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2000 EDITION

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Data 1985-1999

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Foreword

At the Lisbon Summit of March 2000, the European Council set a clear strategic objective for Europe in the next decade: to become the most competitive and dynamic knowledge-based economy capable of sustainable economic growth with more and better jobs and greater social cohesion.

In order to achieve this goal there are several requirements: among them, creating an environment that encourages research and innovation, and facilitating the transition to the knowledge-based economy. Recommendations for the realisation of several of these objectives are laid down in a recent Commission communication entitled *Towards a European research area* (1). Nevertheless, such systematic policy support needs both high quality information on Science and Technology and relevant accompanying analysis.

For this reason and in recognition of the increasing diversity of S&T statistics, the present publication considers many more aspects than Eurostat's R&D Annual Publication. As well as the usual statistics on R&D expenditure, R&D personnel, Government R&D appropriations and patents, it contains, for the first time, data on innovation, employment in high technology sectors and human resources in science and technology. The role of Community RTD policy is also considered and, in a separate chapter, the possible future directions for the development of a new generation of S&T statistics and their evolution thus far.

Limitations of space have prevented the inclusion of complete time series in all cases. However, these data can be found in the CD-ROM version of this publication and are, of course, available in Eurostat's reference database, New Cronos.

All the information in this publication is based on data supplied to Eurostat by the Member States, by the Research DG of the European Commission, by the European Patent Office (EPO) and by the OECD. We express our thanks to our colleagues in the Member States (and in Iceland and Norway), the Commission Services, EPO, the OECD and the Institute for Prospective Technological Studies (IPTS) for their excellent co-operation and their willingness to help in meeting the ever-growing demand for information on S&T.

Yves Franchet

Director-General — Eurostat

(1) Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, *Towards a European research area*, Brussels, 18 January 2000.

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Introduction

I

Since 1993, Eurostat's Annual Publication on Research and Development statistics, containing up-to-date statistics and indicators on both Research and Development and European patent applications, has reported key trends and developments in both the European Union and the European Economic Area. *Statistics on S&T in Europe* marks a deviation from the customary format to present recent developments not just in the four areas considered annually (R&D expenditure, R&D personnel, Government R&D appropriations and Patents), but also in more recent areas of interest to science and technology policy-makers and analysts.

Research and Development (R&D) is regarded as an important contribution to our well-being; it is a driving factor behind economic growth and job creation, a source of increasing quality of products and a prime mover of improvements in health care and environmental protection. For the development of the European Union, its Member States and regions, R&D is therefore a key issue. This is why political decision-makers at all levels are calling for stronger measures in support of R&D.

Yet, despite the frequent clarion calls for greater European investment into the research effort, as well as policy formulated to encourage such a situation, the reality is that more needs to be done. This is the message that is borne out in the European Commission's communication *Towards a European research area*, in January 2000 (1).

The indicators published by Eurostat in *Statistics on S&T in Europe* allow the continued reporting and analysis that permit a close monitoring of recent performances and, therefore, the identification of current and potential future areas of concern. This is made possible by data which are as comprehensive, comparable and as up-to-date as possible, providing analysts with a common system of reference and therefore facilitating the process of identifying best practice.

In recognition of the increasing diversity of science and technology (S&T) statistics, the present publication goes beyond the traditional fields of *Research and development: annual statistics* and looks at more recent areas of Eurostat research: innovation, employment in high technology sectors and human resources in science and technology.

This is because, today, it is necessary to complement the more conventional elements of R&D statistics by additional fields that include indicators on less tangible factors: facets of the knowledge-based economy.

Nevertheless, this *Panorama* version is by no means intended to provide a detailed taxonomic approach to all of the science and technology indicators used at the national and international level, but rather an examination of pertinent domains of S&T today.

Primary focus is on the 15 European Union Member States and to a lesser extent the European Economic Area. To provide further high level international comparison, where possible, Japan and the the United States are also considered. And, at the other end of the scale, a regional analysis across the EU countries is provided. Although no consideration is made of the R&D or innovation situation in the candidate countries or the Russian Federation in this publication, interested readers can refer to another recent Eurostat publication (2).

Given the numerous sources of data involved, the time series differ according to indicator. For example, the first considered year for indicators concerning R&D expenditure, R&D personnel and GBAORD is 1985, whereas for Patents the starting point is 1989.

(1) Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, *Towards a European research area*, Brussels, 18 January 2000.

(2) *R&D and innovation statistics in candidate countries and the Russian Federation*, Office for Official Publications of the European Communities, Luxembourg, 2000.

The chapters on GBOARD and R&D expenditure and personnel also take into account changes brought about by the adoption of the new system of national accounts — the European System of Accounts (ESA) — with ESA '95 replacing ESA '79.

For the other more recently developed indicators, the time series are of course shorter. Indicators on human resources in science and technology begin in 1994, whereas the starting point for data on employment in high technology sectors is 1995. Nevertheless, the goal of this publication remains the same throughout: to provide the most detailed, coherent and comprehensive time series analysis possible.

