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Towards a European Research Area

Key Figures 2001

Special edition

Indicators for benchmarking of national research policies

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PREFACE

As Europe embarks on its journey towards the knowledge-based economy, it needs to set in place the processes and instruments that will allow it to develop appropriate policies for managing this transition. Research and development, as a generator of knowledge, growth, employment and social cohesion, will play a vital role.

The importance of this challenge was recognized at the Lisbon Summit in March 2000, where the European Union set itself a strategic goal for the next decade: to become the most competitive and dynamic knowledge-based economy in the world. To achieve this goal, which requires effective and coherent policy processes, the European Council decided to introduce a new open method of co-ordination, of which benchmarking will be one of the key tools.

In order to implement the Lisbon strategy in the field of R&D, the Council, in its Resolution of June 2000, called upon the Commission to set up a methodology and indicators for the benchmarking of national research policies in Europe in the framework of the creation of a European Research Area.

In November 2000, a working document including a methodological approach and a list of indicators was presented to the Council and received a positive welcome. Since then, much work has been carried out under the aegis of a High Level Group of representatives of the Member States. In particular, a first set of 15 science and technology indicators has been prepared by the European Commission services, in collaboration with the Member States, and is included in the Working Document 'Progress Report on Benchmarking of National Research Policies' submitted to the Research Council.

I decided to dedicate this special edition of *Key Figures 2001: Towards a European Research Area* to these first indicators so as to disseminate this work to a wider European audience and to stimulate a valuable debate on this topic. The indicators presented here are a first contribution to the benchmarking process. With the help of the High Level Group, they will be evaluated and validated as a basis for benchmarking the performance of research policies. Important analytical work concerning the context and content of national policies will help to identify best practices, and thus to enrich the process through which these policies are conceived. At the same time, efforts will be made to improve the quality and completeness of existing indicators, and to develop new indicators.

Benchmarking is a joint activity of the European Union and its Member States. To be successful, benchmarking must involve the active and continuing commitment of many actors, notably policy makers, experts, national statistical services, and the European Commission services. I am happy to say that the first stage of this exercise has been initiated with the support of all these actors, and I hope that their participation can be continued and reinforced in the next phases, which will be vital to the success of constructing a European Research Area.

Philippe Busquin

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Acknowledgements and Authors

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Introduction

Background

This report presents a set of indicators which have been collected as part of the first phase of the exercise of benchmarking of national research policies. The work was carried out in response to the request of the Council made first at the Lisbon Summit of March 2000 — where a new method of open co-ordination was established and the Council Resolution of 16 June which more explicitly invited the Commission to draw up a methodology for benchmarking of national research policies as well as a list of indicators covering four key themes:

- Human resources in R&D, including the attractiveness of S&T professions
- Public and private investment in R&D
- Scientific and technological productivity
- The impact of R&D on economic competitiveness and employment

The aim of this first set of indicators is to provide a broad comparative overview of the performance of Member States in relation to the four themes, using currently available and internationally harmonised statistics. Wherever possible, comparative indicators have been provided for the USA and Japan[1].

[1] This analysis has been prepared on the basis of data received before 15 May 2001 from the Member States, Eurostat, OECD, NSF (USA) and Nistep (Japan)

Approach for benchmarking national research policies

Benchmarking in the context of national research policies is an instrument for increasing national performances through improved policy design and practices. Benchmarking provides an opportunity for learning and stimulates the application of new solutions and practices in research policies. The benchmarking methodology involves analytical and measurement activities at two stages, thus providing a basis for improved policy implementation.

The benchmarking process begins with performance benchmarking. This requires indicators for the measurement of performance, for the identification of best performers, and for the measurement of gaps in relation to the best performers.

Performance benchmarking indicates where best practices are likely to be found, i.e. which processes and designs of research policies lead to high level performance. The analysis of the process underlying these "best practices" involves all analyses and surveys that are useful for understanding best practices in research policies (public support for scientific and business sector research, education systems, financial institutions). However, if we are to fully understand differences in countries' performances in research and innovation, certain conditions relating to other policy areas (education, taxation, employment) may also need to be included in the analysis.

However, a set of indicators and the understanding of best practices are not the final objectives of the benchmarking exercise, but rather the improvement of national research policies. The ultimate aim of the benchmarking is that the new knowledge - gained in these earlier benchmarking stages - should be applied to policy making, and adjusted to the national policy context. Benchmarking does not involve transfer of practices directly from one context to another, but rather draws on experience elsewhere to stimulate new thinking about policy implementation. In this way benchmarking can improve national policies, instruments and practices, or open totally new possibilities that induce higher future performances.

When benchmarking a great number of countries with different economic structures, different institutional set-ups and different cultural/historical backgrounds, certain aspects need to be recognised. In particular, as there is a great diversity of research and innovation systems in Europe, there are also numerous examples of best practices in specific policy areas and, therefore, there is a great potential for learning from others. Finally, it is important to be aware of that excellence or best practices are context-related. If the context changes, the best practice must also be reviewed. Consequently, in a dynamic changing world policies need to be continuously reviewed and adjusted.

Benchmarking, in contrast to traditional comparative analyses of country performances, involves the participation of actors from various institutional levels, and the co-evaluation of performance. The contributions of policy makers, analysts and statistical services in the Member States is a vital element of a successful benchmarking process.

Selection of the first set of indicators: definitions and sources

The first set of indicators provided in this report is therefore a starting point for further analyses, and needs to be complemented and enriched by other information and analytical work by experts in the field: for instance analyses of policy instruments in different countries, and of the relationship between policy measures and the performance of the research and innovation systems. In the text of this report an attempt is made to identify various questions of this nature that deserve more detailed examination.

A total of 20 indicators (5 per theme) were drawn up (see annex) in consultation with the High Level Group on Benchmarking of National Research Policies, composed of Member State representatives nominated by the research ministers. Inputs and advice were also sought from a number of S&T indicators experts, including Eurostat and the OECD. Of the 20 indicators, 15 are indicators available from existing sources, and 5 are new indicators that need to be developed by the European Statistical System. These indicators were presented to the Council in November 2000, and received a positive welcome.

In order to ensure the methodological validity of the indicators, detailed definitions, sources and other methodological notes were sent to the statistical services in the Member States for comments during December 2000 - January 2001.

Benchmarking requires the most up-to-date, internationally comparable and policy-relevant indicators, which need to be available at a sufficient level of disaggregation to allow useful analysis. It was therefore decided that the indicators used for this exercise should be based as much as possible on the official statistics provided to Eurostat and the OECD by the Member States' statistical offices because these are the most reliable and harmonised data that exist. Privately collected data were only used when there was no official source available for all Members States (e.g. venture capital). It should be emphasised that without the data produced by the national and international statistical agencies this benchmarking exercise could not take place.

In order to ensure that the best possible data were used for this work, a two step approach was employed. First, the indicators were collected for each country from harmonised international databases at Eurostat and the OECD. Then these indicators were sent to the Member States' statistical services (via the High Level Group on Benchmarking) for validation and completion. This involved checking that the data were correct, the addition of any revised data not yet available in international databases, and the inclusion where possible of estimates for the most recent years.

All contacts with Member States' statistical services have been managed by Eurostat, including the receipt and checking of data, as well as various discussions with Eurostat's R&D and Innovation Statistics Working Party.

This is a first attempt at using indicators for benchmarking in this area, and it is important to look towards possible improvements for the future. It is possible that, as a result of the analyses carried out during the benchmarking process, needs for new or improved indicators could emerge.

The development of the five new indicators is a first step in this direction. This work will be undertaken by a special Eurostat task force, involving representatives from Member States' statistical offices, which will explore the technical issues for developing these indicators, which include measures of human resources, gender and mobility, all of which are critical issues in the context of the European Research Area.

THEME 1: Human Resources in R&D and Attractiveness of S&T Professions

Living and working in an increasingly knowledge-driven economy puts human resources - as the main 'knowledge carriers' - at the forefront of policy debate. In order for a country to maintain its competitive base, to provide quality of life to its citizens, and to create employment opportunities and employable workers, the skills of its workforce require continuous upgrading and are quintessential to the country's economic performance.

Policy-makers are therefore interested in information that will help them to make policy decisions aimed at better exploiting the country's employment potential, of which the upgrading of skills is an important aspect. A variety of indicators has been developed in recent years and a wide variety of data have been collected for that purpose.

Indicators measuring the number of researchers in relation to the total workforce, their disciplines, their qualifications, their research and publication output, their research efforts and related expenditures as well as their impact on new or improved products, processes and services, are of interest to policy-makers. First of all, because these indicators allow them to get factual information on the basis of which they can make better informed decisions. And secondly, because these data will allow them to compare their country's innovation performance in that particular area with that of other countries.

Unfortunately, there exist relatively few internationally comparable statistics to assist policy-makers in the area of 'Human resources in R&D'. Developing indicators in this area is therefore crucial to help policy-makers interested in fostering an innovation-led economic performance base.

For this theme five indicators were selected, of which two make use of available and internationally comparable data. These two indicators are:

- number of researchers in relation to the total workforce' which measures the human resource capacity in R&D of each country
- number of new science and technology PhDs in relation to the population in the corresponding age group' which gives an indication of the increase in the highly-qualified human knowledge base

Statistical data for these two indicators are available at Eurostat, the Member States, OECD and Unesco. In future work, it would be useful to investigate how the comparability of these data could be improved, and whether further breakdowns, for example by industry, discipline, country of origin, sex, type of organisation, could help to increase our understanding of the role of human resources in R&D.

The other three indicators are completely new and are not available at present in any internationally harmonized databases (they are therefore not presented here). Future work will be required by statistical offices to develop them. These three indicators are:

- number of young researchers recruited in universities and public research centres in relation to the total number of researchers, which reflects the attractiveness R&D professions for young science graduates and the prospects for sustaining a knowledge-based economy

- proportion of women in the total number of researchers in universities and public research centres, which gives an indication of the participation of women in science and their role in contributing to knowledge resources
- proportion of researchers from other countries amongst researchers in universities and public research centres, which reflects the international openness of national science systems and measures the diffusion of external knowledge

Indicator: Number of researchers in relation to the total workforce

What does this indicator tell us?

Research workers are responsible both for producing knowledge and for exploiting it. It is through research workers that firms can appropriate knowledge and use it to produce innovative new products. Moreover, researchers are a key source of new ideas and a crucial channel for learning within the company. They also become an important vector for the transfer of knowledge when they co-operate with other researchers in different institutions/countries, and when they change professions or move from one sector to another. In the public sector such workers play a vital role in the generation and transmission of basic research.

Analysis of national performance

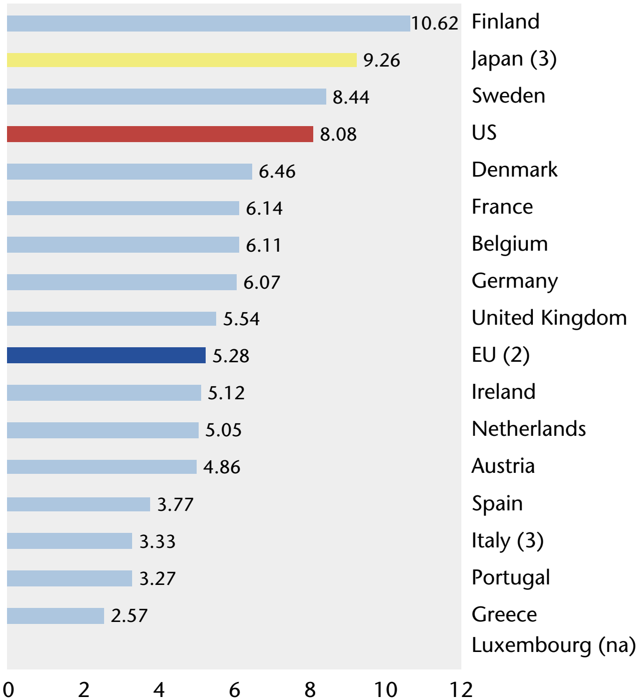
The presence of researchers in the total EU workforce (5.3 per thousand workforce) is considerably below that of Japan (9.3) and the USA (8.1).

Amongst the EU countries one can broadly detect three different groups. In the first one sees Finland and Sweden which have the highest proportion of researchers in their workforce, with levels closer to Japan and the USA than to the European average (Figure 1.1.1). Below these countries, one finds a group of Member States with levels of researchers above the EU average (DK, F, B, D and UK). The third group are situated below the EU average (IRL, NL and A close to the average, and E, I, P, GR somewhat lower).

The rate of increase in total number of researchers is also considerably higher in the USA compared with the EU average. In Europe, Ireland and Finland are the most dynamic countries in terms of increasing their number of researchers (Figure 1.1.2), while Austria, Portugal, Spain and Greece also show above average rates of growth. However, some of the larger Member States show more stable growth patterns below the EU average.

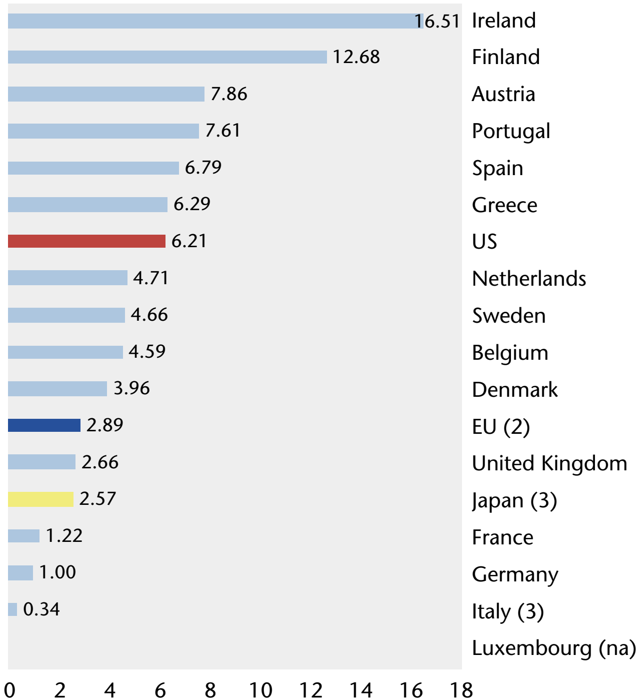
In figure 1.1.3 one sees the close relationship between the total spending on R&D and investment in human capital (number of researchers). Since salaries account for a significant part of R&D expenditure, the strong correlation is not surprising. However, differences in salaries may account for some of the divergence in R&D intensity between countries with similar proportions of researchers in their workforce.

Figure 1.1.1. Total researchers (FTE) per 000 workforce, latest available year (1)



Source: DG Research
Data: Eurostat, Member States, OECD, USA (NSF), Japan (Nistep)
Notes: (1) P,JP: 2000; D,E: 1999; B,EL,IRL,I,FIN,S:,US: 1997; all other countries and EU: 1998. **(2) L data are not included in the EU average.** (3) see annex.

Figure 1.1.2. Total researchers (FTE) - average annual growth (%), 1995 to latest available year (1)



Source: DG Research
Data: Member States, OECD, USA (NSF), Japan (Nistep)
Notes: (1) P,JP: 1995-2000; D,E: 1995-99; B,EL,IRL,I,FIN,S,US: 1995-97; A: 1993-98; all other countries and EU: 1995-98. **(2) L data are not included in the EU average.** (3) see annex.

Questions arising from the analysis of the indicator

It would be interesting to examine the following questions:

- How have Finland and Sweden achieved such a high proportion of researchers in their workforce?
- What are the factors and policies behind Ireland's rapid increase in numbers of researchers (what is the role or focused policies and what is the role of increasing total employment, as well as the catching-up growth observed in Portugal, Spain and Greece?
- What government policy measures are used in Member States to attract young graduates to R&D professions?
- What are the differences between countries in terms of the importance of the public sector as an employer of researchers, and what policies are used to stimulate such employment?
- What are the differences between the public sector and industry in terms of the supply of and demand for researchers?
- What will be the effects of the ageing population on the future stock of researchers?
- What are trends in numbers of researchers by sex? This question is being tackled by the Member States in the Helsinki Group (group of national civil servants on women and science).

Some comments on interpreting the indicator

The number of research scientists and engineers (RSEs) reflects the current use of human resources in R&D occupations. They exclude technicians and other supporting staff, and do not measure the supply of highly qualified S&T personnel, some of whom may be unemployed, or employed in non-S&T professions.

To give a more accurate estimate of human resources, data presented here are in full-time equivalents, and not pure headcounts of researchers. This allows one to take account of part-time working, etc.

Definitions and sources

Researchers are defined as the total number of research scientists and engineers in a country (Frascati Manual definition -paragraph 5.4.2.2) expressed in full-time equivalents (FTEs).

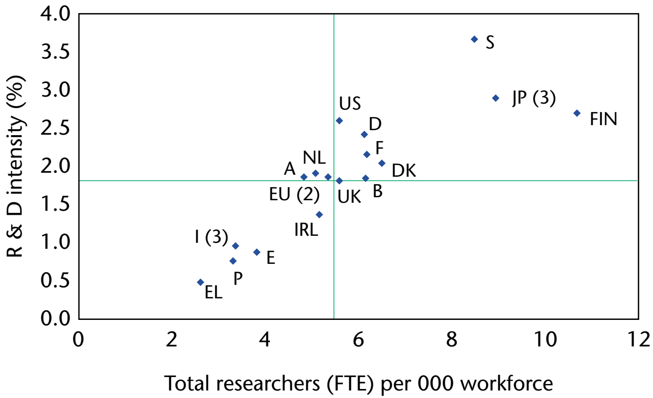
Source: OECD MSTI, Member States, USA (NSF) and Japan (Nistep).

Total workforce is defined as the total economically active population

Source: Eurostat, Community Labour Force Survey, Member States and Japan.

R&D intensity: see definitions in Theme 2 “Total research and development expenditure in relation to GDP”.

Figure 1.1.3. Total researchers (FTE) per 000 workforce and R&D intensity,1998 (1)



Source: DG Research
Data: Eurostat, Member States, OECD, USA (NSF), Japan (Nistep)
Notes: (1) P: 2000; D,E: 1999; B,EL,IRL,IT,FIN,S,US: 1997.
(2) L data are not included in the EU average. (3) see annex.

Indicator: Number of new science and technology PhDs in relation to the population in the corresponding age group

What does this indicator tell us?

In the new knowledge based economy, the availability of high quality human resources is essential for the generation and diffusion of knowledge. New PhD graduates in science and technology represent the highly qualified output of the education system in disciplines that will be of crucial importance for industry in this new economy.

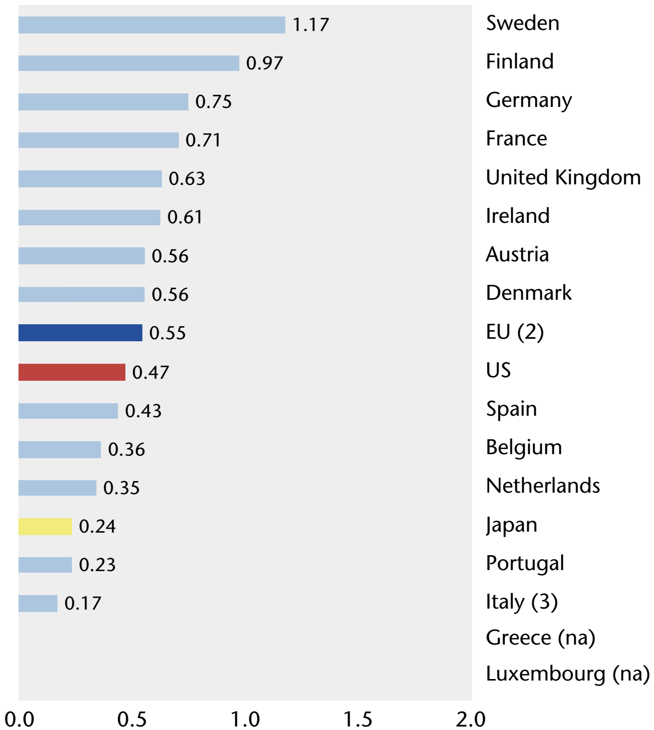
Analysis of national performance

The European Union has slightly more new S&T PhDs per thousand 25-34 year olds (0.55) than the USA (0.47), and significantly more than Japan (0.24).

Sweden, Finland, Germany and France have the highest proportions of new S&T PhDs (Figure 1.2.1).

