 High-tech and medium high-tech industries

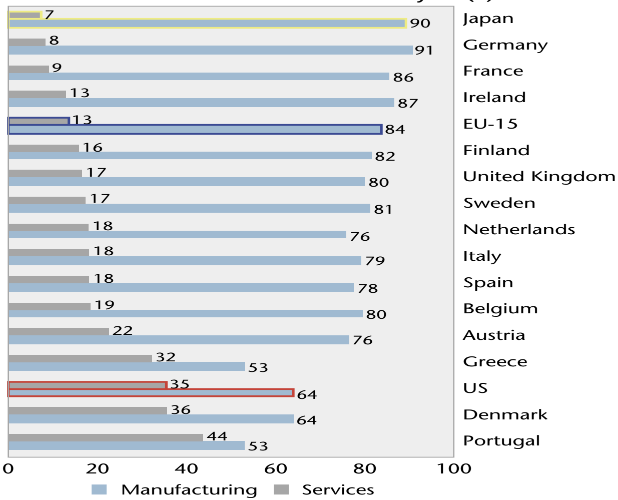
High-tech and medium high-tech industries are defined by the average shares of their expenditure dedicated to R&D. The strength of these industries in an economy reflects the role of R&D intensive activities for economic growth and employment. A high share of high-tech and medium high-tech industries also shows the potential of an economy to transform scientific and technological knowledge into economic activity. This is explored in greater detail in the relevant benchmarking indicators on the next two pages.

4.3 Knowledge intensive services

An analysis of the distribution of business sector R&D activities between manufacturing and services helps to reveal which types of industrial knowledge creation and absorption activities are taking place in the economy. Traditionally, the service sector has been considered to be only marginally involved in research activity. However, recently it has been recognised that at least some parts of the service sector are both very innovative and are also playing a critical role in the emerging knowledge-based economy. However, low levels of involvement in research activity can be a problem for measuring R&D in the service sector.

Quantitatively, the bulk of industrial knowledge creation and absorption activities therefore still take place in the manufacturing sector. There is, however, considerable variation in this share across countries. In the US, the knowledge investment of the service sector (35%) clearly exceeds that of the EU-15 (average 13%). Only two EU Member States allocate relatively more resources to business expenditure on R&D (BERD) in the service sector than the US: Portugal with 44% and Denmark with 36%. The lowest shares can be found in Germany with 8% and in France with 9%.

Figure 4.3.1: Share of Manufacturing and Services in BERD in % latest available year (1)



Source: DG Research Key Figures 2002
Data: OECD, Eurostat
Note: (1) IRL: 1997; A: 1998; B,I,UK: 2000. All other countries: 1999. EU average does not include L.

Benchmarking Indicator

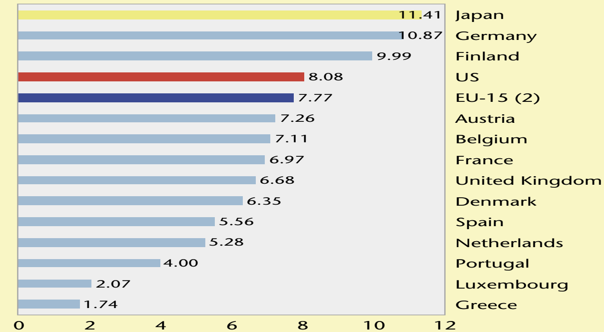
Value added of high-tech and medium high-tech industries

The value added of high-tech and medium high-tech industries as a percentage of total GDP reflects their importance in a country and helps to evaluate their contribution to economic growth.

In 1999, the EU's share of value added from the high-tech and medium high-tech industry in relation to total output was 7.7%, as seen in Figure 4.2.1. This is slightly lower than that found in the US (8.1%) and much behind Japan (11.4%), which has the highest share of all the countries analysed. Germany and Finland, with 10.9% and 10%, are close to Japan, while Greece trails with 1.7%.

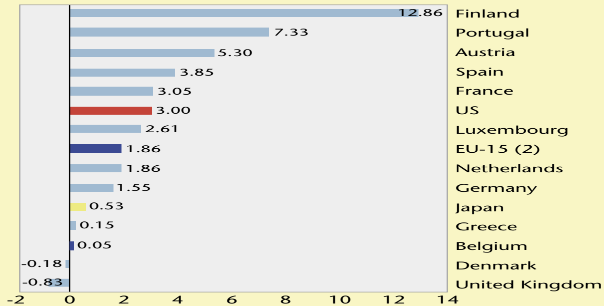
Turning to the changes seen in these shares, Figure 4.2.2 illustrates that on average in the EU, shares have grown in the late 1990s at an annual rate of slightly below 2%. The US achieved 3% growth, while Japan managed only 0.5%. The most dynamic EU country was Finland with almost 13%. Denmark and the UK experienced decreases, the latter at a rate of 0.8%.

Figure 4.2.1. Share of value added of high-tech and medium high-tech industries as % of total output latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) D,US: 1998; B,DK,P,EU-15: 1999. All other countries 2000.
(2) EU average does not include IRL,I,S.

Figure 4.2.2. Share of value added of high-tech and medium high-tech industries as % of total output: average annual growth, 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) B,D,P: 1995-1999. DK,US,EU-15: 1995-1998.
(2) No data available for IRL,I,S, so they are not included in the EU average

Benchmarking Indicator

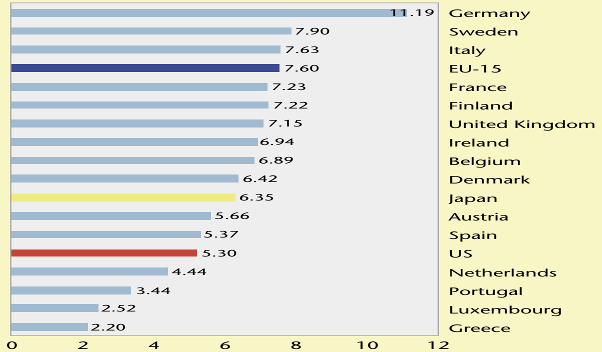
Employment in high-tech and medium high-tech industries

The contribution of high-tech and medium high-tech industries to employment is another important factor to analyse. The growing range of employment opportunities for so-called knowledge workers is an important element of the knowledge-based economy.