Due to constraints of space, the statistical tables used for the analysis are not always available in the paper version of the present publication. Instead, they are provided in their entirety in the electronic version of *Statistics on S&T in Europe*. Electronic versions of this publication can be obtained by visiting the Eurostat Web-site at:

- **http://europa.eu.int/comm/eurostat/**

Furthermore, analyses in the present publication refer to the data on the Eurostat database New Cronos at the time of writing. Because New Cronos is regularly updated as and when new data are received, it may be that data in extractions made or requested subsequently differ somewhat to those available at the time of writing.

Consistency with the analyses conducted in previous publications is also maintained, whilst seeking to complement these important aspects with further research that responds to user requirements. The conceptualisation of these new indicators is the result of rigorous and continual procedures within the policy-making and scientific communities. Methodological notes, explanations and bibliographical references are documented on a chapter by chapter basis.

This publication, intended for both generalists and specialists, is organised thematically. In Part 1, recent trends of the more traditional indicators (R&D expenditure, R&D personnel, GBAORD and Patents) are analysed along with the Community contribution to the research effort. This is followed in Part 2 by the evaluation of innovation, employment in high technology sectors and human resources in science and technology. The publication concludes with some considerations on the likely future key areas in the development of S&T indicators.

GOVERNMENT BUDGET APPROPRIATIONS ON R&D

In Chapter 1, the distribution and main trends of GBAORD in the EU are documented, mapping both the recent developments in the individual Member States and placing Europe in a more international context. In 1999, budget appropriations in the Member States of the European Union totalled more than EUR 59 000 million, with a further EUR 2 400 million earmarked by the European Commission. However, the relative deterioration of GBAORD in the EU as a proportion of GDP is underlined in this chapter. Comparisons with Japan and the US, reveal that Japan has caught up both the EU and the US to a significant degree since 1985 and that, despite a larger relative reduction in government R&D appropriations, the US still retains the highest relative proportion.

The largest EU public R&D appropriations relative to GDP are France and Finland. Spain and Portugal, on the other hand, have shown the highest growth rate over the last five years and are approaching the EU average. Changes have also occurred in the socio-economic objectives of these funds. During the last fifteen years 'Research financed from General University Funds' has seen the strongest increase and is now the first priority in the EU. Next are 'Technological objectives', 'Defence' and 'Non-oriented research'.

I

THE COMMUNITY EFFORT

Community Research and Technological Development (RTD), which is budgeted according to four-year framework programmes, has increased steadily since the inception of the framework programmes in 1984. The current Fifth Framework Programme, running from 1998 to 2002, commits EUR 15 thousand million to RTD. Relative to the overall Community budget, however, this represents a modest diminution on the Fourth Framework Programme level, down from 4 to 3.7 %. The Community Framework Programme accounts for around 5.4 % of the total public research effort.

R&D EXPENDITURE AND R&D PERSONNEL

R&D expenditure continued to develop in the EU in absolute terms and in 1998 represented an estimated ECU 141 thousand million. This is roughly 70 % of the equivalent research effort in the United States (ECU 202 thousand million), but higher than that of Japan (ECU 102 thousand million). Measured as a proportion of gross domestic product, the EU effort in 1998 (1.86 %) is well below corresponding figures for the United States and Japan (2.58 and 3.03 % respectively). The principal source of this difference is the business enterprise sector, in which the EU R&D effort is far below its US or Japanese counterparts.

Apart from adequate funding, successful R&D activities require the deployment of qualified staff. In 1998, in the European Union there were round 2.2 million personnel in R&D activities, which is a modest increase on the 1997 level. In terms of Full Time Equivalent (FTE), this represents 1.6 million R&D personnel, of which just over 50 % worked in the business enterprise sector. This compares with approximately three in four R&D personnel working in the business enterprise sector in Japan.

PATENTS

For a long time, data on patents have been used as a measure of innovative activity, technology development, and particularly for international comparisons of technology growth. Since 1990, patent applications at the European Patent Office (EPO) by EU countries have increased at an average annual rate of 2.7 % and in 1998, just over 40 000 patent applications were filed by the EU-15. By way of comparison, over the same observation period, growth in patent applications at the EPO by the US and Japan stands at 4.8 and 1.3 %, respectively. At the EU level, Germany, France and the UK are the three dominant countries in patenting and in 1998 they accounted for more than 70 % of the EU total. Nevertheless, growth in patents in these countries falls below the EU average.

INNOVATION

Using data from the second Community Innovation Survey (CIS2) in 1997-98, which built upon the knowledge and experience obtained in the first survey conducted in 1992, Chapter 5 presents an overview of innovation by sector, co-operation, expenditure and by facilitating or hampering factors. Coverage concerns the EU Member States (except Greece) and also Norway.