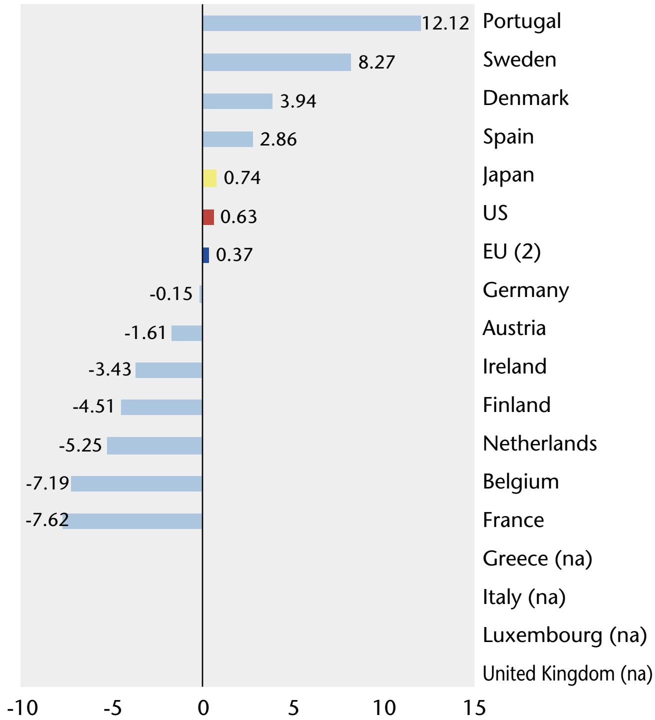
The catching up of Spain and Portugal is clear in Figure 1.2.2, which shows high growth of these two countries from a relatively lower base. Sweden achieves both high numbers of S&T PhDs per 25-34 population, and strong growth in new PhDs in 1999. In the two figures, we see that Germany, Austria and the USA have medium, and fairly stable, levels of S&T PhD output in relation to corresponding population. Amongst the countries with declining numbers of new S&T PhDs in 1999, Belgium and Netherlands have the lowest levels of new PhDs in relation to the corresponding population.

Figure 1.2.1. Total new Science and Technology PhDs per 000 population aged 25 to 34 years, latest available year (1)



Source: DG Research
Data: Eurostat, Member States, OECD, Unesco, Japan (Nistep)
Notes: (1) F,E,UK,EU: 1998; I: 1997; all other countries: 1999.
(2) EL,L data are not included in the EU average. (3) see annex.

Figure 1.2.2. New science and technology PhDs - growth (%), 1998-1999 (1)



Source: DG Research
Data: Eurostat, Member States, OECD, Unesco, Japan (Nistep)
Notes: (1) F,E: 1997-1998; all other countries and EU: 1998-99.
(2) EL,I,IRL,L,UK data are not included in the EU average.

Questions arising from the analysis of the indicator

It would be interesting to explore further the following issues:

- What good practices explain the strong performance of Sweden in producing doctoral graduates in science disciplines?
- While the larger EU countries (Germany, France, UK) have a relatively high annual output of S&T PhDs, these same countries show rather low rates of growth in their population of researchers (Fig. 1.1.2). What are the problems faced in channelling qualified scientists into S&T professions?
- Given that the EU is ahead of the USA and Japan in terms of new PhDs per population aged 25-34, it would be interesting to know more about their eventual career paths: what percentage actually become research scientists or engineers, and what proportion of them find work abroad?
- How does the output of the education system in S&T (both PhDs and S&T graduates more generally) meet the needs of the economy, and what are the key areas for the emerging knowledge economy?
- What are the trends and relevant policies in terms of recruitment of young researchers by universities and public research institutes?

Some comments on interpreting the indicator

It should be borne in mind that there are large variations between the education systems of different countries, which can raise some problems for distinguishing PhDs from certain other forms of advanced research qualification. For example, the number of graduates might also be considered as a potential source for future researchers.

There are also important differences between countries with respect to the age of attainment of a PhD. Moreover, the number of new PhDs is strongly dependent on the population structure. For these reasons, the indicator used relates PhD output to the population in the corresponding age group (taken to be 25-34 to cover the heterogeneity in national education systems).

There may be some discontinuity in PhD data arising from the change from the old ISCED76 to the new ISCED97. For this reason, the analyses presented here only use data collected according to ISCED97 which covers the period 1998 - 1999 (1997-1998 for France and Spain).

Definitions and sources

Science and technology PhDs are defined as PhD graduates in the following disciplines (ISCED97 classes in brackets): Life sciences (ISC42), Physical sciences (ISC44), Mathematics and statistics (ISC46), Computing (ISC48), Engineering and engineering trades (ISC52), Manufacturing and processing (ISC54), Architecture and building (ISC58).

Source: Joint Unesco / OECD/ Eurostat Questionnaire, Member States and Japan.

Population in the corresponding age group is defined as the population aged 25-34 years. *Source:* Eurostat, Demography statistics.

THEME 2: Public and private investment in R&D

R&D expenditure and financing are at the very centre of a knowledge-based economy because its dynamics and competitiveness depend primarily on the production, distribution and exploitation of knowledge and information. In this approach, knowledge is a factor of production and its production (investment in knowledge) responds to economic incentives. Knowledge is produced by public R&D systems, education and training systems and by firms. Therefore, knowledge originates from different actors, sectors and organisations.

This view of the production of knowledge as an investment in different sectors and by various actors is reflected in the indicators relating to R&D expenditure. The R&D expenditure of various actors (public, business) measures the efforts devoted to the production and use of knowledge that takes place in the context of research activities. However, since R&D expenditure is only an input factor, it gives no information about the efficiency of producing knowledge outputs, which is determined by the efficiency of the innovation system (research infrastructure, co-operation, interactions, capability to absorb external technology etc.).

Investment in knowledge is understood as an economic activity. However, certain characteristics of knowledge such as weak appropriability of knowledge outputs, uncertainties and indivisibility in knowledge production, generate an under-investment in knowledge in the economy. The social returns of knowledge investment are higher than the private returns, which justifies public support for basic public, scientific research as well as in certain cases for other actors conducting research activities. The indicators relating to the proportion of the government budget allocated to research, and the share of SMEs in publicly funded R&D executed by the business sector both reflect a political decision to support knowledge production, either generally or by specific actors such as SMEs.

The capital market functions imperfectly in financing new, high tech and knowledge intensive activities that are risky and uncertain. This weakness requires that new sources of finance and adequate institutional frameworks are created for financing new, risky and promising opportunities. The indicator on venture capital investment in early stages of firm's life cycle (seed and start-up) describes the utilisation of new financing instruments. The venture capital industry plays an additional, very important role for firms in early stages as it provides managerial skills and economic competencies for these firms, and therefore increases their probability of survival in the market. However, such competencies still need to be created in Europe where the venture capital industry itself is in early stage of development.

Statistical data for the indicators in theme 2 are available primarily from Eurostat, member states and OECD. The Japanese (Nistep) and US (NSF) data come originally from the OECD. The Japanese authorities have confirmed and completed the data. Only the data for venture capital come from unofficial - but comparatively reliable - sources for the EU countries (EVCA), the USA (NVCA) and Japan (VEC). The comparability is seriously weakened for the data on SMEs even in the EU member states, the USA and - particularly - in Japan because of differences in the definition of SMEs. Such problems should be solved at a later stage.

Theme 2 about public and private investment in R&D, therefore, focuses on knowledge creation through various types of R&D activities and their financing either in the public or business sector and by various actors. The following indicators have been selected:

- Total research and development expenditure in relation to GDP,
- Research and development expenditure financed by industry in relation to industrial output,
- Share of the annual government budget allocation to research,
- Share of SMEs in publicly funded R&D executed by the business sector,
- Volume of venture capital investment in early stages (seed and start-up) in relation to GDP.

Indicator: Total research and development expenditure in relation to GDP

What does this indicator tell us?

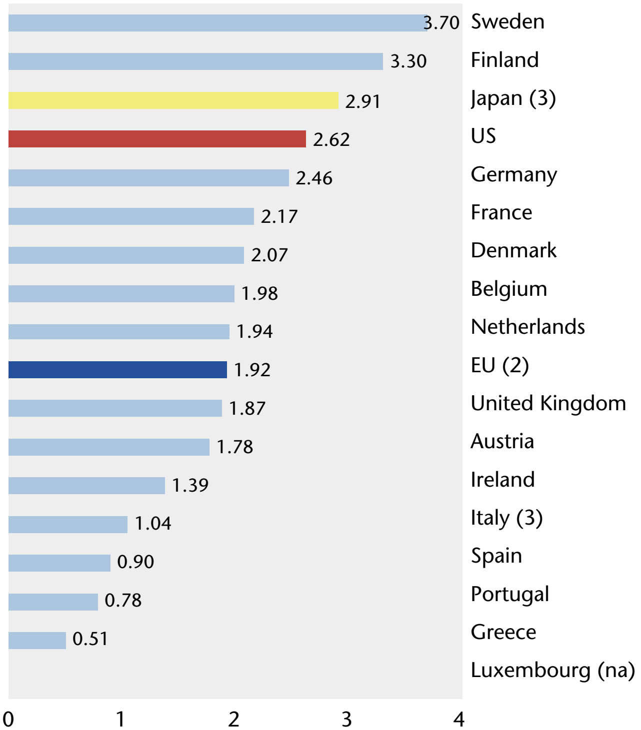
The share of R&D expenditure in GDP expresses a country's relative efforts to create new knowledge, to disseminate and to exploit the existing knowledge bases both in the public and in the business sector. R&D expenditure represents one of the major drivers of economic growth in a knowledge-based economy. High levels and strong dynamics of R&D intensity positively support the future growth dynamics of a country.

Analysis of national performances

R&D intensity was higher in the USA and Japan than in the EU. Average annual growth (1995 to the last available year) of total R&D spending (Figure 2.1.2) and of R&D intensity were also higher for these two countries (Figure 2.1.3). This development implies that the gap in the R&D intensity between the USA and EU widened during this period.

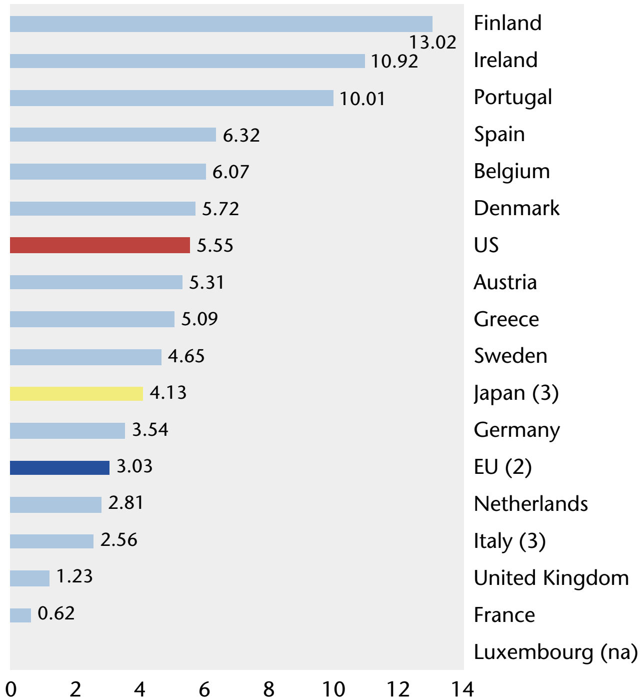
Within the EU there is great diversity. In particular, Sweden and Finland have a significantly higher R&D intensity than all other Member States as well as the USA and Japan. In particular, Finland stands out in that it has both a high intensity and a high real growth rate of R&D expenditure, while Sweden's growth rates are more moderate, although higher than the EU average.

Figure 2.1.1. R&D intensity (%), latest available year (1)



Source: DG Research
Data: Eurostat, Member States, OECD, Japan (Nistep)
Notes: (1) D,A,P,FIN: 2000; NL,JP: 1998; EL,IRL,S: 1997; all other countries and EU: 1999. **(2) L data are not included in the EU average.** (3) see annex.

Figure 2.1.2. R&D expenditure - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research
Data: Member States, OECD, Japan (Nistep)
Notes: (1) D,A,P,FIN: 1995-2000; NL,JP: 1995-98; EL,IRL,S: 1995-97; all other countries and EU: 1995-99. **(2) L data are not included in the EU average.** (3) see annex.

On the other hand, R&D intensity in Germany, France, Belgium, and Denmark is higher than the EU average R&D intensity (Figure 2.1.1). However, only Belgium and Denmark experience relatively high growth rates of R&D intensity followed by Germany while in contrast, Netherlands, United Kingdom and France have negative growth rates. (Figure 2.1.3).

R&D intensities in the Netherlands, UK and Austria are at roughly the level of the EU average. However, only Austria's growth rate of R&D expenditure is higher than that of the EU average. In the Netherlands and UK, the growth rate for R&D expenditure is very modest, and R&D intensity is falling (Figure 2.1.3).

At low levels of R&D intensity, only Portugal is in a real process of catching up. While total R&D expenditure has grown very rapidly in Ireland, so has its GDP, resulting in a more modest increase in its R&D intensity.

Questions arising from the quantitative analysis

A high level and strong dynamics of R&D intensity are the basis for strong growth of a knowledge-based economy. However, market forces alone may not generate the optimal level of R&D investment in an economy. Research and technology policy addresses this gap through support for investment in scientific research as well as in selected business sector research activities. Thus, the dynamics of R&D intensity may also reflect the success of policy measures in a country.

How can Finland and - to a lesser extent – Sweden, both already at high levels of R&D intensity, manage to increase this intensity more than all the other countries? It would be useful to have a better understanding of research and technology policy practices in these countries in order to gain insights into successful policy designs. What role does size of the country, i.e. scale, play in determining policy strategies?

What types of public policy measure might explain Portugal's strong rise in R&D investment from a comparatively low level? The same question is valid also for Ireland and Spain, although the trends are slightly less marked.

What is the role of international technology transfer in technology policy, which is very important for countries at a lower R&D intensity?

What are the roles of the public sector and/or business sector for the dynamics of this indicator, and what are the related policies?

Considering Italy's economic and technological capacity what obstacles explain the relatively lower dynamics of R&D expenditure?

What factors explain the relatively weak dynamics (Germany, UK and France), particularly the decreasing R&D intensities in UK and France? Does this result from policies that allocate economic resources to less R&D-intensive activities because they have a higher return? Or is the optimal level of R&D investment constrained by macroeconomic factors such as public sector budget deficits?

Some comments on interpreting the indicator

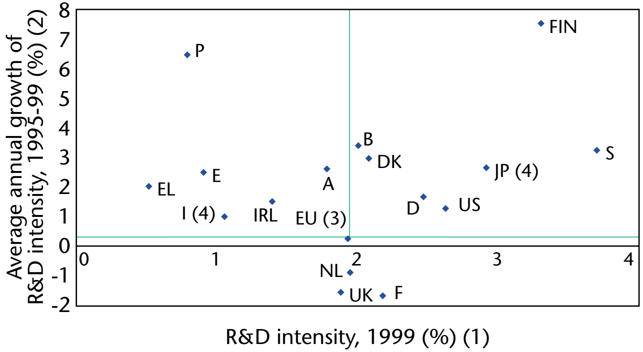
This is an aggregate indicator which conceals several structural and qualitative aspects that should be kept in mind when comparing across countries. The most important aspects are:

- The level of R&D expenditure will depend partly on the structure of the industrial sectors in a country. If a country is specialised in industries that typically have a high R&D intensity the value of the indicator will be high.
- The characteristics of the enterprise population will also affect this indicator because the propensity to invest in R&D differs across types of firms (such as size or nationality).
- Total R&D indicators include both public and business sector R&D expenditure. The breakdown of expenditure between these sectors varies considerably across countries.
- This important indicator measures only the investment in R&D, while performance is also a function of the efficiency of the innovation system.
- R&D intensity is sensitive to the business cycle. Therefore, the period of analysis will affect the value of the indicator.

Definitions and sources

Total research and development expenditure is defined as Gross domestic expenditure on R&D (GERD) according to Frascati-Manual definition, in national currency, converted to Euro and PPS. *Source*: Member States. OECD for the USA. OECD and national sources for Japan.

Figure 2.1.3. R&D intensity and average annual growth of R&D intensity



Source: DG Research
Data: Eurostat, Member States, OECD, Japan (Nistep)
Notes: (1) D,A,P,FIN: 2000; NL,JP: 1998; EL,IRL,S: 1997.
(2) D,A,P,FIN 1995-2000; NL,JP: 1995-98; EL,IRL,S: 1995-97.
(3) L data are not included in the EU average. (4) see annex.

Gross domestic product (GDP) is defined according to National Accounts ESA 1995 definition, in national currency and current prices, converted to Euro and PPS.

Source: Eurostat, Member States and national sources for Japan.

Indicator: Research and development expenditure financed by industry in relation to industrial output

What does this indicator tell us?

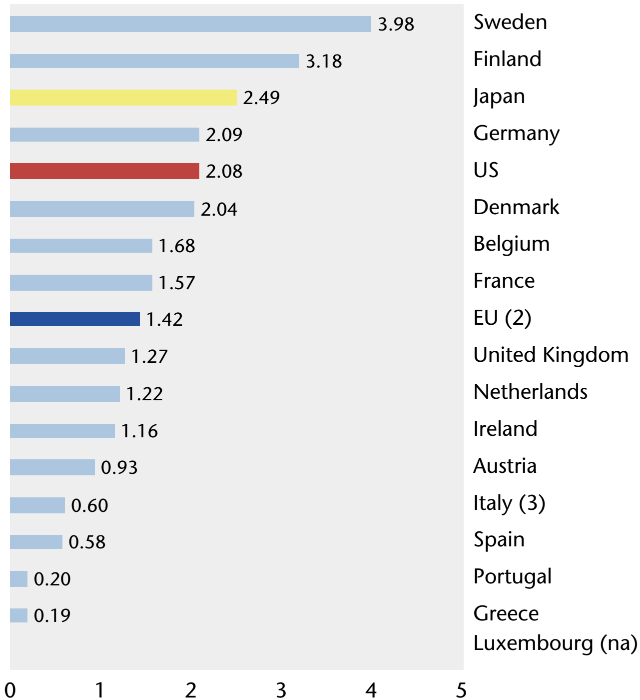
R&D expenditure financed by industry describes the innovative efforts of industry in creating new knowledge and in exploiting existing knowledge bases. These financial resources are directed towards industry needs, and tend to be focused on applied and development research with more direct economic objectives than public research. In addition to public funding of R&D, R&D financed by industry provides the basis for future industrial competitiveness.

Analysis of national performances

The relative effort made by industry to finance R&D is lower in the EU than in the USA and Japan (1.4% in EU versus 2.1% in USA and 2.5% in Japan). Also, the growth rate of R&D financed by industry is considerably higher in the USA than that of EU average.

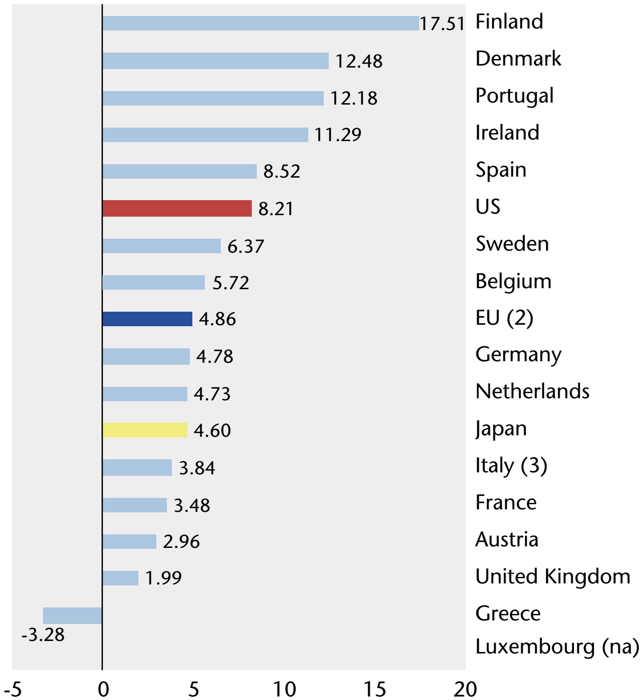
Within the EU the share of industrial output allocated to R&D differs significantly between countries. Certain countries - Sweden, Finland Germany and also Denmark - reach values for the relative industry financed R&D around those of the USA and Japan. In particular, Sweden and Finland have a considerably higher values (4.0% and 3.2% respectively) than the USA. In particular, Finland but also Denmark experience a much stronger growth in industry-financed R&D than the USA.