In 2000, 7.6% of the employment in the EU was in the high-tech and medium high-tech industries – see Figure 4.2.3. This share is higher than in Japan (5.3%) and in the US (6.4%). By far the largest share was in Germany with 11.2%, while the lowest was in Greece with 2.2%.

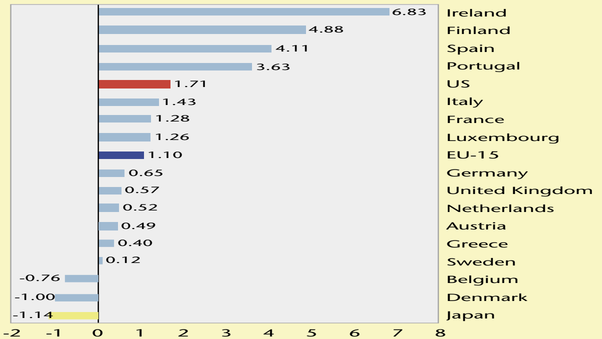
Figure 4.2.4 shows that employment in these sectors in the EU grew only moderately in the late 1990s – just above 1% and even under the US annual growth (1.7%). The most dynamic growth was in Ireland with almost 7%. Belgium, Denmark and Japan even suffered decreases of around 1%.

Figure 4.2.3. Employment in high-tech and medium high-tech industries as % of total employment; latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) US: 1998; A,EU-15: 1999. All other countries: 2000

Figure 4.2.4. Employment in high-tech and medium high-tech employment: average annual growth rates 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Note: (1) US: 1995-1998. A,EU-15: 1995-1999. All other countries: 1995-2000.

Benchmarking Indicator

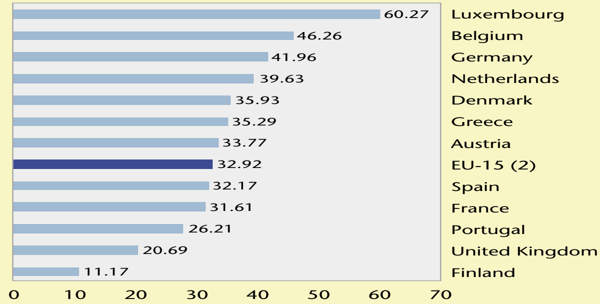
Value added of knowledge intensive services

Knowledge intensive services play a unique role in the knowledge-based economy. First, knowledge intensive services employ highly skilled personnel who embody and create new knowledge. Second, knowledge intensive services offer complementary and intermediary functions to manufacturing and other services, helping to increase productivity. In particular, knowledge service providers play a very important role in the productivity of knowledge production.

The share of knowledge intensive services in the GDP is very clearly the highest in Luxembourg (over 60%), as its economy is strongly specialised in human capital intensive financial services. This is far above the EU average, which is around 36%, while all other countries rank between 47 and 21%, as seen in Figure 4.3.2.

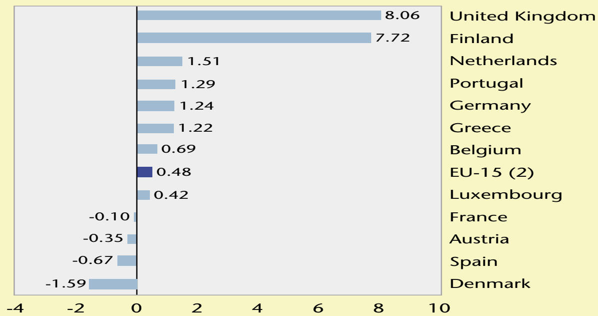
In particular the UK, which started with lower shares of knowledge intensive services in GDP, had exceptionally high growth rates at the end of the 1990s (see Figure 4.3.3.). By contrast, Austria, France and Spain, which also started with relatively low shares, saw negative growth rates. The strongest decline, however, took place in Denmark.

Figure 4.3.2. Share of total output, value added by knowledge intensive services in %: latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) E: 1998; P,DK,B,EU-15: 1999. All other countries: 2000.
No data for IRL,I,S, which are not in the EU average.
(2) EU average does not include IRL, I, S.
(3) No data for the US and JP.

Figure 4.3.3. Average annual growth rates of value added in knowledge intensive services in %, 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) E: 1998; P,DK,B,EU-15: 1999. No data for the US and JP.
(2) EU average does not include IRL, I, S.

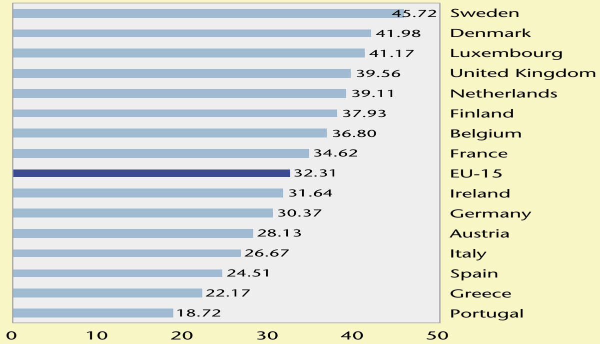
Benchmarking Indicator

Employment in knowledge intensive services

Knowledge intensive services are a significant employer, in particular of highly qualified personnel. Its role as an employer, as shown in Figure 4.3.4, is highest in Sweden (45.7%) followed by Denmark and Luxembourg with a share of over 40%.

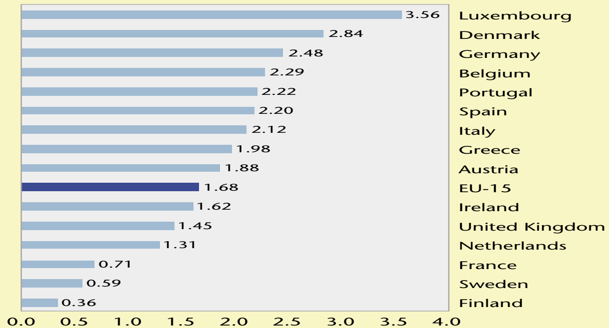
The creation of new high skilled employment in the knowledge intensive service sector is the highest in Luxembourg and Denmark, where the importance of knowledge intensive employment is already high. Growth rates are shown in Figure 4.3.5. Countries that have seen slow rates of employment creation in this sector include particularly Finland and Sweden but also France. The latter also started with a relatively low share of knowledge intensive services in employment.

Figure 4.3.4. Employment in knowledge intensive services as % of total employment: latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) 2000. No data for the US and JP.