On average 51 and 41 % of enterprises in the manufacturing and service sectors respectively were innovative during the period 1994-96, with the proportion of innovating enterprises tending to increase with size-class in both the manufacturing and service sectors. The most innovative Member States were Ireland (73 %), Germany (69 %) and Austria (67 %).

EMPLOYMENT IN HIGH TECHNOLOGY SECTORS

Chapter 6 concentrates on the level of employment growth in the high technology sectors. With the growth in the tertiary sector in all European industrialised nations, industrial employment has shown a downward trend, until more recently when, along with the general economic situation, it has stabilised to some degree. Despite this phenomenon, positive growth has been experienced in the high technology manufacturing sectors at the European Union level. The big four EU nations — Germany, France, Italy and the United Kingdom — accounted for over three quarters of total employment in this sector, a third of which is to be found in Germany alone, where research-intensive industries rank highest even within the economy as a whole.

Growth in the knowledge-intensive service sectors and also the information and communication-oriented service sectors has been more clear-cut. For knowledge-intensive services, there has been annual average growth of 5 % or more for several regions. But it is in the information and communication-oriented service sectors that the highest growth is manifest. Double-digit growth rates are evident in some of the leading high tech regions of the EU.

HUMAN RESOURCES IN SCIENCE AND TECHNOLOGY

Whereas the chapter on employment in high technology sectors concentrated principally on employment growth, with some focus on the level of qualification of individuals, the principal aim of the chapter on Human Resources in Science and Technology (HRST) is to demonstrate to what degree Europe's workforce is qualified and able to prosper in this new economy.

According to the latest available data from the Community Labour Force Survey for 1999, there were approximately 65 million people classified as HRST in the EU, of which just less than 30 million were female. In the vast majority of Member States, the situation is also improving over time, with annual average growth as high as around 8 % per annum. New results on the domestic mobility of Europe's highly qualified workers indicate that they are becoming more mobile, with some variations between the countries analysed.

S&T INDICATORS IN THE NEW ECONOMY

The final chapter looks at problems associated with reconciling the needs of users of S&T indicators and the possible ways for providing them. An underlying theme is that too much emphasis is being placed on the identification and measurement of inputs and outputs, with less effort focused on identifying and classifying the strengths and weaknesses of the underlying stock of S&T knowledge and capability. In short, the search for relevant indicators must move away from the simple model of innovation to a much more complex context for which the definitions and models have yet to be fully established.

I

References

- Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, *Towards a European research area*, Brussels, 18 January 2000.
- *R&D and innovation statistics in candidate countries and the Russian Federation*, Office for Official Publications of the European Communities, Luxembourg, 2000.

PART 1

RESEARCH AND DEVELOPMENT

PART 1

Government budget appropriations on R&D

CHAPTER 1

INTRODUCTION

Government Budget Appropriations and Outlays on R&D (GBAORD) are a way of measuring government support to R&D. GBAORD concerns government funding towards R&D activities performed both nationally and abroad. It includes budget provisions by central government but excludes those made by local government. Only when the contribution is significant does it also incorporate provincial or regional government outlays. It not only covers R&D performed in government establishments but also in the other three national sectors (business enterprise, private non-profit and higher education).

GBAORD data do not consider the amount of money actually spent, but are based on budget provisions, and so should be seen as intentions of spending. This is why final actual spending rarely matches the initially allocated budget. The process of political consensus about public expenditures creates gaps between budgets and final expenditures (gaps in terms of time and amount of resources). However, since there is a greater time lag for data on final R&D expenditure (see Chapter 3), data are usually also collected from budget statistics in order to have up to date indicators.

Data are collected at the national level and the procedure can be articulated in a two step process:

- within the budget statistics, it is first necessary to identify the budget items that involve R&D;
- the R&D contents of these budget items must then be measured or estimated.

Data are also collected according to socio-economic objectives. These data reflect policies at a given moment in time and the concomitant priorities of the policy-makers when allocating their budgets. These data are hard to collect because they are not obtained from *ad hoc* surveys, but in most cases are obtained from national budget statistics. The difficulty is due more specifically to the fact that national budgets already have their own terminology and methodology and therefore do not accord entirely with the Eurostat guidelines and the methodology used by the OECD *Proposed Standard Practice for Surveys of Research and Experimental Development — Frascati Manual.*

This analysis is performed for the years 1985 to 1999 (1999 provisional data) and is divided into four sections. The first section compares the respective evolutions in the European Union, Japan and the United States — the so called Triad. This allows us to place recent trends in the EU within an international context. The second section analyses the evolution of GBAORD for the EU-15 (1) as a whole. The analysis is conducted both in terms of total GBAORD and broken down by NABS (*Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets*) (2), the classification widely agreed to compare budget destination of resources to particular socio-economic objectives. The analysis by NABS reveals priorities placed by individual governments in different categories. The third section deals with the European Community appropriations on R&D, especially under the Framework Programmes. Finally, an analysis is conducted for the individual Member States of the EU, which gives an indication of the relative importance that the Member State governments have granted to R&D over time.