Figure 2.2.1. Industry financed R&D as % of industrial output, latest available year (1)



Source: DG Research
Data: Member States, OECD, Japan (Nistep)
Notes: (1) D: 2000; F,NL,JP: 1998; EL,IRL,P,S: 1997; all other countries and EU: 1999. **(2) L data are not included in the EU average.** (3) see annex.

Figure 2.2.2. Industry financed R&D - average annual real growth, 1995 to latest available year (1)



Source: DG Research
Data: Member States, OECD, Japan (Nistep)
Notes: (1) D,A,P: 1995-2000; F,NL,JP: 1995-98; EL,IRL,S: 1995-97; all other countries and EU : 1995-99.
(2) L data are not included in the EU average. (3) see annex.

The relative effort made by industry to finance R&D is slightly above the EU average in Belgium and France, and in Belgium growth of this R&D is also higher than the average for the EU. All other Member states reach values of relative R&D efforts financed by industry that are below the EU average. Some of them (such as Austria and UK) also have low growth rates of this investment, while Greece has experienced a negative growth. In contrast, Portugal, Ireland and Spain - who all have relatively low intensities of business financed R&D - are catching up, with growth rates well above that of the EU average (and that of the USA).

Questions arising from the quantitative analysis

A high level and strong dynamics of R&D financed by industry indicates strong innovative efforts, i.e. the creation of new knowledge and the utilisation of existing knowledge bases. However, market forces alone do not generate an optimal level of R&D financed by industry for the economy. Therefore, technology policy utilises diverse instruments for supporting the R&D activities of the industry. Consequently, the dynamics of R&D finance reflects also the success of the technology policy in various countries.

What types of policy instruments and designs explain the initially high levels and the strong dynamics of R&D financed by industry in relation to its output in Finland, Sweden and Denmark? What can be learned from these policy practices?

For those countries at a low initial level of R&D expenditure financed by industry, the question arises: what type of policy instruments support the catching-up processes (e.g. in Portugal and in Spain)?

What is the impact of the structure of the enterprise population, and in particular of specialisation in high tech industries, on R&D expenditure?

To what extent is the success of some countries in terms of business financing of R&D activities due to favourable framework conditions?

What factors explain the totally different dynamics of R&D financed by industry in Portugal and Greece, which are both at a low level of relative R&D efforts financed by industry?

Is there a substitution effect between public and business sector financing of research?

Some comments on interpreting the indicator

This indicator also has certain characteristics that may raise problems for interpretation:

- R&D expenditure is divided by industrial production and not by value added. Production, however, may contain differing intermediate chains and values, which makes the comparison across countries difficult.
- The level of R&D financed by industry also depends on the structure of industry. If a country is specialised in industries that typically have a high R&D intensity the value of the indicator will be high.
- The characteristics of the enterprise population will also affect this indicator because the propensity to finance R&D differs across types of firms: SMEs have a typically low propensity to finance R&D, while foreign-owned firms might have a typically higher propensity.
- The efficiency of R&D expenditure financed by the industry will be influenced by the structure of the innovation system and, in particular, existence of connections and networks between public and business research.
- High growth rates of industry financed R&D of a small country might not reach absolute increases of a large country at a much lower growth rate.

Definition and sources

Research and development expenditure financed by industry is defined as GERD financed by the Business enterprise sector according to Frascati-Manual definition, in national currency and converted in Euro. *Source*: Member states, OECD for the USA. OECD and national sources for Japan.

Industrial output is defined as the domestic product of industry (DPI), in national currency and converted in Euro. *Source*: OECD and Member states. National sources for Japan.

Indicator: Share of the annual government budget allocated to research

What does this indicator tell us?

The share of the annual government budget allocated to research measures the relative importance given to R&D in the government's general spending commitments and, therefore, indicates the relative position accorded to R&D amongst government spending measures. The government plays an important role in allocating resources to the production of scientific knowledge and – to a lesser extent - in stimulating knowledge creation in the business sector. Government research budget is, therefore, vitally important in supporting the transition towards the knowledge-based economy.

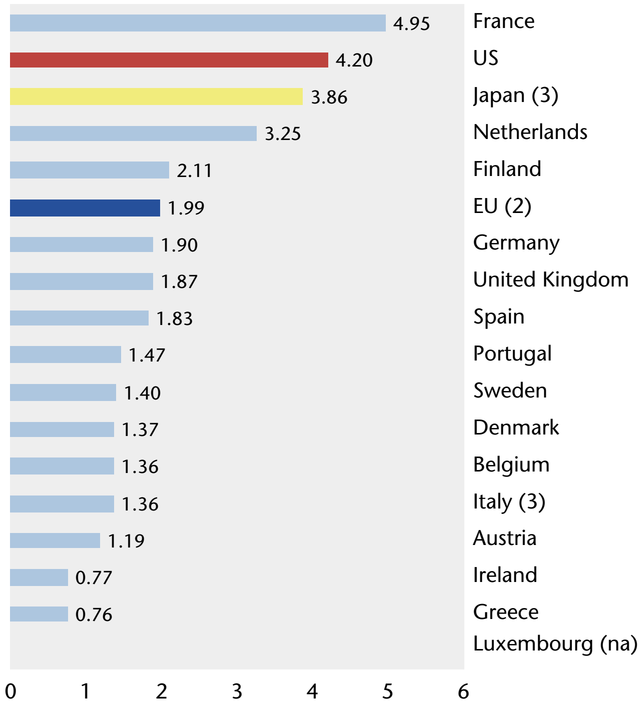
Analysis of national performances

In international context, the share of government R&D budget in the EU is considerably lower than that of the USA and also that of Japan. Similarly, the EU's government R&D budgets grows at a much lower rate than in Japan and also – even if less outstanding – in the USA.

The importance that is given to R&D support in government budgets varies considerably between the member states. In France and the Netherlands the role of the government R&D budget is very high (5.0% and 3.3% respectively) compared to the EU average (2.0%) and to the other European countries. However, in France the government R&D budget – at an initially high level - registered an average annual decline during the period 1995-1999. The shares of government budgets reach in Finland, Germany, UK and Spain values that are around the EU average, but, of these four countries, only Spain had a very high growth rate of government R&D budget followed by Finland.

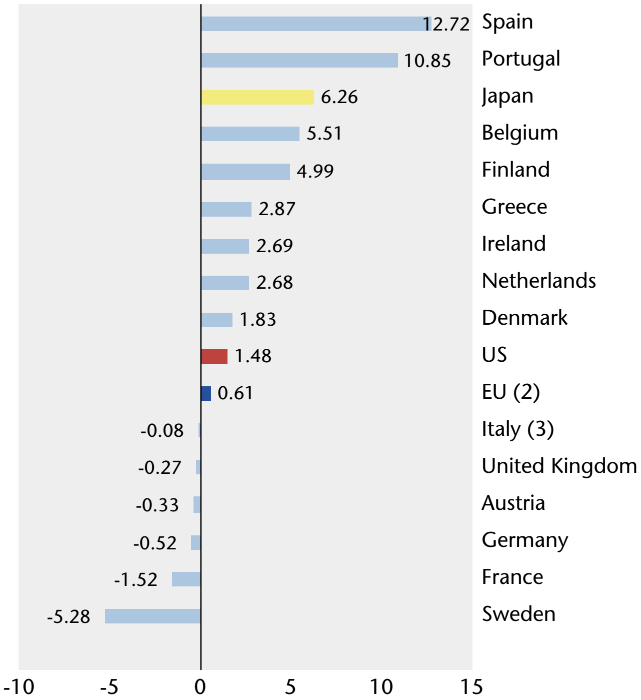
Portugal, Sweden, Denmark, Belgium and Italy have relatively low shares of government budget allocated to research. Among these countries, only Portugal has had a very high growth rate followed by Belgium; both are therefore catching-up from a low level. Sweden showed strong negative growth in 1995-2000, as did Italy, although its decrease was much less dramatic.

Figure 2.3.1. Share of government budget allocated to R&D, latest available year (1)



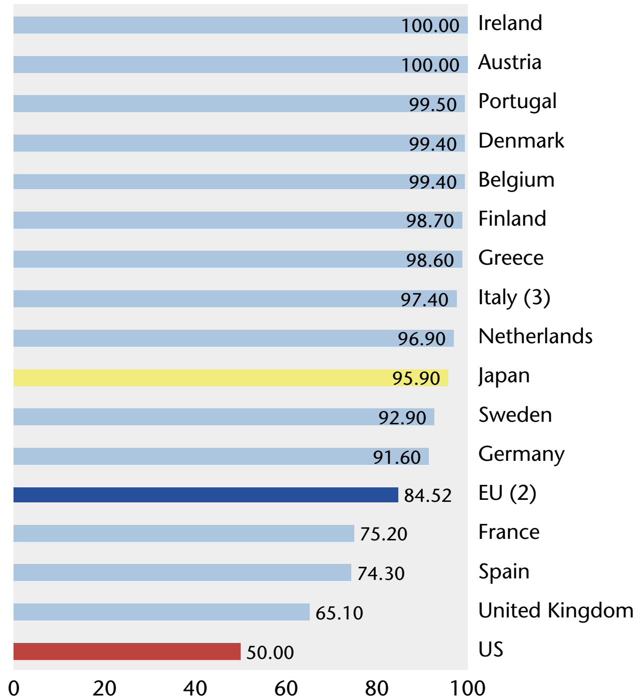
Source: DG Research
Data: Eurostat, Member States, DG Ecfin, USA (NSF), Japan (Nistep)
Notes: (1) B,EL,E,F,IRL,I,UK,US and EU: 1999; all other countries: 2000. **(2) L data are not included in the EU average.** (3) see annex.

Figure 2.3.2. Government R&D budget - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research
Data: Eurostat, Member States, DG Ecfin, USA (NSF), Japan (Nistep)
Notes: (1) 1995-99: B,EL,E,F,IRL,I,UK and EU; all other countries: 1995-2000. **(2) L data are not included in the EU average.** (3) see annex.

Figure 2.3.3. Government R&D budget - civil R&D as % of total, latest available year (1)



Source: DG Research
Data: Eurostat, Member States, DG Ecfin, Japan (Nistep)
Notes: (1) D,A,FIN,S,US,JP: 2000; F,I: 1998; all other countries and EU: 1999. **(2) L data are not included in the EU average.** (3) see annex.

Austria, Ireland and Greece have a very low share of the annual government budget allocated to research (excluding interest). While Greece and Ireland have positive growth rates well above the EU average, in Austria the average annual growth rate was negative during the period 1995-2000.

The relative importance of civil and defence R&D in total R&D budget varies between countries (Figure 2.3.3). Some of the negative growth rates may result from declining defence expenditure in the wake of the breakdown of the Soviet regime - and perhaps also partly due to the efforts to meet the Maastricht convergence criteria.

Questions arising from the quantitative analysis

Given the essential role that the government R&D budget plays in knowledge production in the economy, several aspects relating to policy design are important to explore:

What factors explain the extremely high share of research in the French government budget, and – to a lesser extent – in that of the Netherlands?

What factors explain the negative growth rates in France and Sweden? Is this a result of declining defence expenditure?

What are the reasons for, and what policies explain, the negative growth rates of the R&D budget in Sweden, which already has a relatively low share. Is this a real reduction or a switch to other types of instruments?

What policies explain the strong catching up process in Spain and Portugal?

What share of the government budget for R&D is really available for new active policy, given the large amounts devoted to salaries for researchers and the operating costs of public research institutes?

Some comments on interpreting the indicator

In interpreting this indicator the following points should be kept in mind:

- The government budget covers only the direct government support for a country's R&D expenditures. Other, indirect policy measures are also available that are not included in government budget data, for example R&D credits or tax incentives.
- The bulk of the public budget is usually spent on salaries of public sector researchers and on running of the public sector research institutes.
- The share of the annual government budget allocated to research covers only budget appropriations or outlays as opposed to realised expenditure.
- The comparability of the Japanese data depends on the discrepancy of the definition between "Annual government budget" and "General budget expenditure"

Definition and sources

The government budget allocated to research is defined as government budget appropriations or outlays for R&D (GBAORD) according to The OECD Frascati-definition (except in Japan), in national currency and converted into Euro and 1995 Purchasing

Power Standards (PPS95). *Source*: Eurostat and Member States. For the USA: NSF.

The annual government budget is defined as general government expenditure (excluding interest), in national currency, ESA 1995. *Source*: DG EcFin (AMECO database), data originally from Eurostat and Member States. The data for Japan is provided according to "General budget expenditure" that comes nearest to definition of "Annual government budget". *Source*: Annual Report on Promotion of Science and Technology, Ministry of Education, Culture, Sports, Science and Technology. The source for the US data: NSF.

Indicator: Share of SMEs in publicly funded R&D executed by the business sector

What does this indicator tell us?

This indicator informs us about the relative importance of SMEs in executing publicly funded R&D. Public funding of R&D gives governments an instrument for directing resources to their chosen research priorities (sectors, technology fields) and/or to certain types of performers (categories of firms). Supporting SMEs in their research and development activities has become an important policy objective over recent years, and SMEs appear to provide a fertile breeding ground for new ideas and innovative ways. However, their activities can be hampered by lack of resources, and by the relatively high information and administrative costs of participating in research programmes.

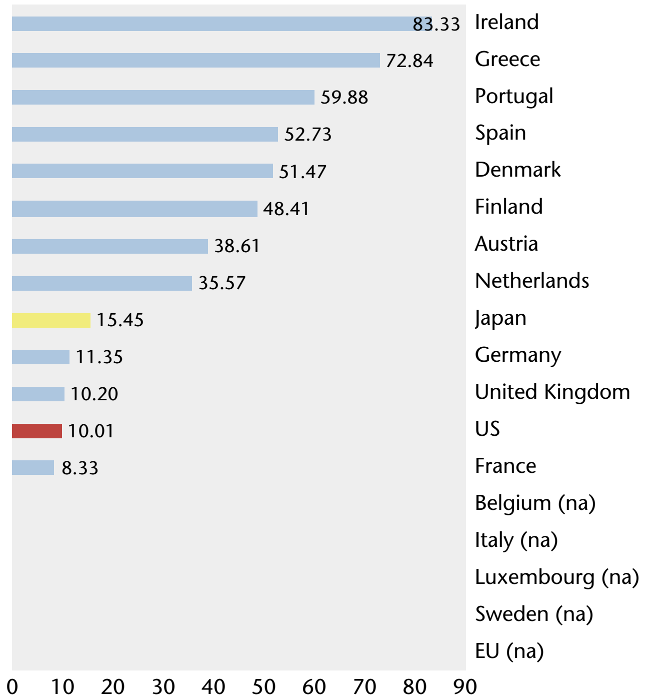
Analysis of national performances

The share of SMEs in publicly funded R&D executed by the business sector is considerably higher in the small European countries (Ireland, Greece, Portugal, Denmark, Finland, Austria, the Netherlands and in Spain) in comparison to Japan. However, in the USA this indicator stands behind almost all European countries. Generally, in Europe the relative share of publicly funded R&D executed by SMEs is considerably higher for the small countries than for the large countries (Germany, UK, France)-Spain making an exception. This might be explained by the size structure of the enterprise population in these countries (i.e. if the small countries have much higher proportions of small companies). In this case, this indicator will score more highly in the smaller countries than in the larger ones.

Among the countries with a high share of SMEs in publicly funded R&D, Ireland (83.3%) has the highest value, followed by Greece, Portugal and Spain. Although they start at high levels, growth rates are still very high for Portugal and Spain and also for Ireland, while in Greece the growth rate is rather low.

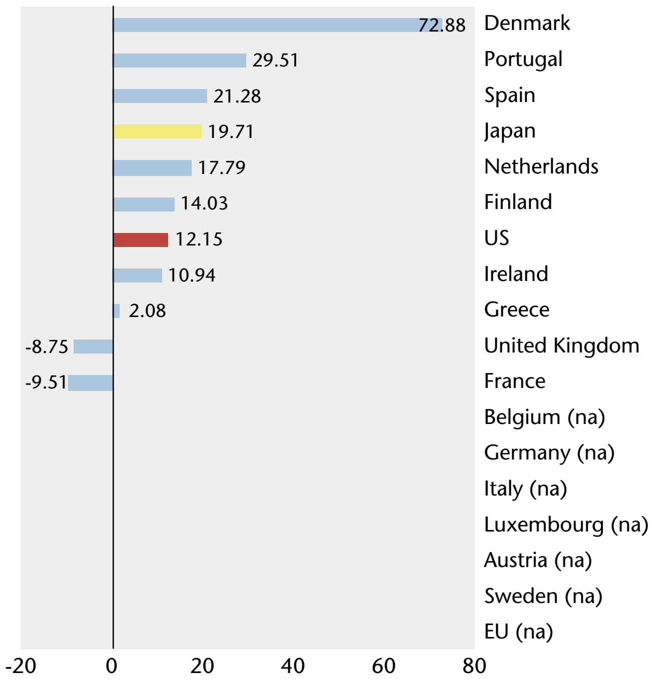
The dynamics of this indicator shows considerably differences between countries and in international comparison. Now Japan's growth rates lies above that of the USA and many European countries – except those in Denmark, Portugal and Spain. In Europe, there are important differences in the dynamics of this indicator. Denmark is an exception as it has both a high value for the share of publicly funded R&D executed by SMEs, combined with a very high growth rate.

Figure 2.4.1. Share of SMEs in publicly funded R&D executed by the business sector (%), latest available year (1)



Source: DG Research
Data: Member States, OECD, USA (NSF), Japan (Nistep)
Note: (1) P: 2000; FIN,UK,JP,US: 1999; D,EL,IRL: 1997; all other countries: 1998.

Figure 2.4.2. Publicly funded R&D executed in the SMEs sector - average annual real growth (%), 1995 to latest available year (1) (only available for eleven countries)



Source: DG Research
Data: Member States, OECD, US (NSF), Japan (Nistep)
Notes: (1) P: 1995-2000; FIN,UK,JP: 1995-99; F: 1995-98; EL,IRL: 1995-97; NL: 1996-98; DK: 1997-98; E,US: 1997-99.

Among the large countries, not only are the shares low, but the growth rates are also negative for UK and France (Germany has only one value, so no growth rate could be calculated).

Questions arising from the quantitative analysis

This indicator reflects the relative importance of SMEs in executing publicly funded research in the business sector. This is one of the principal policy instruments in supporting research activities in the business sector. Some central questions for further analysis include:

- What factors and policies explain the exceptional Danish experience with a high share of publicly funded R&D executed by SMEs and a very high growth rate?
- Are the high shares of SMEs in publicly funded R&D executed in the business sector in Ireland, Portugal and Greece an outcome of a specific policy for supporting SMEs' research activities and research participation?
- For those countries with low values for this indicator, one should analyse whether the result comes from policy priorities towards large firms (more developed policy instruments compared with those for SMEs) or from the structure of the enterprise population.
- What factors explain the negative growth rates in UK and France? (For example, restructuring processes in the economy (M&A) that decrease the number of SMEs).

Some comments on interpreting this indicator

In interpreting this indicator, the following points should be kept in mind:

- The definition of an SME (size and other characteristics) differs between countries. The problem is even more complex than just finding a common definition, because the typical size of large or small firms may vary across countries depending on their size or sectoral characteristics.
- The value of the share is not only influenced by policy priorities, but also by the relative shares of large and small firms in the enterprise population.
- The share of SMEs in high tech industries varies between countries.
- This instrument is one possible instrument for supporting R&D in SMEs. Other possibilities include, for example, R&D tax reductions and R&D credits etc., which may also play an important role.

Definitions and sources

Publicly funded R&D executed by the business enterprise sector (BERD financed by government) is defined according to the OECD Frascati Manual, and expressed in national currency. *Source*: OECD, Member States and Japan.

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 40 million, or an annual balance-sheet total not exceeding ECU 27 million, and conform to the criterion of independence as defined in paragraph 3 in 96/280/EC: Commission Recommendation of 3 April 1996).

The data received on SMEs do not always comply with the above Eurostat definition. The comparability of these data is therefore uncertain and should be analysed in detail at a later date. Japanese definition for SMEs concerns companies with less than "300" employees.