Figure 4.3.5. Average annual growth rates of employment in knowledge intensive services: 1995 to latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat, Member States
Notes: (1) P: 1998-2000. All other countries: 1995-2000. No data for the US and JP.

Perspectives

These indicators draw a complex picture of the way in which countries are competing in the transformation of knowledge into products and services.

From a global point of view, the EU is performing well, but there remains room for improvement in comparison with the US and Japan. The EU's relatively high labour productivity in terms of GDP per hour worked implies that in the EU in general, above average levels of highly qualified people are employed. It also indicates that technology is being integrated into working processes. However, although the existing output gap is not principally due to labour productivity differences between the EU and the US, improving the EU's productivity performance remains important to offset the risks from population ageing of negative implications for the potential output of the EU economy.

High-tech and medium high-tech industries contribute significantly to overall employment, but value added is behind Japan. Thus labour in the high-tech sector is less productive than in Japan, which leads to the conclusion that the EU high-tech sector in the EU is not yet the excellent knowledge producer and transformer it is supposed to be. Amongst the EU Member States there are of course exceptions, see for instance the good overall performances by Germany and Finland. Initiatives of the European Union - on the one hand to learn from these positives examples (e.g. benchmarking exercise) and on the other hand to expand the overall efforts (e.g. the 3% decision of the Barcelona Council) - tackle these problems.

Knowledge intensive services are expected to gain further importance in production and employment in the emerging knowledge-based economy, because of their particular function in knowledge production. This is reflected in the growth of such employment in all countries since the mid-1990s. Unfortunately, no data for the US and Japan are available for the knowledge intensive service sector, so any comparisons are restricted to the EU countries, in order to see if the same as for the manufacturing sector is valid for the service sector.

Part 5: Research in EFTA and Candidate Countries: Great Potential

The EU has already established research partnerships with the four EFTA countries (Norway, Iceland, Liechtenstein, and Switzerland). The future enlargement involving up to 13 Candidate countries (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovak Republic, Slovenia and Turkey) will offer even greater potential for research and science in the EU. In particular, the integration of these countries in the Framework Programme and the European Research Area (ERA) open up new dimensions and opportunities for Europe.

However, the two country groups are quite diverse in terms of their research potential at the present time. The EFTA countries are all at a higher level of economic development with well-established innovation systems.

Some of the Candidate countries are in transition from socialist to market economies, whereas others, such as Cyprus, Malta and Turkey, face different challenges. In some countries, moreover, the transition of the innovation system is importantly linked with the privatisation of the former state-owned firms and their intra-mural R&D activities.

Key findings

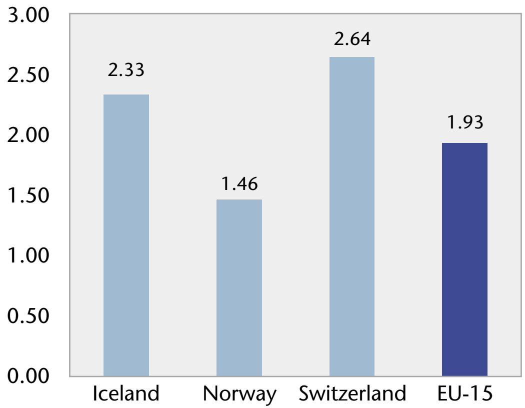
- The EFTA-countries which are at a higher income level (GDP per capita) than the EU average also invest relatively more in R&D activities (with exception of Norway) as well as in the capacity to produce scientific and technological knowledge (human resources in S&T). Also the scientific and technological output as measured by patents and publications is higher than the EU average. Yet, the absolute numbers of course reflect the small size of these economies. The level of high-tech exports is rather low in Iceland and Norway.
- Although the Candidate countries are economically diverse, they are rather similar in terms of a relatively low R&D investment in comparison to the EU average. A common feature for the group of Candidate countries in transition is, however, their strong potential to produce and absorb scientific and technological knowledge which is reflected in high numbers of human resources in S&T. A common feature again is that scientific and technological performance as measured by patents and publications is quite low for all Candidate countries. However, the relatively high number of scientific publications – in comparison to patents - in the group of Candidate countries in transition is probably connected to their abundant human resources in S&T. Also the share of high-tech exports in total exports is generally very low in the Candidate countries – far behind the EU average of 19.7% - reflecting their specialisation in other non-high tech sectors. However, Malta is a clear exception with a high-tech share of 64.4% in total exports which is well above the EU average. Hungary and Estonia also achieve values just above the EU average probably as a result of considerable foreign direct investment.

5.1 EFTA-countries: Investment and performances in scientific and technological knowledge production

Creation and absorption of scientific and technological knowledge

Investment in R&D in relation to GDP describes a country's efforts in producing and exploiting scientific and technological knowledge.

Figure 5.1.1. EFTA countries' R&D intensity (GERD as % of GDP), latest available year (1)



Source: Research DG Key Figures 2002
Data: Eurostat/OECD
Note: (1) IS, CH: 1999; EU-15: 2000 and estimate; NO: 2001 and estimate

Among the EFTA countries Iceland and Switzerland invest more (2.3% and 2.6% respectively) in production and exploitation of scientific and technological knowledge than the EU average (1.9%) while Norway's research efforts represent 1.5% of GDP. In terms of sectoral importance of R&D activities, the most striking feature is the low share of government expenditure on R&D in total gross expenditure (GERD) for Switzerland (Cf. Figure 5.1.1 and Table 5.1.1).

Table 5.1.1. R&D expenditure in EFTA countries (1), 1999

				GERD	
	R&D Intensity (GERD/GDP) %	BERD/GDP ‰	Total Mio ecu	financed by Government %	financed by Business %
Iceland	2.33	10.90	188	41.2	43.4
Norway	1.46[2]	9.50	2 733[2]	42.6	49.5
Switzerland	2.64	19.50	6 865	23.2	69.0
EU-15	1.93[3]	12.63[3]	164 228[3]	56.3[4]	34.2[4]

Source: DG Research Key Figures 2002
Data: Eurostat/OECD
Notes: (1) Data are not available for Liechtenstein.
(2) 2001 and estimate; (3) 2000 and estimate; (4) estimate.