(1) In this chapter the EU-15 does not include Luxembourg.

(2) The breakdown by socio-economic objectives follows the breakdown on the basis of the NABS (Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets, Eurostat 1994 revision).

1.1. GBAORD ALLOCATION OF THE TRIAD

Before analysing GBAORD in the European Union, Japan and the United States, a few cautionary notes should be made. Firstly, neither data on 'Research financed from General University Funds (GUF)' or 'Other civil research' are available for the US, as data there are based on the Federal or central government only. Secondly, for Japan, GBAORD data are in general underestimated because the R&D portion of military contracts is excluded. Finally, GDP throughout this chapter is calculated according to the most recent European System of Accounts — ESA 95.

In absolute values GBAORD data in purchasing power parity (PPS) at 1990 prices show a clear predominance of the US over the last fifteen years. Figure 1.1. shows that the US allocated the largest amount of funds for R&D during 1999: PPS 56.9 thousand million (EUR 70.6 thousand million). The EU follows with PPS 45.9 thousand million (EUR 59.2 thousand million) appropriated to R&D by the Government sector, while Japan is third with PPS 14.3 thousand million (EUR 26.0 thousand million).

A cursory inspection of the evolution between 1985 and 1999 reveals that GBAORD in the US grew moderately between 1985 and 1991. In a first period (1985-92), it grew by 0.87 % per year, reaching the absolute value of 59.4 thousand million PPS (ECU 52.7 thousand million) in 1992 and then declined by 0.82 % per year.

Slightly different trends are shown by the EU in two different phases. In the first period (1985-92) the Member States budgeted an increasing amount of resources to R&D, growing from PPS 42.1 thousand million (ECU 36.4 thousand million) in 1985 to PPS 48.0 thousand million (ECU 53.9 thousand million) in 1992. Between 1992 and 1999, GBAORD declined to PPS 45.9 thousand million (EUR 58.9).

Japan, on the other hand, shows a steadily increasing trend in all the given years, growing from PPS 7.8 thousand million (ECU 8.5 thousand million) in 1985 to PPS 14.3 thousand million (EUR 26.0 thousand million) in 1999. The annual average growth of Japan's GBAORD between 1985 and 1999 was equivalent to 4.4 %.

GBAORD in PPS at 1990 prices shows the absolute value of R&D government funding in real terms but does not give any evidence of the effort a country makes in relation to the dimension of its economy. A second indicator could be used to show the relative effort made by policymakers towards R&D in the Triad: GBAORD as a proportion of GDP. Figure 1.2. shows two existing trends in the Triad: a decreasing one for both the EU and the US and an increasing one for Japan. A convergence is clearly visible. The period between 1985 and 1999 has seen a general decline for the EU and the US budgeted R&D funding in relative terms. GBAORD as a percentage of GDP deteriorated in the US from the 1985 level of 1.18 % to the 1999 level of 0.81 %. In the EU, it fell from 0.99 % to 0.76 % over the same period. After a fairly stable period, from the early 1990s onwards, Japan increased its share of GBAORD relative to GDP from 0.45 % in 1990 to 0.64 % in 1999.

Using the NABS categories as a distinguishing factor, further consideration can now be placed on the relative importance of the various socio-economic objectives in the Triad (Figures 1.3., 1.4., 1.5. and 1.6.) (3).

Among the major sectors in Europe 'Research financed from General University Funds (GUF)' has increased from 22.4 % in 1985 to 31.7 % in 1999, as has 'Non-oriented research' (4) from 10.9 to 14.7 % over the same period. A clearly downward trend is shown for 'Defence' (22.9 to 15 %) and 'Industrial production and technology' (13.5 down to 9.5 %). The tendency for the EU seems to be towards a concentration of resources in 'research financed from GUF' and 'non-oriented research', as we can see that the aggregated sector called 'others' (5) has decreased.