Source: Member States, Japan (Report on the Survey of Research and Development, Statistics Bureau) and the USA (NSF).

Indicator: Volume of venture capital investment in early stages (seed and start-up) in relation to GDP

What does this indicator tell us?

The economic function of seed and start-up venture capital funding is to provide financing to high risk, promising new high tech and knowledge intensive companies. Although small in relative terms, the volume of venture capital in early stages in relation to GDP plays a strategic role in financing innovations and, thus, in supporting structural change towards a knowledge-based economy. In particular, venture capital companies provide not only equity capital, but also managerial skills and competencies that are critical for the success of firms at the early stages of their life cycle.

Analysis of national performances

While the EU average for the intensity of early stage venture capital is clearly below that of the USA and Japan, the real growth rates for this type of venture capital were remarkably higher in EU average than in the USA and Japan.

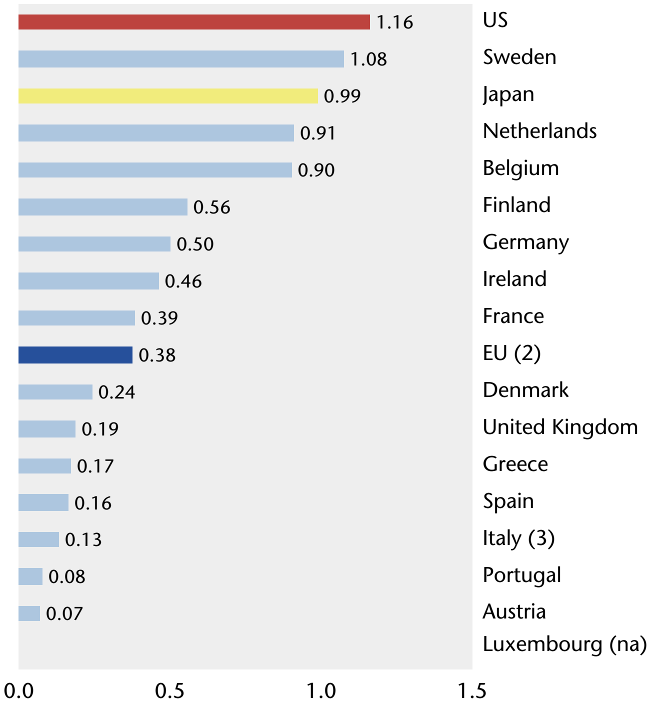
In Europe, the rapid development and catching-up of the venture capital industry began in the 1990s. Certain countries - Sweden, Belgium and NL - already have a high intensity of early stage venture capital. However, only Sweden is in the position of increasing its early stage venture capital investment very rapidly from a high level of intensity.

In Finland, Germany, France and Ireland, the early stage venture capital intensity is roughly around the EU average, at a relatively modest level. However, the growth rates for these countries are rather high, especially in Ireland and France (more than 100 % growth).

Another group of countries - Italy, Greece, Spain UK, Denmark and Austria - have an early stage venture capital intensity that is considerably lower than the EU average. In this group, only Austria is experiencing strong dynamics in its early stage venture capital funding, starting from a very low level, but catching up at an annual average rate of 163.8 % during the period 1995-99.

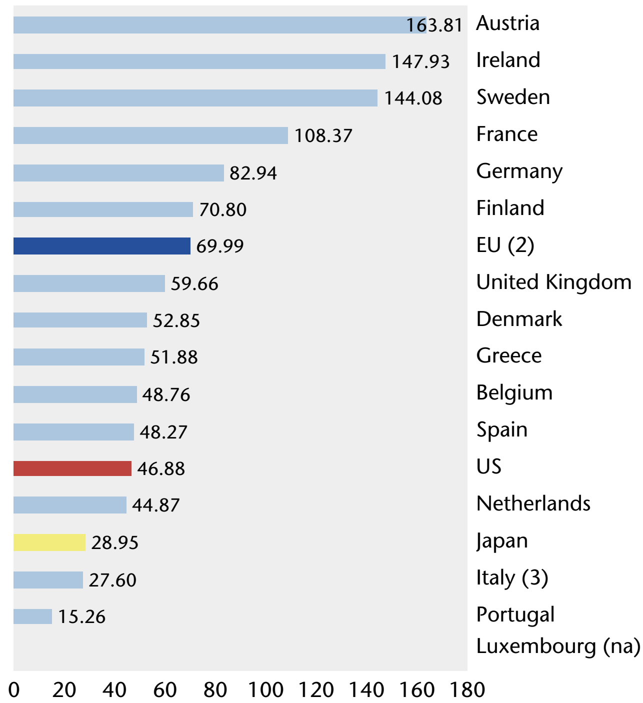
On the other hand, UK, Spain, Greece, Italy, Denmark and Portugal have both relatively low intensities and low growth rates compared with the corresponding EU averages.

Figure 2.5.1. Seed and start-up venture capital - investment per 000 GDP, latest available year (1)



Source: DG Research
Data: Eurostat, EVCA, NVCA, VEC
Notes: (1) JP: 2000; all other countries refer to 1999. **(2) L data are not included in the EU average.** (3) see annex.

Figure 2.5.2. Seed and start-up venture capital investment - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research
Data: Eurostat, EVCA, NVCA, VEC
Notes: (1) JP: 1995-2000; B: 1998-99; all other countries and EU refer to 1995-99. **(2) L data are not included in the EU average.** (3) see annex.

While there is a wide diversity of early stage intensities in Europe, the fast growth of early stage venture capital investment in most countries underlines the increasing importance of venture capital as a source of funding for the R&D activities in early stage firms.

Questions arising from the quantitative analysis

Venture capital funding for early stage high tech and knowledge intensive companies plays a strategic role for economic dynamics, since capital markets function imperfectly in financing risky and uncertain projects (such as high tech and knowledge intensive start-ups). Consequently, supporting the emerging venture capital industry is a significant part of technology policy in several European countries. These policies obviously differ considerably between countries.

What are the financial and other regulatory measures of Member States explaining the surge of early stage venture capital investment, in particular in Sweden?

What policy measures explain the strong growth in early stage venture capital funding in Austria compared with Italy or UK, which have similar levels of early stage venture capital intensity?

At the European level, how important are the efforts of the Risk Capital Action Plan (SEC(98)552) in abolishing the fragmentation of the European risk capital market and in supporting the development of risk capital in the European Union ?

Some comments on interpreting the indicator

The interpretation of this indicator should consider several qualitative aspects when compared across countries:

- Venture capital is only one financial source for start-ups. Other sources such as bank loans and grants or credits backed up by the state can also play an important role. Obviously, the relative importance of venture capital varies between countries, depending on the structure of the capital markets, institutional regulations and the role of the state in early stage financing.
- The managerial quality of the venture capital industry differs considerably between countries, resulting in varying survival rates. In the USA, the tradition of providing business competencies is very strong, while in Europe it is still rather weakly developed.
- The definitions of venture capital and the various stages vary between countries, which makes comparisons difficult between the EU, the US and Japan. Comparisons are particularly difficult with the Japanese figures because certain assumptions must be made for estimating the venture capital in early stages. The credibility of the data depends therefore on the correctness of these assumptions. Also the survey population is different in Japan.

Definitions and sources

Venture capital in early stages of a company - i.e. seed and start-up stages – provides financing mainly for the initial business plan, research activities, the product development and first marketing. It is part of total venture capital (= equity investments made for the launch, early development or expansion of business). Total venture capital itself is a part of total private equity capital to enterprises not quoted on a stock market. The definitions of seed and start-up venture capital in the US also include first-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.

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

Gross domestic product (GDP) has been collected according to national accounts definition (ESA 1995 definition), and is expressed in euros and current prices.

Source: Eurostat

THEME 3: Scientific and Technological Productivity

In our ever globalising economies, with their increasingly similar competition bases, measuring the workforce in science and technology across countries catches the interest of policy-makers. It is, however, a difficult task for three reasons:

Firstly, because there are different definitions in terms of ‘who to count’; secondly, because there are different definitions for ‘occupational or industrial categories’; and thirdly, because of the sheer limitations of existing datasets.

Although measuring the productivity of the workforce in science and technology is a difficult task, several indicators have been developed such as

- the number of patents,
- the number of scientific publications and the number of citations of highly cited publications,
- the percentage of innovative firms cooperating with other firms/universities/public research institutes’ which indicates the cooperation patterns which may contribute to strengthening knowledge and innovation transfers.

For these indicators data are available which allow for international comparisons, and the most recent figures are presented in this section.

Further developments which could be interesting to explore in future work include: the share of patents in high tech areas, per business R&D expenditure or per thousand researchers, and the number of scientific publications by science domain, per non-business R&D expenditure, per thousand researchers, as well as the proportion of joint publications in the national total.

It is important to note that the patent indicator is not only used to measure the technological performance of a country, but is often used as a proxy for innovation activities. However, it should be kept in mind that information on patents should always be seen in relation to the country's size, its economic structure, its degree of specialization and the importance of multinational companies. In order to get a better overview of a country's scientific and technological productivity, patent data should best be combined with other indicators measuring R&D productivity such as, for example, number of publications, number of citations, number of NTBFs, share of high-tech industries (and their average annual growth), share of patents in high tech sectors (and their average annual growth), share of export of high tech products (and their average annual growth), technology balance of payments (and their average annual growth).

Therefore, two new indicators have been suggested for providing additional measures of the productivity of the scientific and technological workforce:

- Number of spin-offs generated by universities and research centres which is intended to measure the development of new economic activities by R&D personnel.

- Rate of usage of broadband electronic networks for research by R&D laboratories which measures the rate of connectivity and use of electronic research networks. The underlying assumption is the larger and better connected electronic research networks are, the more likely is the increase in quantity and quality of scientific productivity and the speedy diffusion of scientific and technological output.

These two indicators are completely new and are not yet available from internationally comparable sources (they are therefore not presented here). Work will need to be launched to develop them in the future with the help of the statistical offices.

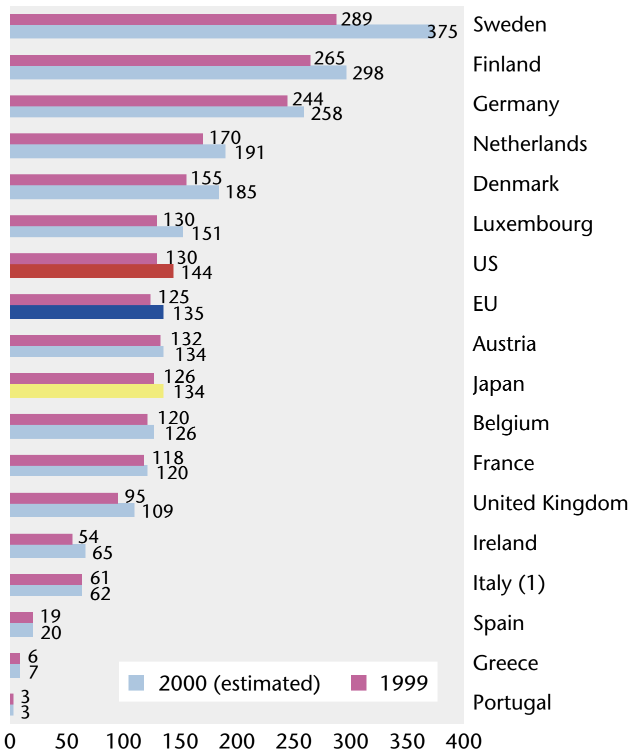
Indicator: Number of patents at the European and US patent offices per capita

What do these indicators tell us?

An application for a patent indicates that there has been a production of new knowledge linked to an invention, and more importantly that this knowledge may have potential economic returns. For a country, patenting therefore reflects part of its inventive activity, and its capacity to exploit knowledge and translate this into potential economic gains. As public information, patents are also an important vehicle for the transfer of technological knowledge.

The use of patents at the two major patenting offices (the European Patent Office and the US Patent and Trademark Office) is important for two reasons. Firstly because the EU and the USA rep-

Figure 3.1.1: European patents per million population



Source: DG Research
Data: Eurostat, EPO, Japan (Nistep) *Calculations:* OST, FhG-ISI,
Note: (1) see annex

resent key markets for future products which exploit the inventions being patented. Secondly, the patenting performance of the EU and the USA varies significantly between the two systems owing to a "home advantage" effect: i.e. the US is dominant in the US patent system because it is their home market, while the European countries are dominant in the European system.

Analysis of national performances

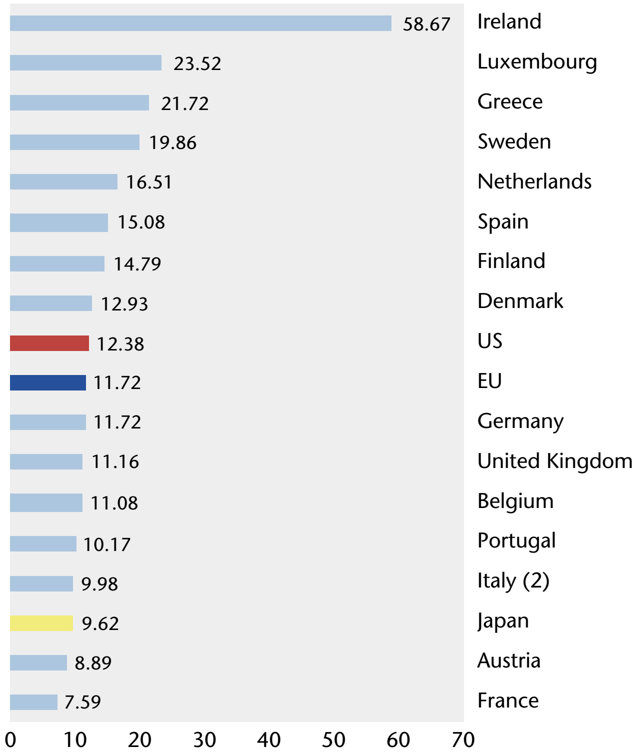
One observes a broadly similar ranking of the European countries in terms of patenting per capita for both European and US patents. (Figures 3.1.1 and 3.1.3).

While in the European patent system the EU and the US have broadly the same level of patents per capita (Figure 3.1.1), in the US patent system the US has a much higher patent intensity than Europe (Figure 3.1.3)

The highest levels of patenting per capita are exhibited by Sweden, Finland and Germany. Some of the Member States have relatively low levels of patenting per capita (and often extremely low numbers of patents in absolute terms), but exhibit a clear upward growth trend. (Figures 3.1.2 and 3.1.4).

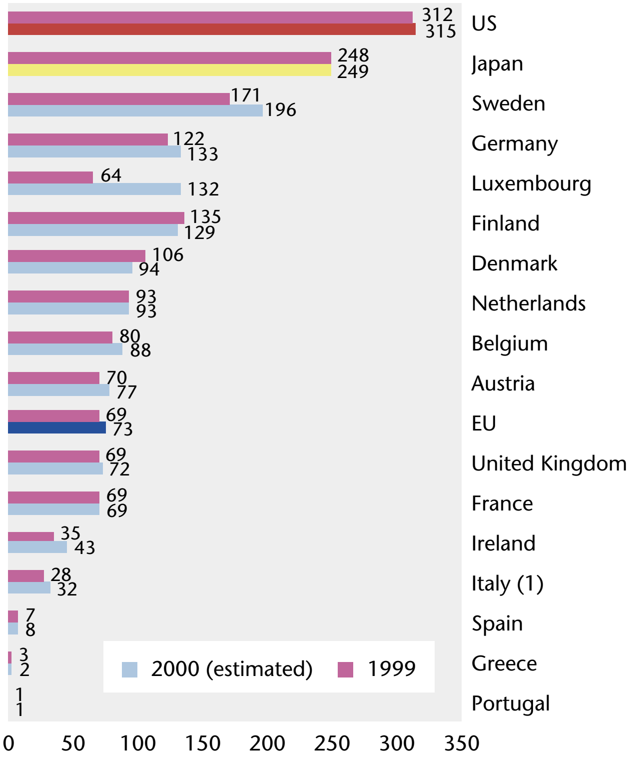
An important factor influencing the level of patenting of a country is its industrial structure. Since some industries have a greater propensity to patent than others, those countries specialised in these industries will tend to have higher rates of patenting.

Figure 3.1.2 : Average annual growth (%) in European patents, 1995 to latest available year (1)



Source: DG Research
Data: EPO *Calculations:* OST, FhG-ISI
Notes: (1) All data refer to 1995-2000. (2) see annex.

Figure 3.1.3: US patents per million population



Source: DG Research
Data: Eurostat, USPTO, Japan (Nistep) *Calculations:* OST, FhG-ISI,
Note: (1) see annex

Questions arising from the quantitative analysis

Some questions of interest that deserve further exploration are:

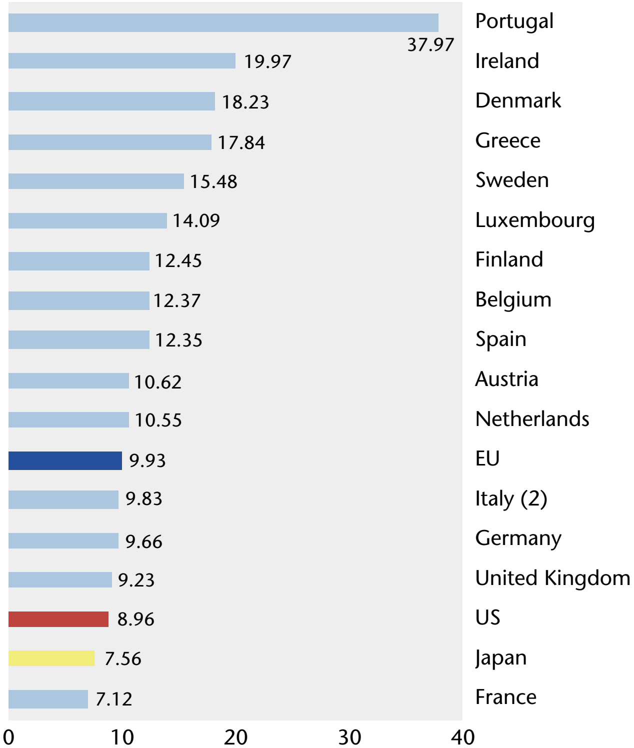
- To what extent does industrial structure explain the relatively low levels of patenting per capita for certain countries, and what other factors may be responsible?
- In which technology fields are different countries strongest / more specialised?
- What role do the patenting strategies of multinational firms play in these dynamics?
- To what extent is the cost of patenting a barrier to more effective protection of inventions for some firms?
- What measures have been taken in different countries to encourage SMEs to protect their inventions through patenting, and how effective have these been?
- What measures have been taken in relation to rules on IPR for government funded S&T programmes?

Some comments on interpreting the indicator

While patents are a much used and useful indicator for the above reasons, there are some limitations to these data that need to be kept in mind:

- The value of patents varies enormously. Some may be of very little commercial value, while others may bring enormous economic returns.

Figure 3.1.4 : Average annual growth in US patents (%), 1995 to latest available year (1)



Source: DG Research
Data: USPTO *Calculations:* OST, FhG-ISI
Notes: (1) All data refer to 1995-2000. (2) see annex.

- Some sectors have a much higher propensity to patent than others. Consequently, when comparing countries' patenting levels there is a need to bear in mind differences in their industrial and technological structures.
- Innovation and invention in the service sector is not adequately captured by patents, since relatively few service companies patent compared with the manufacturing sector.
- Not all inventions are patented. Firms can choose other strategies to protect inventions (e.g. secrecy).

Two other points should be made concerning comparisons between the European and US patent systems. Firstly, because these patent data are recorded by their year of publication, comparisons between the EPO and USPTO figures are difficult (since the publication date of a patent depends upon the administrative delays specific to a particular patent office). Secondly, there is a "home advantage" effect in that, the US will have a dominance in the US patent system because it is their home market, while the European countries will be dominant in the European system.

One method which has been proposed for eliminating the "home advantage" effect is the use of "Triad patents" (i.e. those patents that are applied for at all three patent systems: EPO, USPTO and JPO). The results of research work in this area are promising, and this might be a useful indicator to employ in future benchmarking work.

The treatment of patents of multinational companies is also a complex area. Such companies may carry out research in one country, but may make an application to patent an invention through the headquarters office in another country. The classification of patents by country of inventor (as opposed to country of applicant) attempts to resolve this problem, but this is a complex issue which can benefit from further research efforts.