Human resources in S&T: capacity to produce technological and scientific knowledge

The EFTA-countries with the exception of Liechtenstein[8], have a higher share of R&D personnel in the labour force, i.e. a stronger

(8) No data available.

capacity to produce and absorb scientific and technological knowledge than the EU (9.9 per thousand labour force) (Cf. Table 5.1.2). In absolute terms, however, this capacity is quite low: just 4.7% of the total EU R&D personnel. In Switzerland, the relatively low importance of government sector R&D is also reflected in a extremely low share of researchers in the public sector (1.6%). In contrast, Iceland's public sector employs a rather high share of researchers (27.1%).

Table 5.1.2. Human resources in S&T in EFTA countries (1), 1999

	R&D personnel FTE (2) per thousand labour force	Total R&D personnel FTE	Researchers by sector: Total FTE	Government sector %	Business sector %	Higher education %
Iceland	15.3	2 405	1 614	27.1	36.0	35.9
Norway	10.9	25 402	18 295	16.6	53.2	30.2
Switzerland	13.0	52 225	25 755	1.6	62.9	35.5
EU-15	9.9	1 689 490	919 796	14.2	50.0	34.3

Source: DG Research Key Figures 2002
Data: Eurostat, OECD
Notes: (1) Data are not available for Liechtenstein (2) FTE = full-time equivalent

Scientific, technological and economic performance

The EFTA countries – in particular Norway with 33 490 PPS -have a GDP per capita which is considerably higher than the EU average (23 200 PPS per capita). Also the growth rates of GDP, with the exception of Switzerland, are stronger than that of the EU.

In particular, in terms of scientific output measured by scientific publications, they also perform better than the EU (755) with the performance of Switzerland being especially noteworthy with 1776 publications per million population. Technological output measured by patents per million population is also far higher in Switzerland (343) than the EU (126), which is the case for Norway and Iceland too. Again, the share of high-tech exports in Switzerland (19.7%) is at a similar level to the EU (19.9%) while Iceland with a share of 1.7% and Norway with a share of 4.4% clearly do not specialise in high-tech products.

Table 5.1.3. Scientific, technological and economic performance of EFTA Countries

	GDP (1) per capita 2001	Average annual growth of GDP % 1995-2000	Patents (2) per million population 1999	Publications (3) per million population 1999	High-tech (4) exports as % of total exports 2000
Iceland	27 810[5]	4.79	108	874	1.7
Norway	33 490	3.51	109	933	4.4[6]
Switzerland	27 750[5]	1.81	343	1 776	19.9
EU-15	23 200[5]	2.63	126	755	19.7[7]

Source: DG Research Key Figures 2002
Data: Eurostat/European Patent Office/ISI/CWTS/ Comtrade
Notes: (1) in PPS at current prices (2) European patents (3) Publications from 11 fields: agriculture and food science, basic life science, biological sciences, biomedical sciences and pharmacology, chemistry, clinical medicine and health sciences, computer sciences, earth and environmental sciences, engineering sciences, mathematics and statistics, physics and astronomy (4) High tech fields: aerospace, computers & office machinery, electronics, instruments, pharmaceuticals, electrical machinery, chemicals, non electrical machinery, armement (5) Estimate (6) 1999 (7) Extra EU-trade

5.2 Candidate countries: Investment and performances in scientific and technological knowledge production

Creation and absorption of scientific and technological knowledge

In terms of R&D intensity, none of the Candidate countries reaches the level of the EU 1.9%, although Slovenia (1.5%) and the Czech Republic (1.2%) do reach comparatively high levels of R&D expenditure in relation to GDP. Many Candidate countries (Estonia, Poland, Hungary, Slovak Republic and Turkey) invest in R&D at the same level as those Member States with the lowest R&D intensities (such as Greece with 0.7% or Portugal with 0.8%). In all other Candidate countries the R&D intensity is very low.

The share of R&D financed by the business sector – which reflects profit-oriented R&D activities – is lower than the EU average of 56.3% in almost all Candidate countries, with the exception of Slovenia (56.9%), the Czech Republic (52.6%) and Romania (50.2%) (see Table 5.2.1).

Human resources in S&T: capacity to produce technological and scientific knowledge

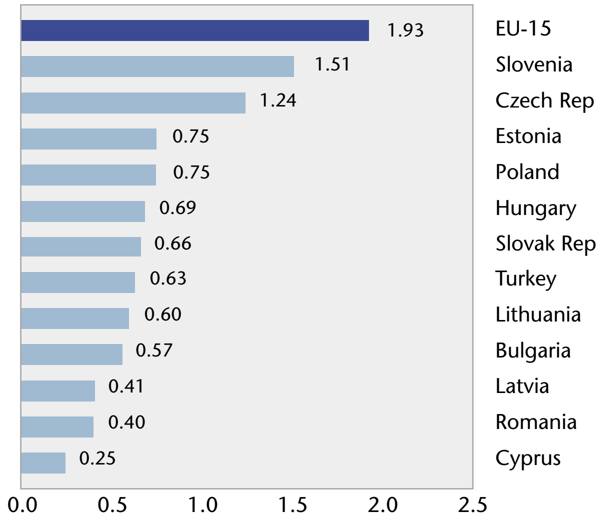
The Candidate countries today possess a huge potential capacity to produce scientific and technological knowledge. This is reflected by the importance of the total R&D personnel and total researchers (in full-time equivalent) which represent 15.2% and 17.8% respectively of the corresponding human capital stocks in the EU, while total R&D expenditure in the Candidate countries only amounts to 2.4% of that in the EU.