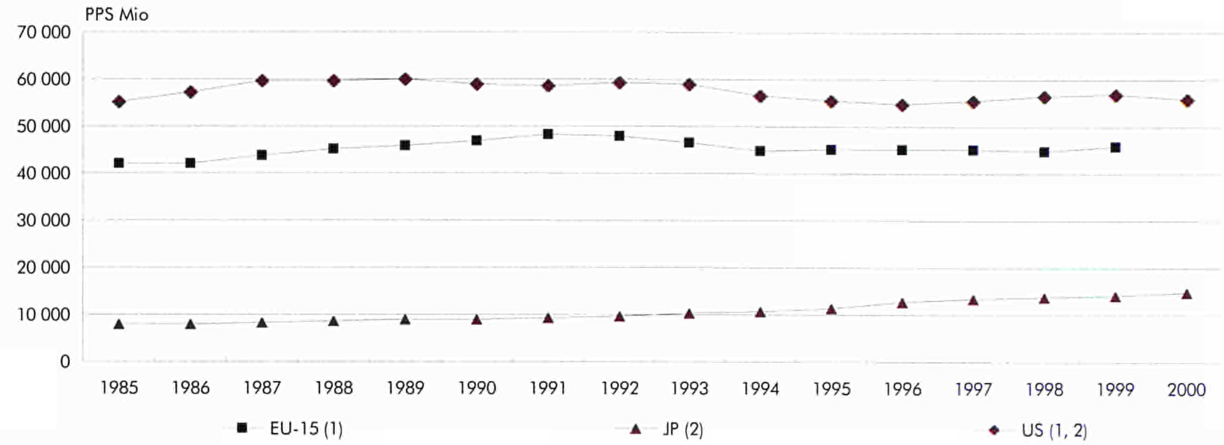
Figure 1.5. shows that Japan has a converging distribution of GBAORD in the various sectors. All the smallest sectors, with the exception of 'Agricultural production and technology', show an increasing trend from 1988 to 1999, and in particular the socio-economic objective 'Non-oriented research' which increased from 7.6 to 12.8 % over this period. On the other hand, the major sectors have experienced a decrease in their share of funding. This is particularly true for 'Research financed from General University Funds' (from 43.7 to 36.6 %) and 'Production, distribution and rational utilisation of energy' (from 22.3 to 19.2 %).

(3) No data on 'Research financed from General University Funds (GUF)' nor 'Other civil research' are available for the US, where data are based on the 'Federal or central government only'. As the GUF is financed through State Funds in the United States, it is also excluded from the GBAORD data. The category 'Other civil research' is included under the appropriate objectives. The absence of these two categories could bias the analysis, in particular due to the importance of the GUF in the European Union and Japan.

(4) 'Non-oriented research' covers all those appropriations or outlays which are earmarked for R&D but which cannot be attributed to an objective.

(5) Residual class considering all other NABS with lower values.

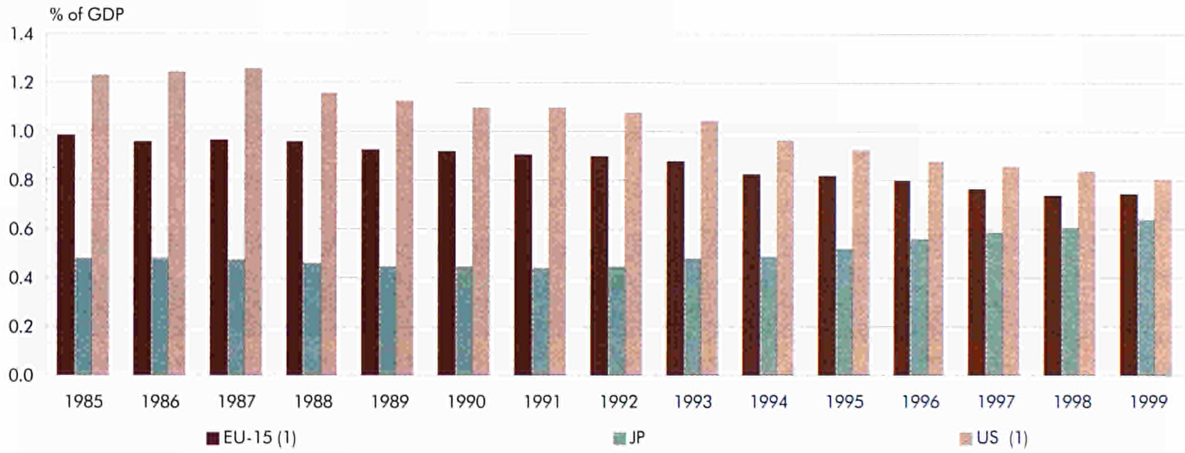
Fig.1.1. Evolution of GBAORD in PPS 1990 — European Union, Japan and the United States 1985-2000



(1) Provisional data for 1999.
(2) Provisional data for 2000.

Sources: Eurostat, OECD.