The denominator used here is million population. One can envisage other possible denominators, depending on the interpretation desired (e.g. number of researchers in a country), and these may produce significantly different results. It is therefore important to interpret such ratios carefully according to the issue and the analysis in question.

Definitions and sources

Total number of European and US patents per thousand population. European patents cover all patents applied for at the European Patent Office (including Euro-PCT applications), and US patents relate to all patents granted at the US Patent and Trademark Office. Patents are recorded by year of publication, and allocated to the country of the inventor (using fractional counting in the case of multiple inventor countries).

Sources: Data from the European Patent Office, and the US Patent and Trademark Office. Calculations by OST and Fraunhofer ISI.

Total population is as defined as in the national accounts (ESA 1995).

Source: Eurostat, National Accounts and Japan.

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

What does the indicator tell us?

The first part of this indicator measures the scientific output (number of publications) per country. This indicator is very often used as a sign of the research capacity and growing knowledge pool of a country, or of a specific research community etc.. Whereas numbers of publications only tell us about quantity, *quality* is more closely associated with the second indicator relating to citation counts. In most scientific domains, the number of citations a paper receives in a particular period (citation window) reflects its importance.

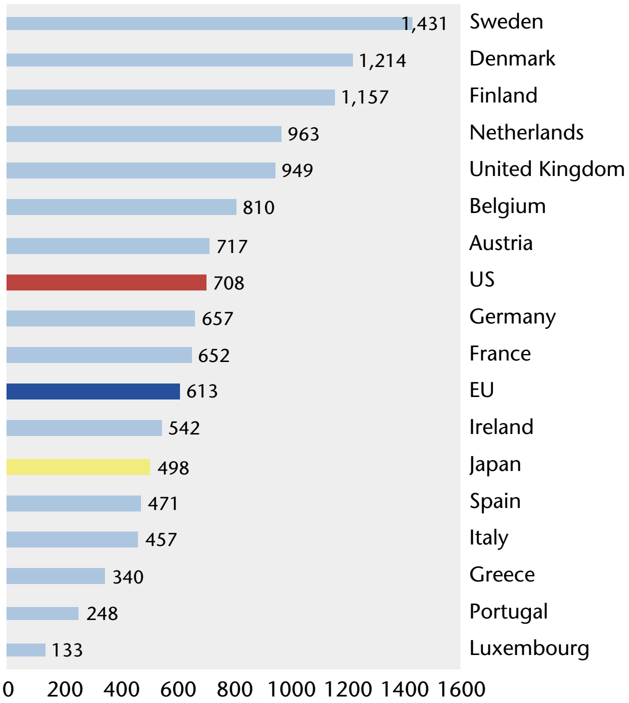
Analysis of national performances

The analysis of the publication data per capita (Figure 3.2.1) show that Sweden, Denmark, Finland, Netherlands, United Kingdom, Belgium and Austria are not only above EU-average, but also above the US and Japan. Except for UK and Netherlands, this group of countries also scores a growth rate of number of scientific publications above both the EU-average and USA for the period 1995-1999 (Figure 3.2.2).

The US decline in number of publications, and its negative growth rate, are quite remarkable and deserve further explanation.

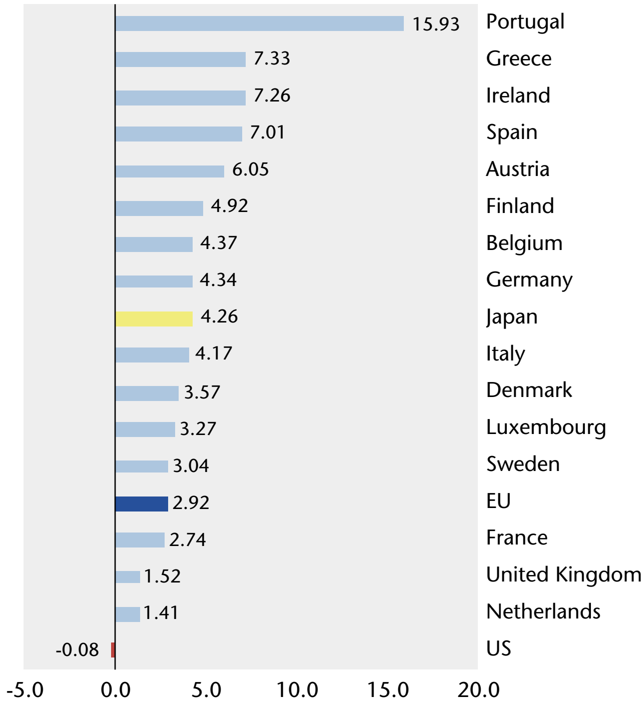
Of the six Member States that score below the EU-average in terms of scientific publications per capita (Figure 3.2.1), Portugal, Greece, Ireland and Spain are catching up ranking as the top four countries - in terms of growth in number of scientific publications (Figure 3.2.2).

Figure 3.2.1: Number of scientific publications per million population, latest available year (1)



Source: DG Research
Data: ISI-SCI, CWTS (treatments)
Notes: (1) All data refer to 1999.

Figure 3.2.2: Average annual growth (%) of number of scientific publications, 1995 to latest available year (1)



Source: DG Research
Data: ISI-SCI, CWTS (treatments)
Notes: (1) All data refer to 1995-99.

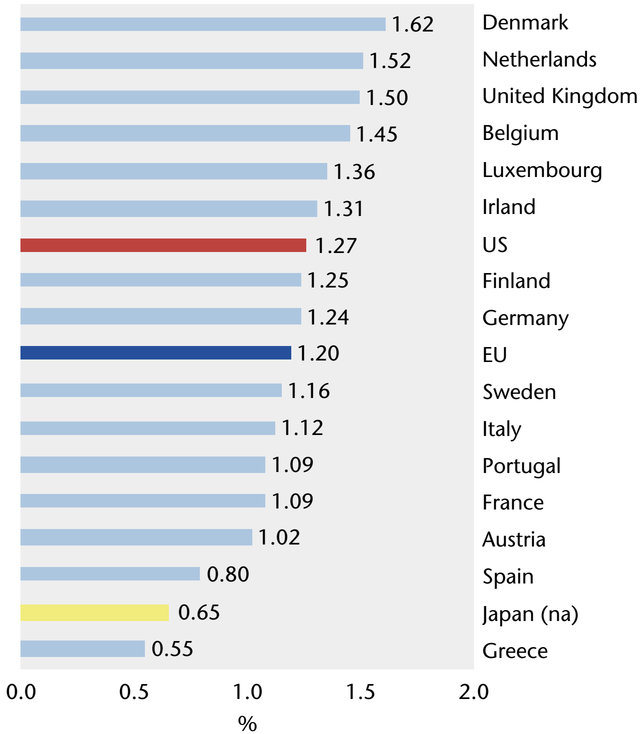
The Scandinavian countries show a remarkable lead measured by their number of scientific publications (Figure 3.2.1). This lead is not something new. In these countries, the growth rates of the number of publications are higher than the EU-average since 1995.

Citation data (Figure 3.2.3) show a different picture. Here, the data has been calculated as the sum of the top 1 % of the publications per field (normalised by field) in a period from 1997-1999. On a country level, achieving more than 1 % of highly cited papers, is in this respect, performing above the world average. Comparing the EU-15, US and Japan, the US percentage is with 1.27% only slightly higher than the EU one with 1.20%. Japan is significantly lower with 0.65% (Figure 3.2.3).

Looking at the total number of the most highly cited papers (Figure 3.2.4), the US and EU-15 produce most of the publications. Japan is behind the larger publishing countries such as UK, Germany, and France, but Italy and the Netherlands also have high levels. Per capita, Sweden and Denmark have a larger number of highly cited publications than the Netherlands, UK and Belgium. The US performs well below 5 Member States and Japan even much lower. (Figure 3.2.5).

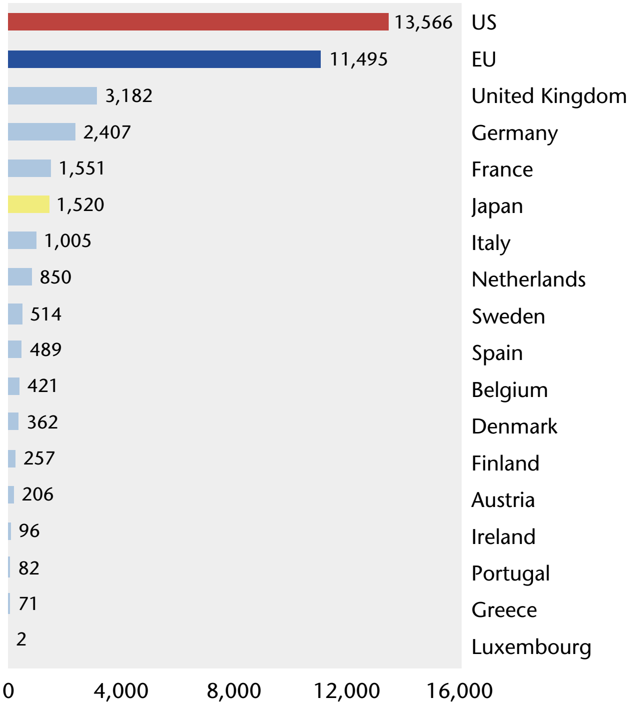
There are several interesting developments, one concerning the Netherlands: despite the fact of a low, far below EU-average growth rate in the number of publications, the Netherlands achieve well above EU-average rates for the number of highly cited papers, number of highly cited papers per capita and number of publications per capita. This pattern is very similar for Denmark and Sweden.

Figure 3.2.3: Number of highly cited papers as percentage of total number of scientific publications, 1997-99



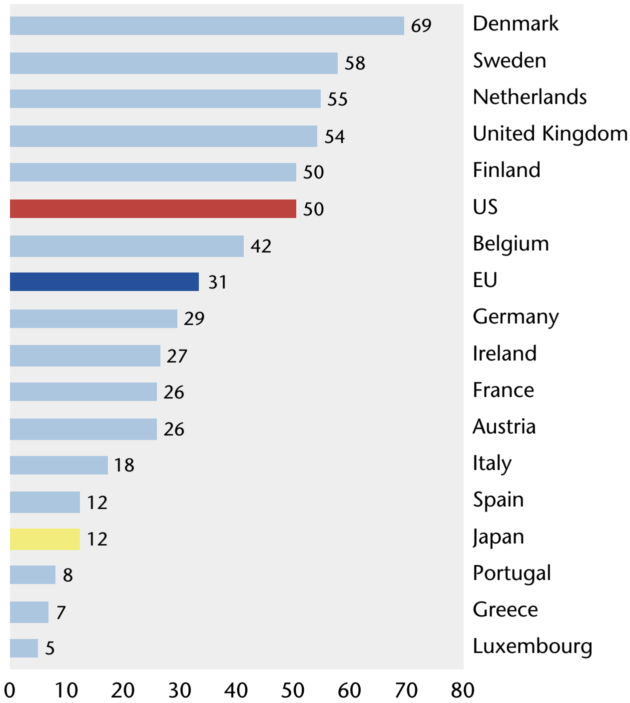
Source: DG Research
Data: SCI, CWTS

Figure 3.2.4 : Total number of highly cited papers, latest available year (1)



Source: DG Research
Data: SCI, CWTS
Note: (1) All data refer to the period 1995-97

Figure 3.2.5: Number of highly cited publications per million population, latest available year (1)



Source: DG Research
Data: Eurostat, SCI, CWTS, Japan (Nistep)
Note: (1) All data refer to the period 1995-97

Finally, if one combines the growth of the number of researchers[1] with the growth of numbers of publications (Figure 3.2.6), one obtains a complex picture. On the basis of figure 3.2.6. one could argue that the countries France, Germany, Italy and Portugal have a higher marginal scientific productivity, as the growth of publications is stronger than the growth of researchers. In contrast, the opposite group of countries showing a lower marginal scientific productivity are Ireland, Finland, Denmark, Sweden, Netherlands and United Kingdom, while Austria, Spain, Greece, Denmark and Belgium hold equal growth positions.

Questions arising from the quantitative analysis

- Which policies could be linked to the high per capita rates (publications and citations) in Denmark and Sweden?
- What causes the discrepancy between the Netherlands' low publication growth rate and low increase in number of researchers on the one hand, and its top performance per capita, as well as its above average performance in total number of highly cited papers on the other hand?
- What underlying factors explain the rapid catching up process of the cohesion countries in terms of growth rate of number of scientific publications in the period 1995-1999?
- Is size of the research system and a critical mass within an explaining factor for the differencies?
- What are the scientific specialization patterns within the member states, e.g., basic/applied research orientation, domestic cooperation and networks, outward orientation, use of English language or another native language?

Some comments on interpreting the indicator

In order to interpret these indicators correctly, some preliminary remarks should be made regarding the nature of the data. The owner of the SCI database (used for all these calculations) is American, and the database therefore tends to have a bias towards English language publications, and to reflect the scientific profile of the USA. For example, almost 50 % of the data of the SCI relates to life sciences, whereas engineering represents only a small number. Therefore, it should be borne in mind when interpreting the data that those countries specialised in fields which either show a low propensity to publish, or fields which are not well represented, will show a lower scientific output than countries with an opposite profile.

In general, the number of citations a paper receives in a particular period (citation window) reflects its influence. However, there exist several cases, were self-citation or citation cartels disturb the analysis significantly.

Citation rates have to be analysed equally careful, as the propensity of citation counts per paper vary according to the size of a field and its scientific community. The scientific community of theoretical physics, for example, is much larger than that for crystallog-

[1] The growth rates of number of researchers (FTE) have been calculated from the data provided by the Member States and the OECD respectively (I). For some countries only 1995 and 1997 data, for others 1995 to 1998 data are available (see Theme 1, Indicator 1). Data for Luxembourg are not available. As the data are rather incomplete, the growth rates need to be interpreted with caution.

raphy. More papers will be produced in the first case, and these face more competition to be cited then in the latter field. It is therefore often necessary to "normalise" these size effects for a citation analysis, and in order to compare between countries or fields. The data for the citation data here have been field normalised, and the top one percent from each field has been taken for analysis

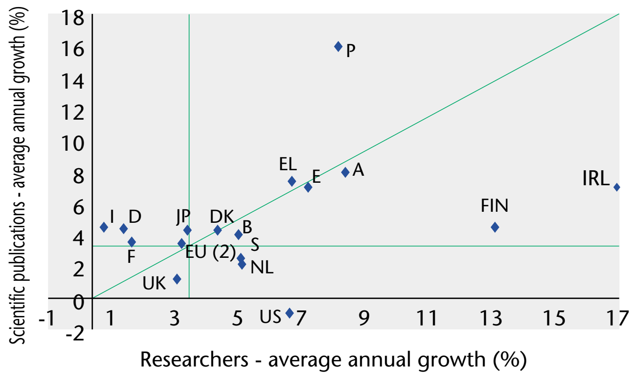
The denominator used here is million population. One can envisage other possible denominators, depending on the interpretation desired (e.g. number of researchers in a country), and these may produce significantly different results. It is therefore important to interpret such ratios carefully according to the issue and the analysis in question.

Definitions and sources

Number of scientific publications: CD-rom version of the database of the Institute for Scientific Information – ISI, Philadelphia and processed by the Centre for Science and Technology Studies – CWTS, Leiden University. Full-counting per country, i.e. a publication by authors from two or more countries will be credited as one publication to each of the respective countries. Only articles, notes, reviews and letters are included.

Most cited publications: the ratio of citation count to publication count. The data are determined by cites from 1997-1999. Only articles, notes, reviews and proceedings are included. The High Impact Papers are calculated as the top 1 % in each field, to normalise by field size.

Figure 3.2.6: Number of scientific publications and number of researchers - average annual growth (%), 1995-98 (1)



Source: DG Research
Data: ISI, CWTS
Notes: D,E,P: 1995-99; B,EL,IRL,I,FIN,S,US: 1995-97
(2) L data are not included in the EU average.

The source of data is the Science Citation Index (SCI), of the Institute for Scientific Information - ISI, Philadelphia, USA. The data on publications has been processed by the Centre for Science and Technology Studies – CWTS, University Leiden, the Netherlands. The data on highly cited papers was directly provided and processed by ISI.

Indicator: Percentage of innovative firms co-operating with other firms/universities/public research institutes

What does this indicator tell us?

This indicator measures cooperation patterns that may contribute to the strengthening of transfers of knowledge and innovation. Increasingly, innovation relies on the combination of different sources of knowledge and expertise. Some of this may be external to the firm, and can be acquired through co-operation with other firms, as well as through the exploitation of public research by means of links between firms and universities/public research institutes. Such cooperation can help to accelerate the generation of new ideas and their diffusion.

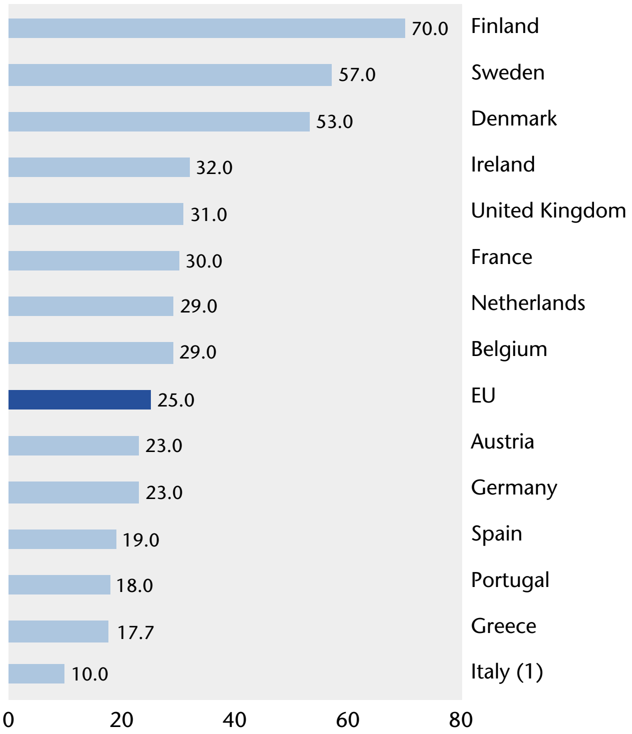
Innovation cooperation can have important effects on S&T productivity in firms, through sharing (and thus reducing) the costs of R&D, while at the same time improving the quality of new products and shortening product life cycles.

Analysis of national performances

On average 25% of innovative EU firms co-operate with other firms, universities or public research centres (Figure 3.4.1). This phenomenon is strongest in Finland, Sweden and Denmark where more than 50% of firms are involved in such co-operation.

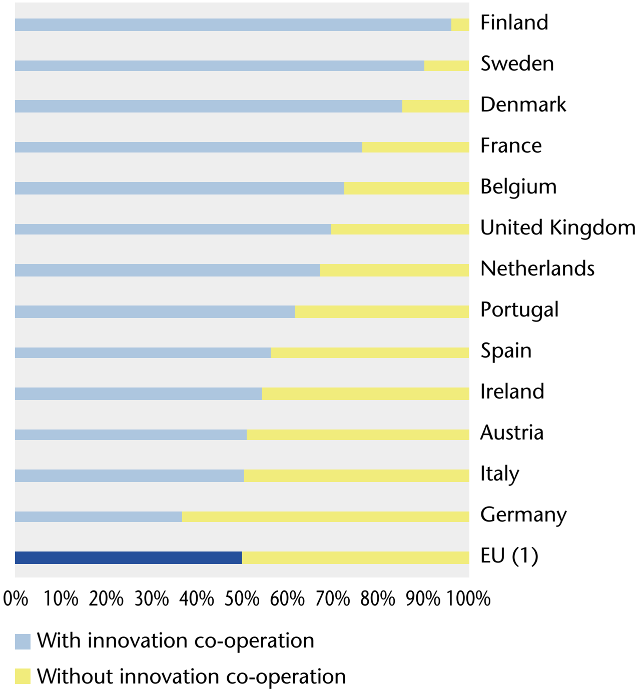
If one examines the link between the co-operative activities of innovators and their sales of new or improved products (Fi-

Figure 3.4.1. Percentage of innovating firms cooperating with other firms, universities or public research institutes (1996)



Source: DG Research
Data: CIS, Eurostat, DG Enterprise, Member States
Note: (1) see annex

Figure 3.4.2: Share of turnover linked to new or improved products from innovators by engagement in innovation co-operation, manufacturing (1996)



Source: DG Research
Data: CIS, Eurostat, DG Enterprise
Note: **(1) L data are not included in the EU average**

gure 3.4.2), one finds that in France, Denmark, Sweden and Finland enterprises involved in innovation co-operation account for more than three-quarters of the sales due to innovative products. Germany is the one country below the EU average (which it strongly influences due to its high share of turnover in new and improved products), with less than 40% of its sales due to innovative products.