Table 5.2.1 R&D investment and human resources in S&T in Candidate Countries (1), 1999

	R&D Intensity (GERD/GDP) %	BERD /GDP ‰	GERD			R&D personnel FTE per thousand labour force	Total R&D personnel FTE[2]	Researchers by sector			
			Total Mio ecu	financed by Government %	financed by Business %			Total FTE[2]	Government sector %	Business sector %	Higher education %
Bulgaria	0.57	1.16	69	69.7	22.8	:	16 087	10 580	66.7	11.8	20.9
Cyprus	0.25	0.50	21	68.5	17.4	:	681	278	29.7	23.1	42.7
Czech Rep	1.24	7.81	641	42.6	52.6	4.7[3]	24 106	13 535	31.6	42.9	25.0
Estonia	0.75	1.79	37	64.8	24.2	:	4 545	3 002	20.7	12.6	66.3
Hungary	0.69	2.76	309	53.2	38.5	5.7[3]	21 329	12 579	36.2	25.9	37.9
Latvia	0.41	0.70	26	55.6	15.7	:	4 301	2 626	28.6	7.3	64.1
Lithuania[4]	0.60	1.29	73	:	:	:	11 791	7 777	32.9	3.7	63.4
Poland	0.75	3.08	1 086	58.5	38.1	:	82 368	56 433	19.2	18.3	62.5
Romania	0.40	2.99	134	46.7	50.2	2.9[3]	44 091	23 473	24.3	65.8	9.9
Slovak Rep	0.66	4.16	126	47.9	49.9	5.8[5]	14 849	9 204	26.4	27.4	46.2
Slovenia	1.51	8.32	284	36.8	56.9	8.9[3]	8 495	4 427	34.1	34.8	29.5
Turkey	0.63	2.40	1 094	47.7	43.3	1.0	24 267	20 065	10.9	16.2	72.9
EU-15	1.93[6]	12.63[6]	164 228[6]	34.2[7]	56.3[7]	9.9	1 689 490	919 796	14.2	50.0	34.3

Source: DG Research
Key Figures 2002
Data: Eurostat/OECD
Notes:
1) Data are not available for Malta
2) FTE = full-time equivalent
3) 2000
4) All values for Lithuania from year 2000
5) 2001
6) 2000 and estimate
7) estimate
Data may not be comparable between countries due to different statistical classifications.

Figure 5.2.1. Candidate countries' R&D intensity (GERD as % of GDP), latest available year (1)



Source: DG Research Key Figures 2002
Data: Eurostat/OECD
Notes: 1) EU-15: estimate, LT: 2000; All other countries: 1999

The distribution of researchers across the government, business and higher education sectors indicates where the capacity to produce and absorb scientific and technological knowledge can presently be found. In all Candidate countries the share of the business sector is much lower than the EU (50%) – except Romania (65.8%). In some countries this sector has a particularly low share - for example Lithuania (3.7%), or Latvia (7.3%) - reflecting a very low scientific and technological knowledge creation and absorption capacity in the business sector. However, the real profit-oriented business sector in-house R&D capacity cannot be assessed without additional information about the present state of privatisation across the transition countries.

In many Candidate countries the role of researchers in the higher education sector is quite significant – with the notable exception of Romania. In particular, the education sector employs the bulk of the researchers in Turkey (72.9%) and in Estonia, Latvia, Lithuania and Poland (all with over 60%). Bulgaria is the only country in which the public sector has the leading role.

Scientific, technological and economic performance

The average GDP per capita for the EU as a whole (23200 PPS per capita) is considerably higher than in any of the Candidate countries which range between 5 000 and 18500 PPS. There is therefore considerable diversity across these countries, with Cyprus and Slovenia reaching levels near to 20 000 PPS, while Turkey, Bulgaria and Romania reach considerably lower levels. In Romania and Bulgaria the low levels of GDP per capita probably reflect the still on-going transition of the economic system.

In terms of technological output – as measured by patents applied for at the European Patent Office per million population – all Candidate countries range with values between 1 and 22 EPO patents per million population far behind the EU (126). For many of the

Candidate countries this is due to the rather recent emergence of intellectual property rights regimes related to the establishment of market economy conditions.

However, many Candidate countries perform relatively better in the production of scientific knowledge (measured by publications per million population). The difference between the Candidate countries and the EU average (755) is much smaller than is the case of patents. In particular, Slovenia is the best performer among the Candidate countries with 577 publications per million population – and interestingly, it is also top in terms of patents per million population. The relatively high numbers of scientific publications in most Candidate countries in transition are probably associated with their abundant S&T human resources (cf. table 5.2.2).

The share of high-tech exports in total exports is generally very low in the Candidate countries – with a range of 2% to 8%, far behind the EU average of 19.7% - reflecting their specialisation in other non-high-tech sectors. However, Malta is a clear exception with a high-tech share of 64.4% in total exports which is well above the EU average. Hungary (22.9%) and Estonia (21.7%) reach high shares that are above the EU average as a result of the considerable foreign direct investment in high-tech sectors.

Table 5.2.2. Scientific, technological and economic performance of Candidate Countries

	GDP (1) per capita 2001	Average annual growth of GDP % 1995-2000	Patents (2) per million population 1999	Publications (3) per million population 1999	High-tech (4) exports, as % total exports 2000
Bulgaria	6 510	-0.83	3	185	2.3[6]
Cyprus	18 460	3.78	7	170	2.7
Czech Republic	13 280	1.22	10[5]	352	7.8
Estonia	9 820	4.90	2	330	21.7
Hungary	11 880	4.02	12	370	22.9
Latvia	7 710	5.28	3	143	2.2
Lithuania	8 730	3.33	1	127	2.7
Malta	:	4.37	5	67	64.4
Poland	9 210	5.14	1	221	2.1[7]
Romania	5 860	-1.33	1	70	4.5
Slovak Republic	11 060	3.78	:	293	4.1[7]
Slovenia	15 970	4.34	22	577	3.7[7]
Turkey	5 210	3.95	:	69	4.0
EU-15	23 200[8]	2.63	126	755	19.7[9]

Source: Research DG Key Figures 2002
Data: Eurostat/European Patent Office/ISI/CWTS/ Comtrade
Notes: (1) in PPS at current prices(2) European patents (3) Publications from 11 fields: agriculture and food science, basic life science, biological sciences, biomedical sciences and pharmacology, chemistry, clinical medicine and health sciences, computer sciences, earth and environmental sciences, engineering sciences, mathematics and statistics, physics and astronomy (4) High tech fields: aerospace, computers & office machinery, electronics, instruments, pharmaceuticals, electrical machinery, chemicals, non electrical machinery, armement (5) Czech Republic and Slovakia could not be separated in the data
(6) 1997 (7) 1999 (8) Estimate (9) Extra-EU trade

Perspectives

The inclusion of the EFTA and the Candidate countries in the European Framework Programme and the European Research Area as well as the future enlargement of the EU provides great possibilities for European research and its competitiveness.

Given their diversity – whether it concerns their economic performance, sectoral specialisation, technological profile, different historical experiences, national and regional cultures, natural endowments, or policy orientations, to name a few aspects – all the European countries can enrich and contribute to the overall performance of the European Research Area.