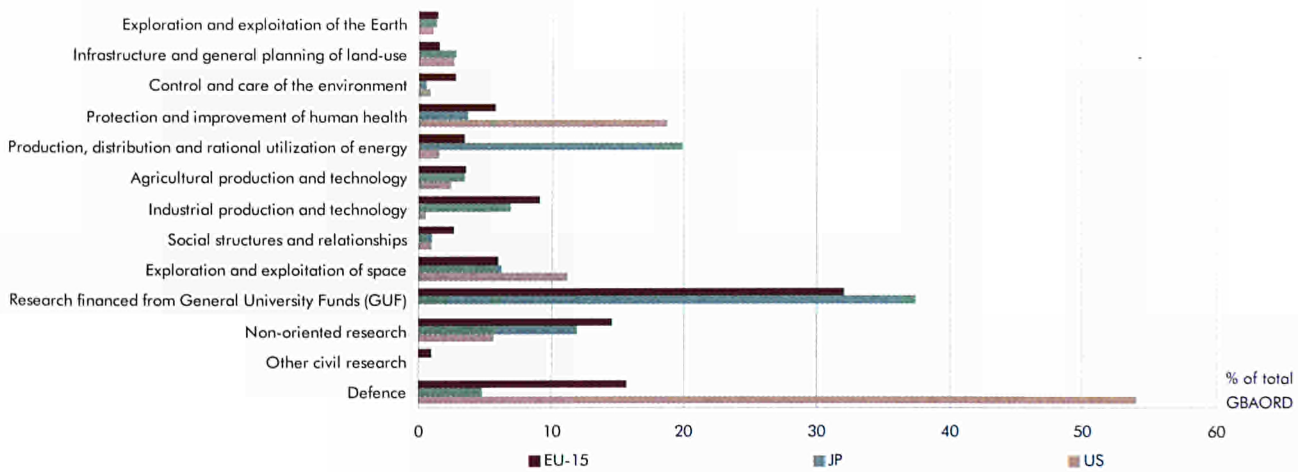
Fig.1.2. GBAORD as a % of GDP — European Union, Japan and the United States 1985-99



(1) Provisional data for 1999.

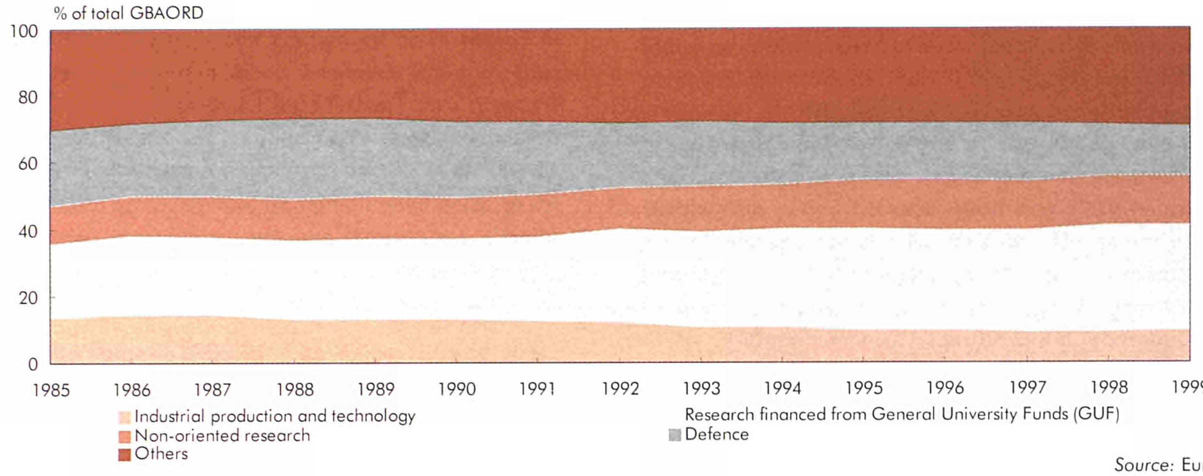
Sources: Eurostat, OECD.

Fig.1.3. GBAORD by NABS — European Union, Japan and the United States 1999



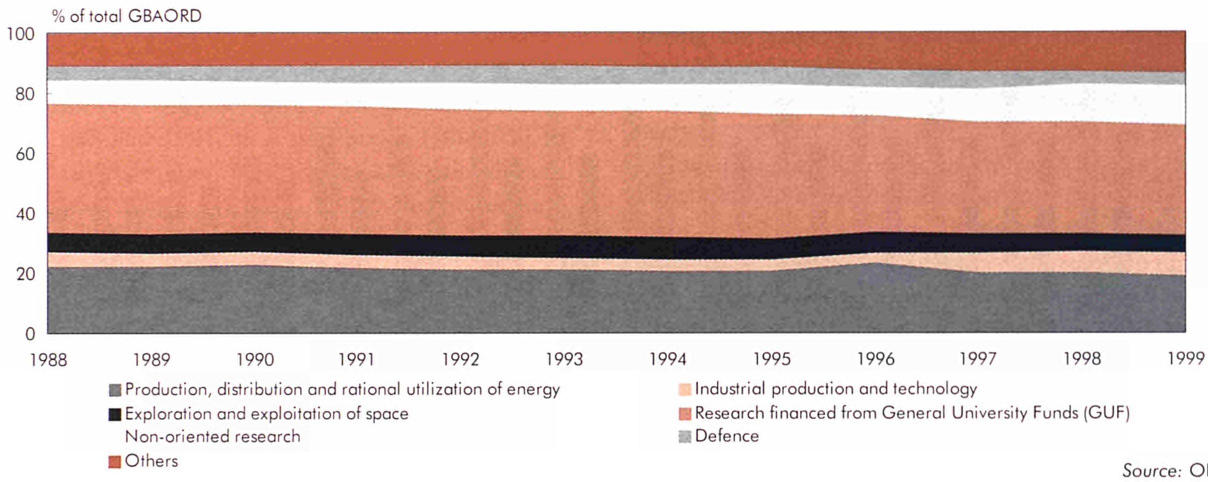
Sources: Eurostat, OECD.