Questions arising from the quantitative analysis

Notwithstanding some methodological reasons for differences between countries (see below), it would be interesting to examine:

- Why do innovative firms in certain countries achieve higher levels of co-operation. Is this mostly explained by structural factors (higher proportion of sectors where co-operation is more prevalent, higher proportion of large firms…)?
- What are the public efforts in the Member States to stimulate university-industry links, and what is the assessment of the effects of these measures?
- What measures do countries employ to support the development of networks and clusters of innovative firms?

Some comments on interpreting the indicator

The source of data on innovation co-operation is the 2nd Community Innovation Survey (CIS), which covered innovative activities during the period 1994-96. While the 2nd CIS was significantly better than the 1st CIS in its coverage and comparability, there was some evidence that the definition of innovation was still not interpreted in exactly the same way in all countries.

For example, the term "technological innovation" gave rise to different interpretations in different countries (the term was not used by Germany due to possible ambiguities). Some of the variations in the percentage of innovative firms per country may be due in part to this problem.

It has been found that co-operation tends to be significantly higher for large firms than for small ones, and is stronger in particular sectors, hence a country's industrial structure will have an effect upon the size of this indicator.

There were also significant variations between countries in the response rate to the CIS2 questionnaire. However, where non-response was below 70% of the active enterprises in the sample, a non-response analysis was performed, and the results of this analysis were taken into account to adjust the weighting factors used to produce grossed-up figures for the whole population.

Nevertheless, this survey represents the most robust and harmonised source of data on innovation in Europe that currently exists.

Data for the US and Japan are not available, as these countries do not carry out surveys comparable to the CIS.

Definitions and sources

The indicator is defined as the percentage of all innovative firms in the manufacturing sector that co-operate with other firms (competitors, clients or customers, consultative enterprises, suppliers), or with universities or other higher education institutes, or with government or private non-profit research institutes.

An innovative firm is defined as one that has introduced technologically new or improved products or services on the market, or technologically new or improved processes. The product should be new to the enterprise, but does not necessarily have to be new to the enterprise's market.

Innovation cooperation is defined as active participation in joint R&D and other innovation projects with other organizations. It does not necessarily imply that both partners derive immediate commercial benefit from the venture. Pure contracting out work, where there is no active participation, is not regarded as cooperation.

(These definitions are in accordance with the 2nd Community Innovation Survey and OECD/Eurostat Oslo Manual methodology.)

Source: Eurostat, 2nd Community Innovation Survey

THEME 4: The impact of R&D on economic competitiveness and employment

Economic competitiveness is essentially measured by the capacity to produce with less work, either direct or indirect. For a country, labour productivity is an appropriate indicator for this purpose. Employment is linked to the level of activity and to competitiveness: if an activity is not competitive, its growth is impossible. R&D is an essential instrument in increasing competitiveness and employment.

Potential economic growth depends directly on investment in new knowledge innovations. They increase the technology set and the productive capacity of the traditional factors of production. This implies that new knowledge innovations increase the rates of return of all other types of investments (education, capital goods, etc.).

The accumulation of these investments – which are needed in the growth process – is therefore induced by innovations. Investment in knowledge and other types of investment is complementary and interactive Economic competitiveness is achieved through the capacity to transform knowledge into economic performance, by means of investment in new technologies. In this case, this is associated with high growth and employment rates. However, the direct measurement of the impact of R&D is the growth rate of labour productivity, as it captures both the direct and indirect effects of innovations.

The process of commercialisation and increasing competitiveness is reflected in emerging new activities and new products for the domestic and export markets. This induces restructuring of existing activities both through strong structural change towards high tech and knowledge intensive activities and through the modernisation of the old economy by diffusion of new technologies. Knowledge and innovation are the ultimate sources of the competitiveness of firms. Competencies to commercialise the knowledge and complementary assets to knowledge are also required for competitiveness in the knowledge-based economy.

The following indicators measure some aspects of this restructuring and growth of new knowledge and technology activities:

- "Growth rate of labour productivity" measures the rate at which the GDP per hour worked is increasing. At least a considerable part of the increase in efficiency of production is assumed to reflects the impact of R&D
- "Share of high and medium high-tech industries" in GDP and total employment shows the importance of economic activity in the creation and use of new products and new process,
- "Share of knowledge intensive services" in GDP and total employment shows in what measure new knowledge has been mastered and improved in the economy, and to what extent new technology is used and disseminated,
- "Technological balance of payments receipts as a proportion of GDP" indicate the degree of specialisation and competitiveness (if we analyse also exports minus imports) in knowledge innovation,

- Growth in a country's world market share of exports of high-tech products" is also an indicator of specialisation, but here in the production and export of products with a high knowledge content.

Indicator: Growth rate of labour productivity

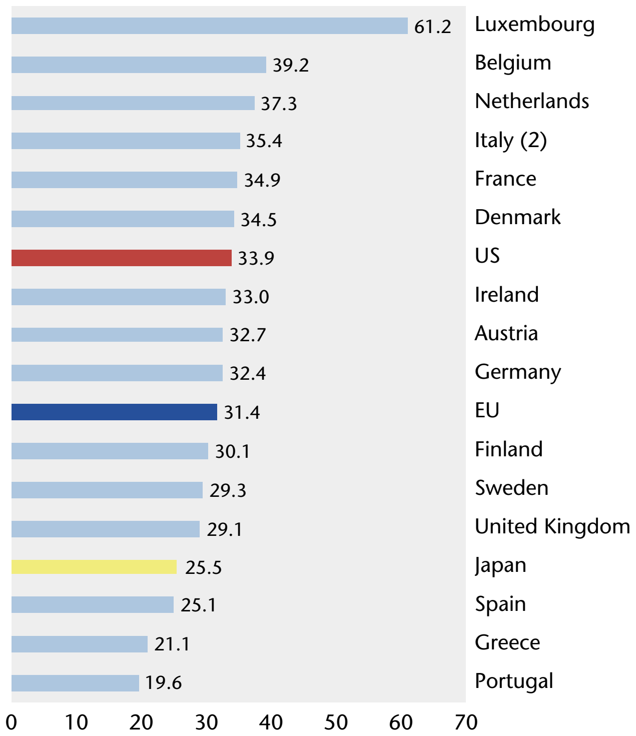
What does this indicator tell us?

Labour productivity is an indicator that measures the value added created by one unit of labour (here one hour of average working time). It is clearly associated with the level of technology across all economic activities and to the relative share of activities in high and low productivity sectors. However, it also depends upon the capacity to absorb new technology, and in particular upon the availability of highly qualified workers able to exploit the benefits of technological progress. High growth rates of labour productivity require prior innovative investment and are crucial for enhancing competitiveness and social welfare.

Analysis of national performances

One observes that labour productivity in the USA is a little higher than in the EU and much higher than in Japan. However, Japanese labour productivity growth is the highest, followed by the EU and the USA.

Figure 4.1.1. Labour productivity (GDP per hour worked) in PPS, latest available year (1)



Source: DG Research
Data: Eurostat, OECD
Notes: (1) US,JP: 1999; all other countries: 2000. (2) see annex.

In the European Union, Luxembourg has the highest level (nearly twice the average EU level) and the second highest growth rate of labour productivity.

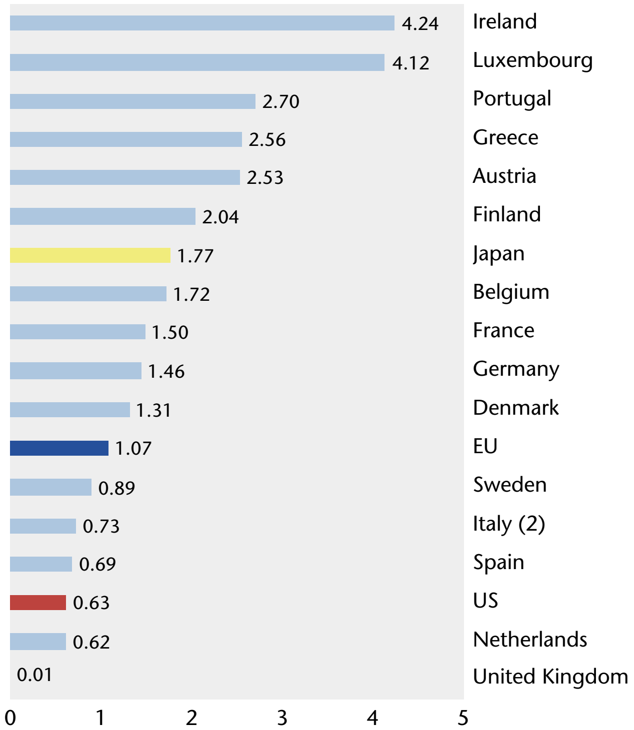
The labour productivity levels of many other European countries follow with great distance to Luxembourg but are still above (Figure 4.1.1) the EU average (Belgium, Netherlands, Italy, France, Denmark, Ireland, Austria and Germany). Also the annual average growth rate is lower than the EU average for only two of these countries, Italy and the Netherlands. The highest rate of growth of labour productivity is found in Ireland (4.2%), just before Luxembourg. For Austria it is also quite high (2.6%). (Figure 4.1.2).

Just below the European Union average level we find Finland, Sweden, United Kingdom, while the lower levels of labour productivity are found in the Mediterranean countries (Portugal, Greece and to a lesser extent Spain). As the annual average growth rates of their labour productivity are rather high, Portugal and Greece are on a « catching-up » trajectory. However, this is not the case for Spain where the rhythm of productivity growth is rather slow. The United Kingdom's level of productivity, which is slightly before the EU average, remains steady during this period.

Questions arising from the quantitative analysis

- Why is it that the strong R&D investment of the Scandinavian countries (except for Denmark) has a relatively low impact on

Figure 4.1.2. Labour productivity (GDP per hour worked) - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research
Data: Eurostat, OECD
Notes: (1) US, JP: 1995-99; all other countries: 1995-2000. (2) see annex.

labour productivity? (Sweden and Finland are below the EU average).

- Why is Spain's productivity growth so low compared with Greece and Portugal, which have similar levels of productivity? Why is growth for Italy and the Netherlands also so low?
- What political instruments could stimulate growth in productivity without negative impacts on employment and sustainable growth?

Some comments on interpreting the indicator

- We have to be cautious when comparing countries' values. Firstly it is difficult to compare the levels of productivity of European Union, the United States and Japan because of the large fluctuations in exchange rates in recent years. The need to convert national currencies into one comparable unit poses special problems. Here GDP data have been converted into purchasing power standards (PPS) at constant prices (to adjust for differences in purchasing power of currencies, and to eliminate the effects of inflation). While such conversion methods are well developed and widely employed, they do not eliminate all problems of comparability. Secondly, the evaluation of total annual hours worked is complex and not yet considered as totally reliable by all the users for comparison between countries. Thus, even if this unit is theoretically better than "number of workers", some still prefer to use number of workers as unit of labour.
- The level of productivity and GDP both depend upon the structure of the economy. Certain industries are associated with higher productivity and higher value added. Countries whose economies are more oriented to such sectors may tend to have higher rates of productivity. The most significant case is illustrated by Luxembourg, but more generally by less populated countries.
- The growth rate of labour productivity depends also on other factors than the R&D investment. Important factors affecting the growth rate of the labour productivity are for example are the investment in real capital, infrastructure or the micro-foundation of the economy.
- Even with high level of technology, labour productivity can remain low. Where the rhythm of innovation is very fast, and technological obsolescence is rapid, the replacement of equipment, re-training, etc. can lead to more labour intensive activity.
- Labour productivity also depends on the utilisation of production capacities, i.e. the stage of the business cycle is important.
- Other productivity indicators also exist relating to factors of production other than labour force, for example total factor productivity. However, they are not well adapted for our purpose here.

Definitions and sources

This indicator is measured by the ratio « GDP divided by the annual number of hours worked ».

Gross domestic product (GDP) is calculated according to NA ESA 1995 definition, and has been converted into Purchasing Power Standards.
Source: Eurostat.

Quantity of labour is measured by the total annual hours worked, which are calculated by multiplying number of persons employed (source Eurostat, from national accounts) by a yearly average of hours worked (calculated by OECD) plus forecasts for 2000.
Source: Eurostat/OECD

Indicators: high-tech and medium high-tech industries:
– Share of total output and contribution to growth of output
– Share of total employment and contribution to growth of employment

What do these indicators tell us?

The share of high- and medium high-tech industries indicate the strength of an economy in R&D intensive activities and the strength in transforming scientific and technological knowledge into economic activity. They are associated with intensive R&D and the creation of knowledge and new products. Some of these industries are responsible for profound changes in the organisation of work as well as in the consumption of households. The presence of high levels of activity in a high- and medium high-tech industry also indicates a degree of competence and mastery in a specific technology.

The value added of high- and medium high-tech industries as a percentage of total GDP, and employment in these industries as a percentage of overall employment help us to evaluate the importance of high- and medium high-tech industries in a country and their contribution to growth and employment.

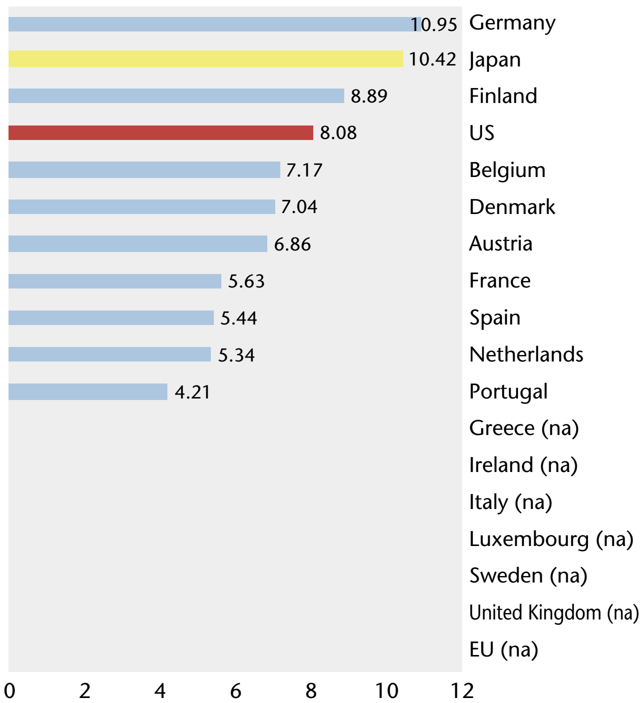
Analysis of national performances

For the USA and Japan, the share of value added in high- and medium high-tech industries is higher (10.42 and 8.08 respectively) than for most of the European countries except Germany for which data are available. In the USA value added in the high- and medium high-tech industries is growing more slowly than GDP. In particular, the annual average growth of high- and medium high-tech industries is negative for Japan in 1995 - 99 (Figure 4.2.3).

In Europe, only Germany has a higher share of value added of high- and medium high-tech industries than both the US and Japan although Finland's is above that of the US. Belgium and Denmark reach values just below the EU average followed by Austria, France, Spain and Netherlands. The share is lowest in Portugal. However, only in Portugal - starting at a low level - and in Finland are these industries growing at a considerably faster rate than GDP, i.e. the share of high- and medium high-tech industries is increasing since 1995 (Figure 4.2.3). In Belgium, the Netherlands and Spain the growth of value added in high- and medium high-tech industries is very low since 1995.

Turning to the share of high-tech industries in total employment (Figures 4.2.2 and 4.2.4), the EU average is now considerably higher than that of the USA and lightly higher than in Japan. Among the European countries, Germany has the highest share of

Figure 4.2.1. Share of value added of high- and medium high-tech industries in total output (%), latest available year (1) (only available for eleven countries)



Source: DG Research
Data: Eurostat, Member States, OECD, Japan (Nistep)
Notes: (1) D,P,US: 1998; DK: 1997; all other countries: 1999.

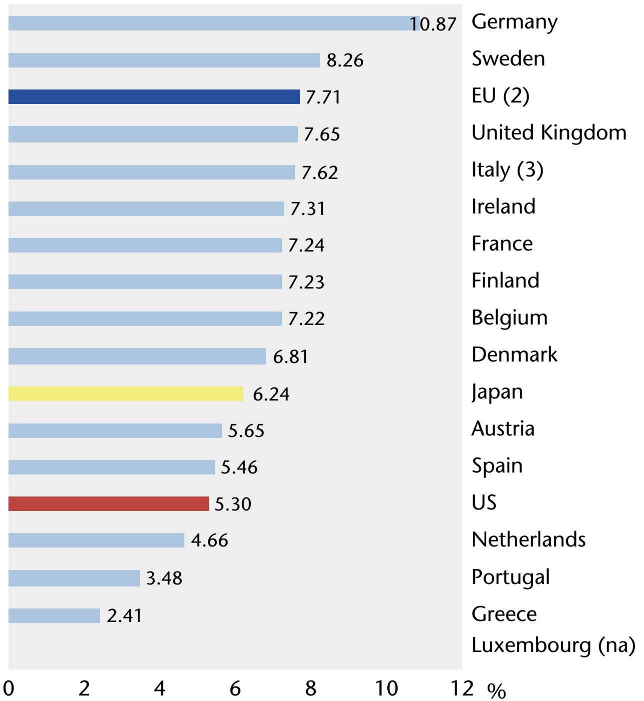
employment in high-tech industries followed by Sweden at levels above the EU average. Another group of European countries (UK, Italy, Ireland, France, Finland, Belgium and Denmark) reach values that are under the EU average but relatively near to it. Austria and Spain lie further down with their shares. Finally, Greece and Portugal have the lowest shares but again the share of high tech industries is growing faster than the total employment (see Figure 4.2.4), i.e. the shares are increasing since 1995. Also in Ireland, Finland and Spain the growth of high- and medium high-tech industries is relatively high. However, since total employment has also risen strongly over the same period the share remains roughly constant.

In some large countries (UK and France) growth in high tech industries is comparable to growth in total employment, with relatively low levels of average growth. In particular, while the growth of total employment is negative in Sweden and Austria, growth of employment in the high- and medium high-tech industries is positive since 1995. Again, the share of high- and medium high-tech industries is declining in Japanese total employment since 1995.

Questions arising from the quantitative analysis

- What policy measures and instrument support the permanently strong dynamics of high tech industries in Finland and catching-up processes in Ireland and Portugal?
- It would be interesting to examine more closely the specific high-tech industries in which countries are specialised. Observation of

Figure 4.2.2. Share of high- and medium high-tech employment in total employment (%), latest available year (1)



Source: DG Research
Data: Eurostat, OECD, Member States, Japan (Nistep)
Notes: (1) DK,EL,A,EU,US: 1998; all other countries: 1999.
(2) L data are not included in the EU average. (3) see annex.

long term evolution of their specialisation in this area could be necessary. This may partly explain some of the differences in growth rates.

- High- and medium high-technology industries are considered as driving sectors of the economy that require high quantities of skills, excellence and competencies. What is the role of these factors in the countries increasing their share, what policy measures have been applied and what policy measures could assure this "technology mastery"?
- What are the factors behind the relatively slow dynamics of the Netherlands and Belgium in high- and medium high-tech industries?
- What are the factors that explain the large differences between countries in labour productivity (in terms of value added divided by the number of workers) in high and medium high-technology industries? To what extent is this linked to differences in the composition of « high- and medium high-technology industries », purchasing power exchange rates, or the measurement of the number of annual hours worked per employee?

Some comments on interpreting the indicators

"High- and medium high-tech industries" do not produce only high-tech products, but may even produce some low-tech products. Conversely, there can be "high- and medium high-tech" production in some traditional industries.