Obviously, new and adequate polices and strategies are needed to achieve better synergies in utilising the stock of available human resources in S&T, for example by facilitating greater mobility of researchers throughout the European Research Area. The present low rate of investment in R&D activities and R&D performers indicate weak exploitation of the potential of human resources in S&T. Given the vast capacity for knowledge production and knowledge absorption in an enlarged Europe, better co-ordination of national policies – in addition to more investments – is also needed.

Annex I: Basic Macroeconomic and Demographic Data

Table I. Basic macroeconomic and demographic data for the EU Member States, the US and Japan

	GDP		Population		Young population (25-35)		Employment		Unemployment	
	in mio € 2000	growth (%) 1995-2000	in mio 2000	growth (%) 1995-2000	in 1000 2000	growth (%) 1995-2000	in 1000 2000	growth (%) 1995-2000	in 1000 2001	growth (%) 1995-2001
Belgium	248 338	3.24	10.24	0.21	1 459	-1.48	4 120	1.67	286	-5.72
Denmark	176 490	5.07	5.33	0.43	798	-0.24	2 725	0.87	123	-6.86
Germany	2 025 534	1.50	82.16	0.15	12 167	-2.86	36 324	0.30	3 073	-0.22
Greece	122 986	6.47	10.54	0.19	1 618	0.88	3 946	0.65	457	2.85
Spain	608 787	6.38	39.44	0.13	6 534	0.79	14 450	3.74	1 892	-7.43
France	1 404 775	3.41	59.23	0.41	8 592	-0.16	23 388	1.18	2 221	-3.78
Ireland	103 470	15.25	3.78	0.98	567	2.11	1 672	5.79	68	-14.71
Italy	1 165 677	6.80	57.68	0.14	9 185	0.14	20 930	0.97	2 248	-2.43
Luxembourg	20 564	8.25	0.44	1.39	68	-0.23	262	4.14	4	-3.82
Netherlands	401 089	5.82	15.86	0.56	2 491	-0.97	7 860	2.99	198	-13.63
Austria	204 843	2.64	8.11	0.16	1 277	-2.11	3 683	0.04	137	-1.31
Portugal	115 262	6.89	10.24	0.41	1 648	2.91	4 909	1.90	212	-781
Finland	131 229	5.82	5.17	0.28	662	-2.20	2.367	3.27	238	-7.61
Sweden	248 479	6.24	8.86	0.10	1 237	-0.19	4 125	-0.04	225	-8.26
UK	1 547 902	12.27	59.62	0.38	8 943	-0.98	27 793	1.32	1 485	-7.89
EU-15	8 525 424	5.34	377.89	0.27	57 177	-0.77	158 555	1.30	12 861	-4.41
US	10 689 461	13.57	278.06	0.93	37 189	-1.84	147 036	2.03	6 740	-1.55
Japan	5 162 452	4.99	127.29	0.23	18 567	1.88	66 570	0.61	3 398	8.35

Source: DG Research Key Figures 2002
Data: GDP, (Un)Employment: Eurostat. (Younger) Population: OECD
Notes: GDP: data for B, DK, EL, E, F, IRL, I, A, P, FIN, S, UK, EU-15 are estimates. Population: EU, US, JP: 2001. Younger population: EU average does not include L. Employment: US: 1999

Annex II: Definitions and Sources

Symbols used

:	no data available
–	zero
0	less than 0.5 unit

Country codes

B	Belgium	NL	Netherlands
DK	Denmark	A	Austria
D	Germany	P	Portugal
EL	Greece	FIN	Finland
E	Spain	S	Sweden
F	France	UK	United Kingdom
IRL	Ireland		
I	Italy	US	United States
L	Luxembourg	JP	Japan
EU-15	European Union (15 Member States)		

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.

Industrial output

Definition: Industrial output is defined as the domestic product of industry (DPI).
Sources: OECD and Member States. National sources for Japan.

Small and medium-sized enterprises

Definition: Small and medium-sized enterprises (SMEs) are defined as follows: enterprises which have fewer than 250 employees, and have either, an annual turnover not exceeding ECU/euro 40 million, or an annual balance-sheet total not exceeding ECU/euro 27 million, and conform to the criterion of independence as defined in paragraph 3 in 96/280/EC: Commission Recommendation of 3 April 1996). However, the data received on SMEs do not always comply with the above Eurostat definition. Japanese definition of SMEs relates 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)

Definitions: Financial aggregates are expressed in Purchasing Power Standards (PPS), rather than in ECU/Euros 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., Research and development: annual statistics, data 1990–2000 (2001) by Eurostat]

Part 1: Investment in knowledge

Total investment in R&D

Definition: Total research and development expenditure is defined as gross domestic expenditure on R&D (GERD) according to the

OECD Frascati Manual definition. The same methodology also applies to data on financing and execution of R&D, which relate to financing/execution of total gross domestic expenditure on R&D.

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

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).

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 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 is defined as private equity capital investment in seed and expansion phase of business plans or enterprises not quoted on a stock market.

The definitions of seed and start-up venture capital investment in the US also include first-stage financing until 1999. Since 2000 both in the EU and US seed start-up capital includes other early stage financing. The Japanese data for early stage financing are based on two assumptions: firstly, early stages correspond to the period before establishment or less than 5 years of the company's life time and, secondly, the ratio of early stage venture capital in new investment is the same as that in total new investment.

In the category of expansion financing the definitions in the EU and US differ in some extent while again the Japanese figure is based on an estimation by Nistep.

Sources: European Venture Capital Association for the Member States and National Venture Capital Association for the US. Source for Japan: The Venture Enterprise Center (VEC)/Nistep.

Part 2: Human resources in S&T

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, Proposed standard practice for surveys of research and experimental development, "Frascati Manual", Paris 1993).

Sources: Member States, Benchmarking indicators; Eurostat: Community Labour Force Survey (CLFS), NewCronos database.

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

S&T graduates

Definitions: 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: it includes 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 'Canberra Manual', OECD, Manual on the measurement of human resources devoted to S&T, "Canberra Manual", Paris 1994).

Sources: Member States, Benchmarking indicators; OECD, Education database.

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

Part 3: Scientific, technological and innovation performance

Publications

Definition: Publications are articles and reviews that were published in journals which are included in the SCI database of the Institute of Scientific Information (ISI).

Sources: ISI, University of Leiden-CWTS (data treatment).