Fig. 1.4. Evolution of GBAORD by selected NABS as a % of total GBAORD — European Union 1985-99



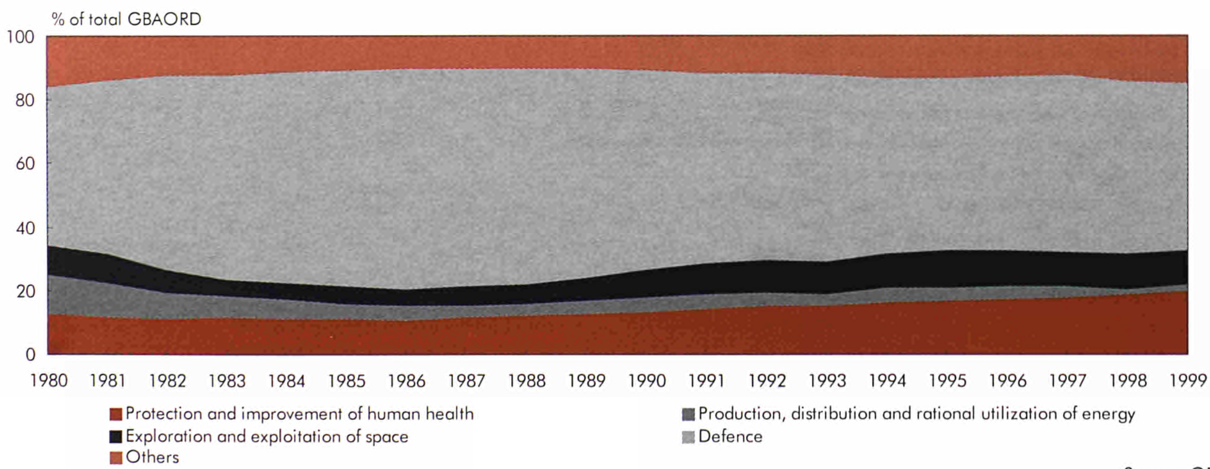
Source: Eurostat.

Fig. 1.5. Evolution of GBAORD by selected NABS as a % of total GBAORD — Japan 1988-99



Source: OECD.

Fig. 1.6. Evolution of GBAORD by selected NABS as a % of total GBAORD — United States 1980-99



Source: OECD.

Finally, consideration of the US reveals that the relative weight of the 'Defence' sector has decreased fairly rapidly in the 1990s, even if it remains by far the one attracting the majority of resources (Figure 1.6.). Before then, it grew from 50.2 % in 1980 to 69.4 % in 1986. From 1987 to 1999, however, it fell from almost 70 % of total GBAORD to 52.8 %. A decreasing trend is also evident for 'Production, distribution and rational utilization of energy', whilst concomitantly, the others sectors are growing. This latest is the case of 'Exploration and exploitation of space' — from a share of 5.5 % of total GBAORD in 1985, it grew steadily to a share of 10.7 % in 1999 — and 'Protection and improvement of human health' increased its share from 11.3 % in 1985 to 19.8 % in 1999.

1.2. GBAORD ALLOCATION IN THE EUROPEAN UNION

Total government R&D appropriations

Figures 1.7. and 1.8. show the values of GBAORD for the EU in thousand millions of ECU/EUR at current prices, in PPS at 1990 constant prices and as a proportion of GDP. When analysed in terms of current prices GBAORD shows a quite constantly increasing trend, starting from ECU 36.4 thousand million in 1985 up to EUR 59.2 thousand million in 1999. However, there is low growth in terms of constant prices and a decrease in the effort made by governments towards R&D — GBAORD as a percentage of GDP.

Two very different periods are noticeable, with 1991-92 a turning point for the three indicators considered. The different annual average growth rates shown in these two periods clearly give a dimension of the change. The annual average growth rate of GBAORD in constant prices was 2 % in the first period (1985-91) and – 0.62 % in the second (1992-99). This same growth rate in current prices was 5.3 % in the first period and 1.3 % in the second.

GBAORD by socio-economic objectives

Analysis of the disaggregated data reveals the priorities placed by individual governments in different categories. Figure 1.9. shows that in the EU the majority of funds (32 %) are allocated to the field 'Research Financed from General University Funds' (6).

The second socio-economic objective in order of importance is the technological one (20 %), followed by 'Defence' (15 %), 'Non-oriented research' (15 %), and the aggregate 'Human and social objectives' (13 %).