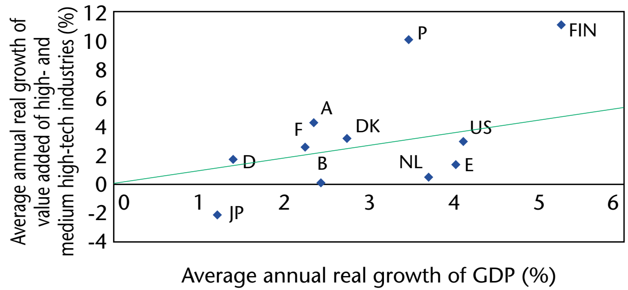
These indicators only give information on the direct effects on output and employment in high- and medium high-tech industries. However, there may be considerable indirect effects on growth and employment in other sectors of the economy due to dissemination of technical progress in other sectors, derived innovations, and substitution of new products or services for traditional ones. In some cases secondary effects may also create unemployment in other sectors.

Definitions and sources

In Europe, output in high-tech and medium high-tech industries is measured by value added, in euro, in high-tech and medium high-tech industries according to the OECD-high-tech and medium high-tech industries definition (see OECD STI working paper 1997, (OECD/GD(97)216)), which includes: aerospace, computers, office machinery, electronics-communications, pharmaceuticals, scientific instruments, motor vehicles, electrical machinery, chemicals, other transport equipment and non-electrical machinery, (i.e. NACE Rev. 1 codes: 35.3, 30, 32, 24.4, 33, 34, 31, 24 (excl. 24.4), 35.2+35.4+35.5, 29) *Source*: These data were collected in the Member States and the USA.

The Japanese data utilises a different classification by converting the NACE rev. 1 to SICJ Rev. 10 through ISIC Rev. 3. Therefore, the definition of high- and medium high-tech industries differs from that for the member states and USA and causes problems with comparability. *Source*: Census of Manufactures, Ministry of Economy, Trade and Industry.

Figure 4.2.3: GDP and value added of high- and medium-high tech industries - average annual real growth,1995-99 (1) (only available for eleven countries)



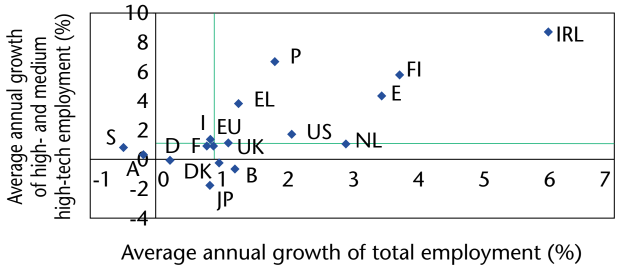
Source: DG Research
Data: Eurostat, Member States, OECD, Japan (Nistep)
Note: (1) D,P and US: 1995-98; DK: 1995-97; FIN: 1996-99.

Employment in high-tech and medium high-tech industries is defined as the number of employed persons (full and part time) in the high-tech and medium high-tech industries (see above for the member states, USA and Japan). *Source:* Eurostat (Labour Force Survey)

Total employment is defined as the number of employed persons according to the Labour Force Survey

Source: Eurostat (Labour force survey), Member States. For Japan: Labour force survey, statistics bureau, Ministry of public Management.

Figure 4.2.4: Total employment and high- and medium high-tech employment - average annual growth, 1995-99 (1)



Source: DG Research
Data: Eurostat, Member States, OECD, Japan(Nistep)
Notes: (1) DK,EL,A,EU,US: 1995-98; P: 1998-99.
(2) L,P data are not included in the EU average.
(3) see annex.

Total output is defined as gross domestic product (GDP) according to National Accounts ESA 1995 definition, in national currency and current prices, converted to Euro and PPS. *Source:* Eurostat

Indicators: knowledge intensive services:

– Share of total output and contribution to growth of output

– Share of total employment and contribution to growth of employment

What do these indicators tell us?

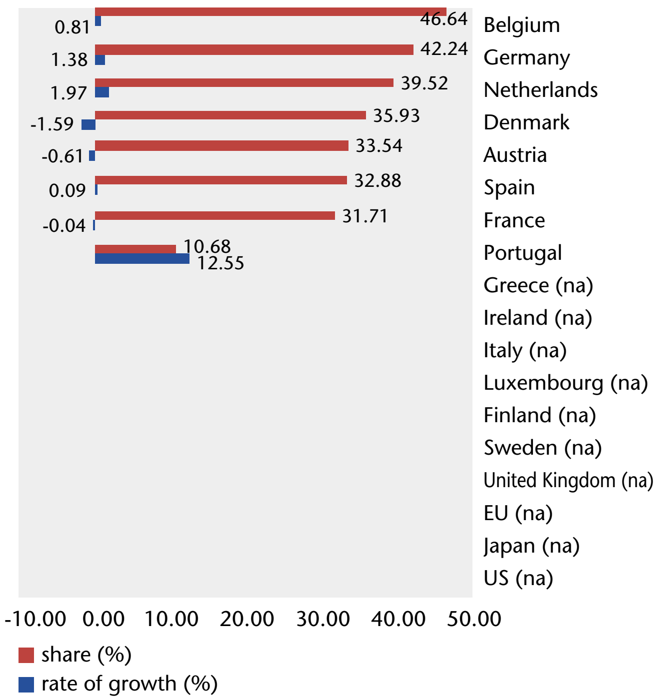
The shares of knowledge intensive services in total economic output and total employment inform us about the relative importance of knowledge intensive activities and structural change towards knowledge-based economy. Knowledge intensive services require highly skilled personnel and cover a very broad range of activities. Some of these activities play a very important role for the productivity of research activities as they provide research services to manufacturing firms and also to other services.

Analysis of national performances

Amongst the countries for which data are available, Belgium, Germany and the Netherlands have the highest shares of value added of the knowledge intensive sectors in GDP. These three countries are followed closely by France, Austria, Denmark and Spain. Portugal's share is considerably lower.

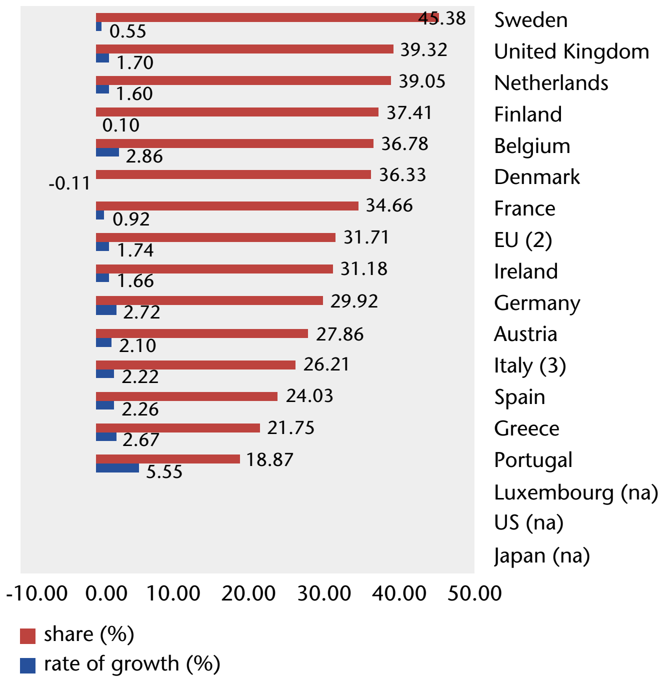
Nevertheless, Portugal - starting at a low level - has a very much higher rate of growth of value added in these sectors than all other countries. In other countries the dynamics of the knowledge inten-

Figure 4.3.1. share of value added of knowledge intensive services in total output: latest available year and average annual real growth from 1995 to latest available year (1) (only available for eight countries)



Source: DG Research
Data: Eurostat, Member States
Notes: (1) D: 2000; P: 1998; all other countries: 1999.

Figure 4.3.2. Share of knowledge intensive services employment in total employment: last available data and rate of growth from 1995 to last available data



Source: DG Research
Data: Eurostat
Notes: (1) EL,EU: 1998; all other countries: 1999.
(2) L data are not included in the EU average.
(3) see annex.

sive sectors is rather modest (between – 1.59% for Denmark and 1.97% for the Netherlands. (Figure 4.3.1).

Surprisingly, the values and rankings of the employment shares are quite different from those for value added. (Figure 4.3.2). Sweden has the highest level of employment in knowledge intensive services, followed by the UK and the Netherlands. Also Finland, Belgium, Denmark and France reach values higher than the EU average, while Ireland, Germany, Austria, Italy and Spain are below the EU average. The lowest shares of employment in these activities are achieved by Portugal and Greece. But Portugal exhibits the highest rate of growth , along with Ireland (Figure 4.3.2).

The contribution of knowledge intensive services to employment is growing in nearly all countries, even in the large countries (which is not the case for the high-tech sectors). The only countries whose share of employment in these services is decreasing are Denmark and Finland (Figure 4.3.2).

The differences between the results for value added and those for employment can be explained by differences in labour productivity of these sectors across countries.

Questions arising from the analysis

- What are the reasons for the significant differences between countries in labour productivity for these industries? To what extent is this due to differences in average working hours (since the employment data used here are in headcount)? What part is played by the country differences of specialisation in knowledge intensive sectors with high productivity or in low productivity for the different levels of labour productivity?
- In what extent do the practices of manufacturing sector for outsourcing services and the easiness for establishing new enterprises explain the differences in the shares?
- What type of policies can explain the relatively much higher growth for the value added in the knowledge intensive service sector in comparison to that of the GDP?
- What is the impact of the size of the economy, i.e. that of the internal market for the dynamics of knowledge intensive sector?

Some comments on interpreting the indicators

- Knowledge intensive services are providers of services to manufacturing firms or to households. However, it is also possible that many knowledge intensive services are provided in-house of manufacturing enterprises. Therefore, the labour productivity in manufacturing firms and in services should not be analysed independently.
- The definition of “knowledge intensive services” may be different from that employed in other analyses published elsewhere on this subject (or in relation to “high-tech services” etc.). Some definitions are more selective according to the sectors used.
- Using the highly aggregated 2 digit level of the NACE (or ISIC) classification does not allow a fine distinction between those services that may be highly knowledge intensive and those which are not. Further improvements in the classification of these services will be necessary.

Definitions and sources

For Europe, output of knowledge intensive services is defined as the value added of knowledge intensive services 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)

Source: collected in the Member States

Data are not presented here for the USA because it is not possible to obtain disaggregated figures for codes 61, 62 and 92.

Data for Japan has been sent by Japanese authorities. However, because of some issues of comparability which still need to be resolved, these data have not been included at the present stage.

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) *Source:* Eurostat, Community Labour Force Survey

Total employment: for definition and source see the section “high-tech and medium high-tech industries”.

Total output is defined as gross domestic product (GDP) according to National Accounts ESA 1995 definition, in national currency and current prices, converted to Euro and PPS. *Source:* Eurostat

Indicator: Technology balance of payments receipts as a proportion of GDP

What does this indicator tell us?

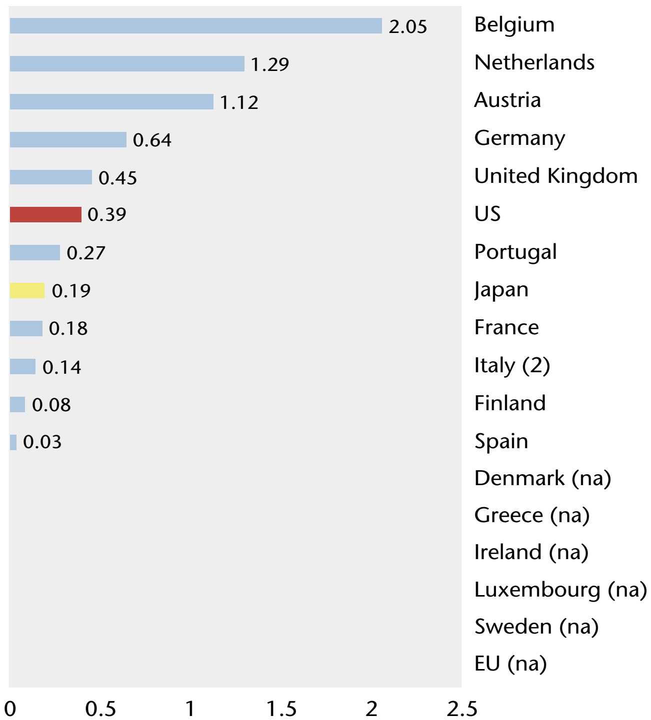
This indicator measures the importance of a country’s receipts from exporting technical knowledge and services (including licenses, know-how, trademarks, technical services, etc.). It indicates country’s competitive position on the international market for knowledge. The use of TBP receipts data here, in the context of competitiveness, is intended to measure a country’s capacity to sell its intangible knowledge outputs. Technology exports - as well as imports - are of course also a vehicle for the transfer of technology.

While this is an extremely valuable indicator, some caution is necessary in interpreting the results, since the items included under TBP can vary considerably from one country to another (see below).

Analysis of national performances

When the competitiveness of knowledge products is measured by TBP receipts as % of GDP, several European countries - in particular, Belgium, Netherlands and Austria - as well as Germany and the UK - appear ahead of the USA and Japan (Figure 4.4.1). Spain and Finland, countries that have lower levels of receipts, nevertheless register the highest increases (Figure 4.4.2).

Figure 4.4.1. Technology balance of payments receipts as % of GDP,latest available year (1)



Source: DG Research
Data: Eurostat, OECD
Notes: (1) D: 2000; E,F,FIN: 1998; I: 1997; all other countries: 1999.
(2) see annex

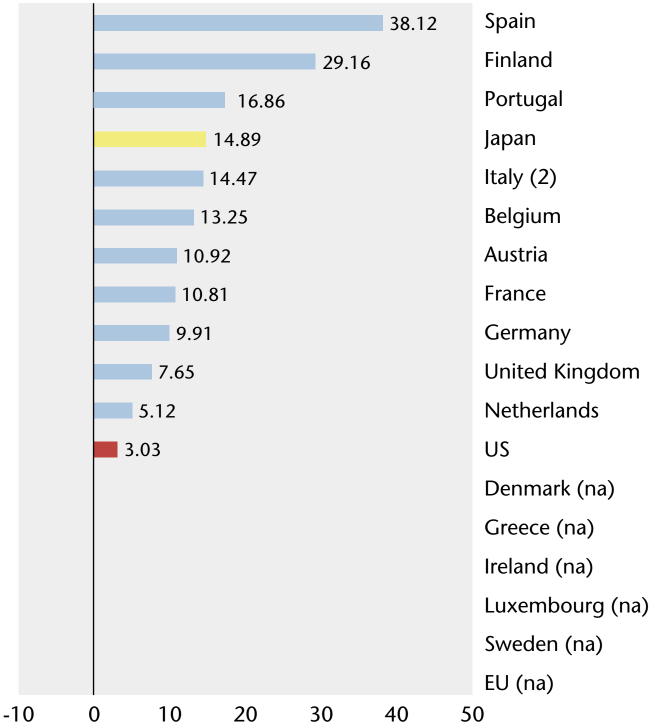
While technology receipts are one measure of a country's competitiveness in selling its intangible knowledge outputs, imported technology can also have an effect on competitiveness through enhancing the technological potential and innovativeness of the purchasing country (especially if it complements existing domestic technology). If one considers the balance of technology exports and imports (Figure 4.4.3), one sees Portugal in particular – but also Finland, Germany and Spain – are significant net importers of technology.

Questions arising from the quantitative analysis

Some important questions for further analysis include:

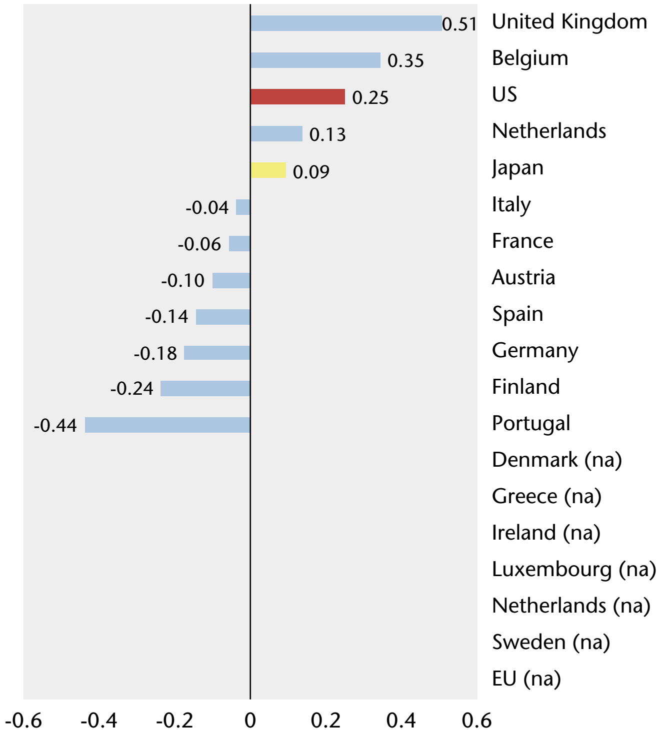
- What are the factors explaining the high levels of technology receipts recorded by Belgium, the Netherlands and Austria?
- What are the effects on technology exports and imports of tax and regulatory policies? What makes technologies difficult to buy and sell ?
- How do the transactions of multinational firms influence technology receipts and payments in certain countries?
- How can government help firms to absorb technologies better, and aid SMEs in procuring the technologies they need at reasonable cost?
- What is the complementary role of national R&D effort and the acquisition of foreign technologies?

Figure 4.4.2. Technology balance of payments receipts - average annual real growth (%), 1995 to latest available year (1)



Source: DG Research
Data: OECD, Member States, Japan (Nistep)
Notes: (1) D: 1995-2000; E,F,FIN: 1995-98; I: 1995-97; P: 1996-99; NL: 1998-99; All other countries: 1995-99 (2) see annex.

Figure 4.4.3. Technology balance of payments (exports - imports) as % of GDP, latest available year (1)



Source: DG Research
Data: Eurostat, OECD, Member States
Note: (1) E,FIN,UK,JP: 1998; F,I: 1997; all other countries: 1999.

Some comments on interpreting the indicator

In interpreting this indicator, the following points should be kept in mind:

- The structure of a country's industry will influence the value of indicator: the higher the share of knowledge intensive sectors, then the higher the potential for knowledge exports (assuming these sectors are competitive).
- Strong imports of these products are not a sign of a weak competitive position of the knowledge producing industry in the domestic market when the imports are not close substitutes to the exported knowledge products.
- For some countries, a significant part of these flows may be accounted for by the technology exports of multinationals to their foreign subsidiaries.
- Similarly, in those countries where there is a strong presence of foreign multinationals, there may be high levels of technology receipts.
- In spite of the efforts of international agencies (and notably the OECD) to harmonize these data, there are still differences between countries in terms of what is included in the TBP.

Definitions and sources

Technology balance of payments receipts are defined according to the Technology Balance of Payments Manual of the OECD, and are expressed in current euros. It is not possible to calculate an EU 15 estimate because the TBP data include intra-EU flows. *Source:* OECD, MSTI, Member States and Japan (Nistep).

Gross domestic product (GDP) is defined according to National Accounts definitions (ESA 1995), and has been converted into euros in terms of 1995 purchasing power standards (PPS).

Source: Eurostat, Member States and national sources for Japan.

Indicator: Growth in a country's world market share of exports of high-tech products

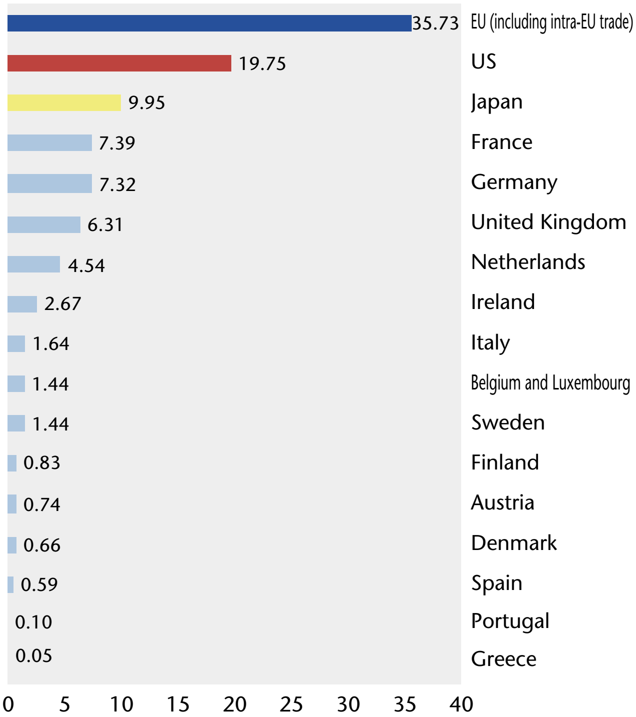
What does this indicator tell us?