Highly cited papers

Definition: The highly cited papers have been calculated from the top 1% of the most cited publications per sub-field and added at the country level. Only 'articles' and 'reviews' are taken into account. Author self-citations are excluded. The field 'Multidisciplinary' has been excluded. Usage of a three year publication period (1996, 1997, 1998) and a four years fixed citation window, i.e., the citations are calculated including the publication year plus three years. For example, publication year 1997 plus citation window 1998-2000 etc. A full counting method has been used whereby each author/country involved in an international co-publication receives a citation. EU- averages or totals cannot be calculated due to this multiple counting.

For methodological changes in the bibliometric benchmarking data see also Annex III.

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

Patent indicators

Definitions: 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.

Sources: EPO, OST (data treatment); USPTO, Fraunhofer-ISI (data treatment).

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.

Part 4: Competitiveness

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, the high-tech and medium high-tech industries consist of eight manufacturing sectors: NACE 24 (manufacture of chemicals and chemical products), 29, 34 and 35 (mechanical and automotive engineering, machinery and transport), 30 to 33 (electrotechnology, information and communication, measurement, control and instrumentation, optics).
Sources: Eurostat, OECD.
Classification: NACE Rev. 1.

Knowledge intensive services

Definitions: Knowledge intensive services are defined according to the Eurostat definition: post and telecommunications, computer and related activities, research and development, water transport, air and space transport, financial intermediary, 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 gross domestic product (GDP) according to National Accounts ESA 1995 definition.
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, Member States; Eurostat CLFS; National Sources for Japan.

Part 5: European non-Member States

Definitions: see definitions of the indicators in the previous parts.
Sources: Eurostat, OECD, EFTA and Candidate countries.

Annex III: Methodological Changes in Bibliometric Benchmarking Data

Table III: Number and growth in number of publications (1995-2001)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Belgium	810	897	→	864	↓	4.37	4.65	↓	2.49	↓
Denmark	1 214	1 335	→	1 307	↓	3.57	3.76	↓	2.23	↓
Germany	657	754	↓	780	↑	4.34	4.81	↑	4.42	↓
Greece	340	384	→	501	↑	7.33	8.12	→	10.13	↑
Spain	471	521	→	613	↑	7.01	7.70	↑	7.99	↑
France	652	732	↓	779	↑	2.74	3.28	→	2.90	↓
Ireland	542	593	→	600	↑	7.26	7.53	↓	5.50	↓
Italy	457	504	→	573	↑	4.17	4.55	→	5.28	↑
Luxembourg	133	147	→	188	↑	3.27	3.45	↓	6.88	↑
Netherlands	963	1 061	→	1 120	↑	1.41	1.60	→	2.14	↑
Austria	717	789	→	845	↑	6.05	6.21	→	5.36	↓
Portugal	248	280	→	333	↑	15.93	16.57	→	14.55	↓
Finland	1 157	1 251	→	1 320	↑	4.92	4.84	→	4.19	↓
Sweden	1 431	1 551	→	1 657	↑	3.04	3.38	↓	3.39	↑
UK	949	1 043	→	1 152	↑	1.52	1.80	→	3.00	↑
EU-15	613	754	↑	818	↑	2.92	3.92	↑	4.07	↑
US	708	777	→	926	↑	-0.08	-0.01	→	3.44	↑
Japan	498	536	→	648	↑	4.26	4.54	↓	6.43	↑

Source: DG Research
Data: ISI, CWTS (treatments)
Notes: (1) Number of scientific publications per million population, 1999. Original benchmark data.
(2) Number of scientific publications per million population, 1999. Amended calculation according to EC's indicators report (2002).
(3) Indicates changes in rank comparing (2) and (1) data.
(4) Number of scientific publications per million population, 2001. Calculated according to EC's indicators report (2002).
(5) Indicates changes in values comparing (4) to (2) data.
(6) Average annual growth (%) of number of scientific publications, 1995 to latest available year (1999). Original benchmark data.
(7) Average annual growth (%) of number of scientific publications, 1995 to latest available year (1999). Amended calculation using data (2).
(8) Indicates changes in rank comparing (7) to (6) data.
(9) Average annual growth (%) of number of scientific publications, 1995 to latest available year (2001). Amended calculation using data (2).
(10) Indicates changes in rates comparing (9) to (7) data
↑↓ Indicate ups and downs in consecutive rankings → signifies no change

Annex IV: Methodology of Composite Indicators

Introduction

The use of composite indicators to assess progress towards the knowledge-based economy is an emerging and pioneering field. Such indicators have already been successfully used at both national and international level in a number of different policy fields where it is necessary to summarise complex multidimensional phenomena[1].
In the framework of the Commission's Structural Indicators exercise[2] it was decided that it would be useful for the Commission services to investigate and develop composite indicators of the knowledge-based economy. A number of Commission services have been involved and consulted during the development work including DG Education, Eurostat, DG Information Society and DG Enterprise. External technical assistance with the refinement of the methodology was provided by Anthony Arundel and Catalina Bordoy of MERIT. The Applied Statistics Group of the Joint Research Centre also contributed significantly to reviewing different approaches and testing the sensitivity of the chosen method[3].
This latest edition of Key Figures presents some first preliminary results emerging from this work on composite indicators.

(1) For example: · United Nations, *Human Development Report*, 2001 [Human Development Index, Technology Achievement Index]. · International Institute for Management Development, *The World Competitiveness Yearbook* (2000 and 2001), Lausanne. · Nistep, *Composite Indicators: International Comparison of Overall Strengths in Science and Technology»*, Report No 37, Science and Technology Indicators 1994, A Systematic Analysis of Science and Technology Activities in Japan, January 1995. · World Economic Forum, *Pilot Environmental Performance Index*, Yale Center for Environmental Law and Policy, 2002. · Alan L. Porter, J. David Roessner, Xiao-Yin Jin and Nils C. Newman, *Changes in National Technological Competitiveness: 1990-93-96-99*, (available on Internet). · Michael E. Porter and Scott Stern, *The New Challenge to America's Prosperity: Findings from the Innovation Index*, Council of Competitiveness, Washington DC, 1999. · Progressive Policy Institute, *The State New Economy Index*, www.neweconomyindex.org/states, 2000.

(2) Communication from the Commission : Structural indicators, COM(2001) 619 final, Brussels, 30 October 2001.

What do the composite indicators tell us?