High-tech industries (and the high-tech products they produce) are of considerable importance for the knowledge based economy. They are generally associated with high levels of R&D investment and increased productivity, while providing highly paid jobs for skilled workers. A growing export market share is an indicator of competitiveness in these key sectors.

Analysis of national performances

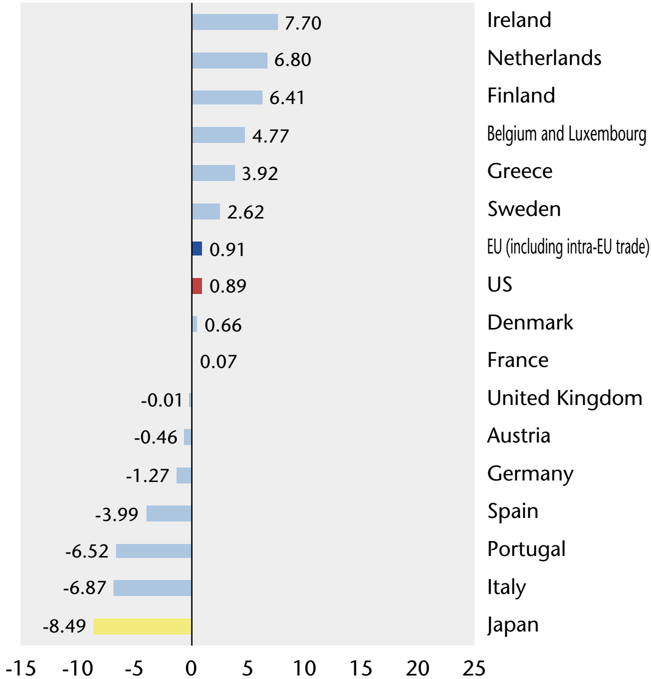
The market share in exports of high-tech products is closely correlated with the size of a country. This is evident in figure 4.5.1, where we see the larger countries tend to have the highest market shares, with the USA and Japan in the lead. Ireland's relatively high position is exceptional, given its size, and is a clear indication of its dynamic high-tech sector. (The very high share of EU-15 in this graph is discussed below.)

Figure 4.5.1. World market share of exports of high-tech products (%), latest available year (1), (2)



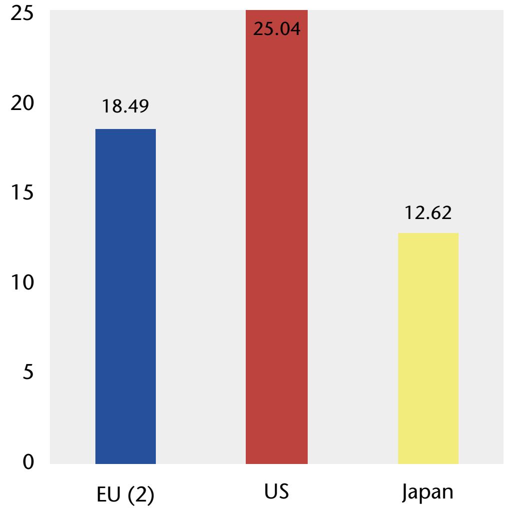
Source: DG Research
Data: Comext, Comtrade
Notes: (1) The world market refers to total world HT exports including intra-EU exports. (2) All data refer to 1999.

Figure 4.5.2. World market share of exports of high-tech products - average annual growth (%), 1995 to latest available year (1), (2)



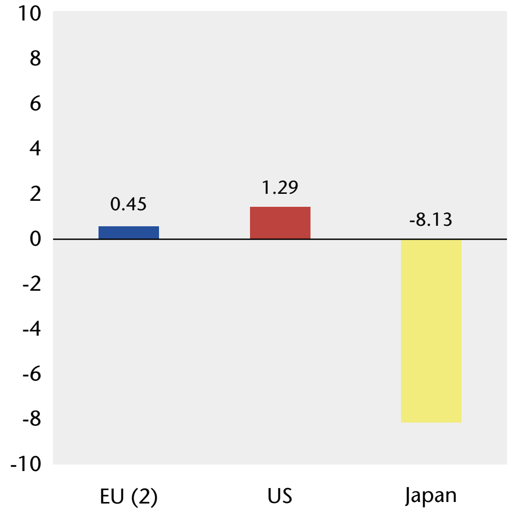
Source: DG Research
Data: Comext, Comtrade
Notes: (1) The world market refers to total world HT exports including intra-EU exports. (2) All data refer to 1995-99.

Figure 4.5.3. World market share of exports of high-tech products excluding intra-EU trade (%), latest available year (1)



Source: DG Research
Data: Comext, Comtrade
Notes: (1) All data refer to 1999; The world market refers to total world HT exports excluding intra-EU trade
(2) EU refers to extra-EU HT exports.

Figure 4.5.4. World market share of exports of high-tech products excluding intra-EU trade - average annual growth (%), 1995 to latest available year (1)



Source: DG Research
Data: Comext, Comtrade
Notes: (1) All data refer to 1999; The world market refers to total world HT exports excluding intra-EU trade.
(2) EU refers to extra-EU HT exports.

The main indicator to be analysed here, and a more comparable indicator, is the growth of market share. This is shown in figure 4.5.2, in which we see that Finland, Ireland, the Netherlands and Greece have recorded significant increases in their share of the world market in high-tech exports (Figures 4.5.2 and 4.5.3). France and the UK have relatively high market shares which have remained relatively stable, but the share of Germany has shown a slight average decrease. Portugal, Italy, and to a lesser extent Spain have seen a shrinkage of market share over the same period. The declining share of Japan over the last few years is also particularly striking.

The very high market share for total EU-15 exports in figure 4.5.1 is due to the fact that this includes intra-EU trade as well as exports to non-EU countries. In order to make a more accurate benchmarking between the EU-15, the USA and Japan, one should exclude intra-EU trade, in much the same way as one would exclude internal trade between states within the USA. An analysis of this kind is shown in figure 4.5.3, where exports for EU-15 are those with non-EU countries (i.e. excluding intra-EU exports), and the world market is taken to be the sum of all countries' high-tech exports, excluding intra-EU exports.

Here we see that the European Union's share of the high tech export market is situated between the USA and Japan. The growth of market share (Figure 4.5.4) is also highest for the USA, with the EU also showing a average increase over the period, but again we see that Japan's share has fallen quite sharply.

Questions arising from the quantitative analysis

- What are the main barriers for countries trying to access high technology markets (regulations, non-tariff barriers…)?
- How can government policy help to enhance a country's comparative advantage in particular technology fields?
- What are the factors behind the high growth in Ireland and Finland? What has been the influence of the ICT sector in particular in these countries? In Ireland, what has been the role of multinationals in exports of high tech products?
- What sorts of measures to protect intellectual property rights are required in order to promote competitiveness in high technology products (e.g. improvements in copyright protection to encourage the development of software and internet-based materials)?

Some comments on interpreting the indicator

High-tech products often have highly specialised niche markets. Exports of such goods are therefore especially important for small countries with limited domestic demand.

Some of a country's high-tech exports may relate to sales by affiliates of foreign companies, which can be significant in certain product markets that are dominated by multinational firms.

An important distinction needs to be made between high-tech products and high-tech industries. While most high-tech products are produced by high-tech industries, some are manufactured by medium- or even low-tech industries. At the same time, some high-tech industries also manufacture medium- or even low-tech products.

It is also important to bear in mind the role of business cycles in the evolution of exports of specific high-tech products (for example Japanese semi-conductors).

This analysis has used two data sources: Eurostat's Comext database for the EU Member States, and Comtrade (a UN database) for the USA, Japan and World totals (which is the same approach used to calculate high tech exports for the Structural Indicators exercise). The advantage of this method is that Comext gives much more up-to-date and accurate data for the EU countries, while Comtrade is the only source for the other countries. However, these two sources use slightly different definitions and methodologies for recording trade, which may affect comparability in some cases.

The introduction of the single market on 1 January 1993 led to the abolition of customs formalities between the Member States, which had served as the traditional source of trade statistics. In order to continue to monitor intra-EU trade, a new collection system was introduced known as INTRASTAT, which involves statistical declarations sent directly by businesses to the competent national authorities, as well as a system of thresholds abolishing all statistical obligations for almost two thirds of businesses. INTRASTAT requires various adjustments to be made to data in order to correct for the under-estimation of certain flows. For this and other reasons, Eurostat advises that figures on intra-EU trade should be interpreted with caution. They are also subject to frequent revision.

Definitions and sources

High-tech products are those with a high R&D intensity, as defined in the OECD high-tech product classification. The detailed list of products included is as follows (SITC Rev.3 product codes in brackets):

1. *Aerospace*
   [7921+7922+7923+7924+7925+79293 +(714-71489-71499)+87411]
2. *Computers-office machines*
   [75113+75131+75132+75134+(752-7529)+75997]
3. *Electronics-telecommunications*
   [76381+76383+(764-76493-76499)+7722+77261+77318+77625+7763+7764+7768+89879]
4. *Pharmacy* [5413+5415+5416+5421+5422]
5. *Scientific instruments*
   [774+8711+8713+8714+8719+87211+(874-87411-8742)+88111+88121+88411+88419+89961+89963++89967]
6. *Electrical machinery*
   [77862+77863+77864+77865+7787+77844]
7. *Chemistry* [52222+52223+52229+52269+525+57433+591]
8. <u>Non-electrical machinery</u>
   [71489+71499+71871+71877+72847+7311+73131+73135+73144+73151+73153+73161+73165+73312+73314+73316+73733+73735
9. *Armament* [891- -]

Exports are measured in value terms and in current prices (Euro).

Source: Comext (Eurostat) for the EU Member States, Comtrade (UN) for the USA, Japan and World totals.

ANNEX 1: Notes concerning the data

GENERAL NOTES

(1) Country codes

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

(2) na means not available.

(3) EU: The EU averages were derived from the data received from the Member States. Estimates were used to fill gaps in the data.

(4) Italy: The data have not yet been approved or amended by Italy.

(5) The average annual real growth rates for all financial indicators with the exception of labour productivity were calculated from data in PPS at 1995 prices and exchange rates. The conversion from national currency was carried out using the PPS rates (*source:* Eurostat) and price indices of GDP (*source:* DG ECFIN) available at the beginning of April 2001. In the case of labour productivity, the data were provided directly by DG ECFIN.

(6) The average annual rate of growth g of I between first year (year a) and last year (year b) is given by:

$$g = \left(\frac{I_b}{I_a}\right)^{\frac{1}{b-a}} - 1.$$

NOTES BY INDICATOR

INDICATOR. Number of researchers in relation to the total workforce.

(i) Number of researchers for B (1995-97), DK (1998), D (1999), P (2000) and JP (1999-2000) are estimated or provisional.

(ii) Japan: Number of researchers (1995-98) adjusted by OECD. Number of researchers (1999-2000) and total workforce (2000) supplied by Japan.

INDICATOR. Number of new science and technology PhDs in relation to the population in the corresponding age group.

(i) All PhD data refer to the ISCED97 definition of science and technology PhDs.

(ii) Japan: PhD and population data supplied by Japan.

INDICATOR. Total research and development expenditure in relation to GDP.

(i) Gross domestic expenditure on R&D (GERD) for B (1999), DK (1999), D (2000), F (1999), A (2000), P (2000), FIN (2000) is estimated or provisional.

(ii) Gross domestic product (GDP) for A (2000), P (2000), FIN (2000) is estimated or provisional.

(iii) Japan: GERD adjusted by OECD.

INDICATOR. Research and development expenditure financed by industry in relation to industrial output.

(i) R&D expenditure financed by industry for DK (1999), D (2000), EL (1997), P (2000) and US (1999) is estimated or provisional.

INDICATOR. Share of the annual government budget allocated to research.

(i) Government budget appropriations or outlays for R&D (GBAORD) for B (1999), D (2000), EL (1999), E (1999), F (1999), S (2000) and US (1999 and 2000) are estimated or provisional.

(ii) General government expenditure excluding interest for DK (2000), A (2000), P (2000), FIN (2000), S (2000) is estimated or provisional.
(iii) Japan: General government expenditure refers to the 'general account budgets' and was supplied by Japan.
(iv) US: The % share of the annual government budget allocated to research was supplied by the US.

INDICATOR. Share of SMEs in publicly funded R&D executed by the business sector.

(i) Publicly funded business sector R&D performed by SMEs for D (1997), EL (1997), P (2000) and JP (1995-99) is estimated or provisional.

(ii) Total publicly funded business sector R&D for EL (1997) and P(2000) is estimated or provisional.

INDICATOR. Volume of venture capital investment in early stages (seed and start-up) in relation to GDP.

Total seed and start-up venture capital for DK (1999) is estimated or provisional.Total seed and start-up venture capital for Japan (1995-2000) is estimated and was supplied by Japan.

INDICATOR. Number of patents at the European and US patent offices.

Total number of EPO applications and total number of USPTO patents granted for all countries for the year 2000 are estimated or provisional.

INDICATOR. Percentage of innovative firms co-operating with other firms/universities/public research institutes.

Percentage of innovating firms for DK (1996) is estimated or provisional.

INDICATOR. High-tech and medium high-tech industries: share of total employment and contribution to growth of employment.

Employment in high-tech or medium high-tech industries for DK (1998) is estimated or provisional.

INDICATOR. Share of knowledge intensive services in total output and contribution of these services to growth of output.

Value added of knowledge intensive sectors for D (2000) and F (1999) is estimated or provisional.

INDICATOR. Technology balance of payments receipts as a proportion of GDP.

Total technology balance of payments receipts for D (2000) is estimated or provisional.

ANNEX 2: List of indicators specified in the Working document from the Commission services "Development of an open method of co-ordination for benchmarking national research policies: Objectives, methodology and indicators"[1]

1. THEME 1: Human resources in RTD, including attractiveness of science and technology professions

INDICATORS	STATUS [2]	FURTHER DEVELOPMENTS TO BE EXPLORED	SCIENTIFIC AND SOCIO-ECONOMIC MEANING
■ Number of researchers in relation to the total workforce	**Data available** *Source:* Eurostat/ OECD/ Member States	– Investigate how comparability of data could be improved – Breakdown by industry, universities and public research centres	Measures the human resource capacity in R&D of each country and its breakdown by main sector
■ Number of new science and technology PhDs in relation to the population in the corresponding age group	**Data available** *Source:* Eurostat/ OECD/ UNESCO	– Breakdown by discipline, including socio-economic sciences – Breakdown by the country of origin	Indicates the increase in the highly-qualified human knowledge base
■ Number of young researchers recruited in universities and public research centres in relation to the total number of researchers	**New indicator** (to be developed)	– Data on average age of researchers and number of research posts created – share of researchers retiring in the next 10 years – Salary levels	Reflects the attractiveness of science for young people and the prospects for sustaining a knowledge-based economy
■ Proportion of women in the total number of researchers in universities and public research centres	**New indicator** (to be developed)	– Investigate possibility of breakdown by level of responsibility	Indicates the participation of women in science and their role in contributing to knowledge resources
■ Proportion of researchers from other countries amongst researchers in universities and public research centres	**New indicator** (to be developed)	– Breakdown by country of origin – Data on researchers' participation in European programmes	Reflects the international attractiveness of national science systems and measures the diffusion of external knowledge

[1] The absolute values of indicators will be supplemented with growth rates when appropriate.
[2] "Data available" indicates that a harmonised source of data exists (e.g. Eurostat, OECD). "New indicator" means that either no data are currently available nationally or internationally, or that only very partial data that are not harmonised exist.

2. THEME 2: Public and private investment in RTD

INDICATORS	STATUS	FURTHER DEVELOPMENTS TO BE EXPLORED	SCIENTIFIC AND SOCIO- ECONOMIC MEANING
■ Total research and development expenditure in relation to GDP and breakdown by source of funding	**Data available** *Source:* Eurostat/ OECD/ Member States	– Breakdown of the funding by basic and applied research	Measures the economy's propensity to allocate resources to research and development
■ Research and development expenditure financed by industry in relation to industrial output	**Data available** *Source:* Eurostat/ OECD/ Member States	– Proportion of R&D executed by industry financed by public funding	Measures the relative importance of business sector R&D expenditure in the total economy, and public support for R&D executed by industry
■ Share of the annual government budget allocated to research	**Data available** *Source:* Eurostat/ OECD/ Member States	– Breakdown of research budget by main policy objectives – Allocation of budget to policy support – Breakdown of research budget by main sector (e.g. civil and defence)	Measures the relative importance given to R&D in the government's general spending commitments
■ Share of SMEs in publicly funded R&D executed by the business sector	**Data available** (but no regular harmonised statistics)	– Proportion of SMEs (and if possible new SMEs) amongst enterprises conducting research activities	Measures the public support for research activities of SMEs
■ Volume of venture capital investment in early stages (seed and start-up) in relation to GDP	**Data available** (but no harmonised statistics) *Source:* EVCA, NVCA, AVCA, Member States	– Investigate how comparability of data could be improved – Share of venture capital invested in high-tech industries	Indicates the financing of new high-growth/innovation-based firms

3. THEME 3: Scientific and technological productivity

INDICATORS	STATUS	FURTHER DEVELOPMENTS TO BE EXPLORED	SCIENTIFIC AND SOCIO- ECONOMIC MEANING
■ Number of patents at the European and US patent offices per capita	**Data available** *Source:* EPO/USPTO	– Share of patents in high-tech areas – Explore other possible scaling factors (e.g. business R&D expenditure, number of researchers)	Measures technological performance of countries
■ Number of scientific publications and most cited publications per capita	**Data available** *Source:* Science Citation Index	– Breakdown by science domain (examine the possible inclusion of social sciences and humanities) – Explore other possible scaling factors (e.g. non-business R&D expenditure, number of researchers) – Proportion of joint publications in the national total – Need to examine methodological issues	Measures scientific performance and co-operative patterns
■ Number of spin-offs generated by universities and research centres	**New indicator** (to be developed)	– Indicators of performance of spin-offs – Explore suitable scaling factors (per capita, GDP, etc.)	Measures the development of new economic activities by R&D personnel
■ Percentage of innovative firms co-operating with other firms/universities/public research institutes	**Data available** *Source:* Eurostat	– Other forms of co-operation between universities and industry	Indicates co-operation patterns which may contribute to strengthening knowledge and innovation transfers
■ Rate of usage of broadband electronic networks for research by R&D laboratories.	**New indicator** (to be developed)	– Need to examine methodological issues	Measures the rate of connectivity and use of electronic research networks - the larger and better connected, the more likely is the increase in quantity and quality of scientific productivity and the speedy diffusion of scientific and technological output

4. THEME 4: Impact of RTD on economic competitiveness and employment

INDICATORS	STATUS	FURTHER DEVELOPMENTS TO BE EXPLORED	SCIENTIFIC AND SOCIO- ECONOMIC MEANING
▪ Growth rate of labour productivity	**Data available** *Source:* Eurostat/ OECD/ Member States	– Growth in total factor productivity – Growth rate of labour productivity in high tech, medium-tech. and low-tech. companies	Measures overall competitiveness of an economy and captures all economic effects induced by innovations and S&T progress
▪ Share of high-tech and medium-high-tech industries (+ their contribution to growth) in total employment and output	**Data available** *Source:* Eurostat/ OECD/ Member States	– Breakdown by sectors (including contribution of the ICT sector)	Indicates the contribution of high-tech (and medium-high-tech) sectors to growth and employment
▪ Share of knowledge intensive services (+ their contribution to growth) in total employment and output	**Data available** *Source:* Eurostat/ OECD/ Member States	– Breakdown by individual service sectors	Measures the contribution to employment and output of knowledge intensive services
▪ Technology balance of payments receipts as a proportion of GDP	**Data available** (but not for all countries and all years) *Source:* Eurostat/ OECD/ Member States	– Breakdown by type of transaction (e.g. rights of use of patents, etc.) – Breakdown by intra-EU and extra-EU – Investigate how to redefine the indicator for S&T purposes	Measures the importance of a country's receipts from exporting technical knowledge and services (including licenses, know-how, trademarks, technical services, etc.)
▪ Growth in a country's world market share of exports of high-tech products	**Data available** Eurostat (Comext)/UN (Comtrade)	– Breakdown by type of product	Indicates changes in international competitiveness in high-tech products

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