The composite indicators used here are a weighted average of a number of component or sub-indicators (see below). They reveal several things:

1) For any given year, they show the position of the country concerned (as the mean of the various base indicators) compared with its partners: if one country's composite index is higher than another's, the country with the higher index is in a better position.
2) If we follow one particular indicator for several years, it shows us how the country is progressing over time. If the index is higher in year *n*+1 than it was in year *n*, the country's performance (or capacity) has improved over that period.
3) The value of an index during year *n* shows the position of the country compared with the European average in the reference year (1995 in this case):
   - a positive index means that the position of the country in year *n* is above the European average for 1995;
   - a negative index means that the position of the country in year *n* is below the European average for 1995.

(3) *State-of-the-art Report on Current Methodologies and Practices for Composite Indicator Development*, Joint Research Centre - Applied Statistics Group, Ispra, June 2002 (www.jrc.cec.eu.int/uasa/prj-comp-ind.asp).

Component indicators and their weights

The composite indicators are calculated using the component indicators and weights[4] listed below.

Table IV.1 Component indicators and weightings for the composite indicator on investment in the knowledge-based economy

Component indicators	Conceptual group	Weight
Total R&D (GERD) per capita	Knowledge *creation*	2/24
Number of Researchers per capita	Knowledge *creation*	2/24
New S&T PhDs per capita	Knowledge *creation*	4/24
Total Education Spending per capita	Knowledge *creation* and Knowledge *diffusion*	4/24 + 3/24
Life-long learning	Knowledge *creation:* human capital	3/24
E-government	Knowledge *diffusion:* information infrastructure	3/24
Gross fixed capital formation (excluding construction)	Knowledge *diffusion:* new embedded technology	3/24

The technique adopted here is to base weights of sub-indicators on a conceptual understanding of the phenomenon that we are trying to measure. Each composite indicator contains a number of "conceptual groups". These conceptual groups may contain one indicator or several. The different conceptual groups are given equal weightings, while within each group the components indicators are also accorded an equal weight[5]. For example, the investment composite indicator contains two conceptual groups : knowledge creation and knowledge diffusion, both of which receive an overall weight of 12/24 (see table above), the component indicator "total education spending" contributing to both groups (4/24 to creation group and 3/24 to the diffusion group). The performance composite indicator has four "conceptual groups" which are equally weighted.

Table IV.2 Component indicators and weightings for a composite indicator on performance in the knowledge-based economy

Component indicators	Conceptual group	Weight
GDP per hours worked	Productivity	4/16
European and US patents per capita	S&T performance	2/16
Scientific publications per capita	S&T performance	2/16
E-commerce	Output of the information infrastructure	4/16
Schooling success rate	Effectiveness of the education system	4/16

Whilst this system may not correspond to the *theoretically ideal* set of weights that we would choose if we knew precisely the contribution of each component indicator to explaining the knowledge-based economy (which is impossible to estimate whatever method we use), it has the advantage of being clear, transparent and conceptually coherent.

(4) These are the weights used for the calculation of the *positions* of EU Member States. The weights used for the growth rates and for comparisons with the US and Japan are slightly re-adjusted owing to non-availability of some variables or time series (see section below on data availability).

(5) With the exception of R&D expenditure and numbers of researchers which are given the weighting of one instead of two component indicators because of the close link between these two variables (most of R&D is researchers' salaries).

Calculation method

All methods of calculating a composite indicator must transform indicators that are measured in different units into the same unit. For example, indicators measured in terms of Euros, percentages, and per capita must be transformed into a single measurement unit. The method used here for the composite indicators of the knowledge-based economy is to calculate z-scores (standardised units of the number of standard deviations from the mean).
To be precise, if x^t_{ji} is the value of the *j*th component indicator for country *i* at time *t*, for each component indicator one can calculate the standardised z-score:

$$y^t_{ji} = \frac{x^t_{ji} - x^0_{jUE}}{\sigma^0_j},$$

where x^0_{jEU} is the EU average, and σ^0_j the standard deviation, of the component indicator *j* at time 0. (In the calculations of the composite indicators presented here the base year 0 has been chosen as 1995.)
The composite indicator I^t_i of a country *i* is then calculated as the sum of these standardised values y^t_{ji} weighted by the coefficients q_j (whose sum is equal to "1", so that the composite indicator is commensurable with its components), i.e. :

$$I^t_i = \sum_{j=1}^{m} q_j y^t_{ji}.$$

The growth rate is calculated using the transformation without the "centring" element, i.e.:

$$y'^t_{ij} = \frac{x^t_{ji}}{\sigma^0_j} \text{ instead of } y'^t_{ij} = y^t_{ij} - \frac{x^o_{jUE}}{\sigma^0_j} = y'^t_{ij} - y^0_j.$$

To arrive at this non-centred value we have to add the following,

$$I^0_0 = \sum_{j=1}^{m} q_j y^0_j$$

To the value of the composite indicator for each country. This operation purely re-scales the indicator along the same axis.
If we take then, $I'^t_i = I^t_i + I^0_0$, the annual average growth rate of the composite indicator between 0 and *t* is

$$\tau^{t/0}_i = \left(\frac{I'^t_i}{I'^0_i}\right)^{1/t} - 1.$$

Data availability

The availability of complete time series for all countries and component indicators is very important for the calculation of composite indicators, since gaps in data are compounded when aggregating across many variables, countries and years. An important criterion for the selection of the component indicators (along with quality and comparability) was therefore the completeness of the datasets.

Nevertheless, comparable data for some component variables (e-commerce, e-government, education expenditure, life-long learning, schooling success rate) were not available for the US and Japan, and the indicator calculated for comparisons with these countries excludes these components and uses a re-adjusted weighting. Since certain component indicators are only available for one year (no time series), growth rates are calculated excluding these indicators, and the weights have been re-adjusted accordingly.

In particular, in Figure A, for the intra-European comparison, all 7 indicators were included for the investment level in 1999 (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). Luxembourg is not included (no data for most of the indicators).

In Figure B, for the intra-European comparison, all indicators were included for the performance level (horizontal axis), however, the indicator on e-commerce could not be included in the comparison of the growth rates (no data available for 1995). The data for the UK's schooling success rate are partial and not completely harmonised. To allow calculations, UK growth from 1995 to 1999 has therefore been taken as 0, which may lead to a marginal underestimation overall of the performance growth for UK and EU-15.

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