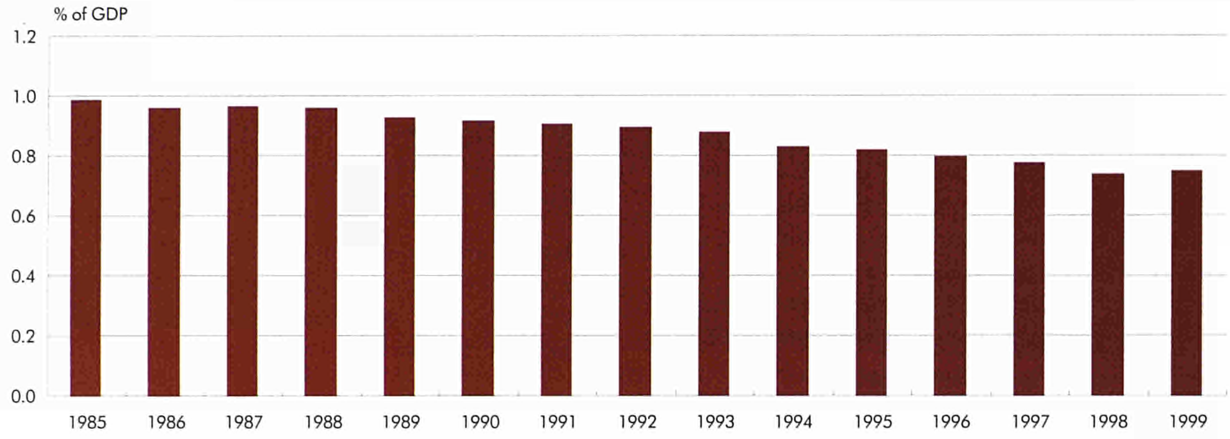
Analysis of the evolution of individual objectives during the period 1985-99 (Figure 1.10.) shows that:

- 'Research Financed from General University Funds' has almost constantly increased its share of GBAORD in the EU, especially since 1991 and is by far the most important for the majority of governments in R&D funding.
- The other two major fields ('Defence' and 'Technological objectives') show quite constant declining trends in the 1990s, after periods of growth in the 1980s. The aggregate 'Technological objectives' declined from 29.2 % in 1985 to 25.3 % in 1990 and finally lost its first place among EU objectives, diminishing to a share of 20.2 % in 1999. A similar evolution is shown by 'Defence', whose share fell from 22.9 % in 1995 to 15.0 % in 1999.
- Over the same period, other socio-economic objectives that seemed to be of secondary importance ('Human and social objectives' and 'Non-oriented research') raised their shares of fund allocations to 13.5 and 14.7 % respectively in 1999, against 12.1 and 14.6 % in 1995.

(6) The category 'Research financed from General University Funds (GUF)' includes the general grants received by Universities from the Ministry of Education or from the corresponding provincial or local authorities in support of their overall research/teaching activities.
See *Frascati Manual*, p. 100, paragraph 381.

Fig. 1.7.

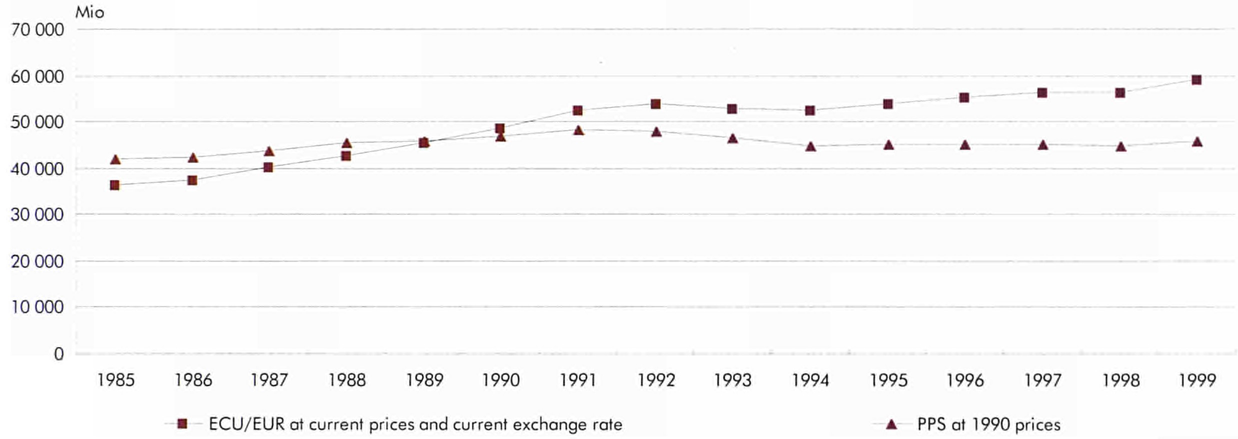
GBAORD as a % of GDP — European Union 1985-99



Source: Eurostat.

Fig. 1.8.

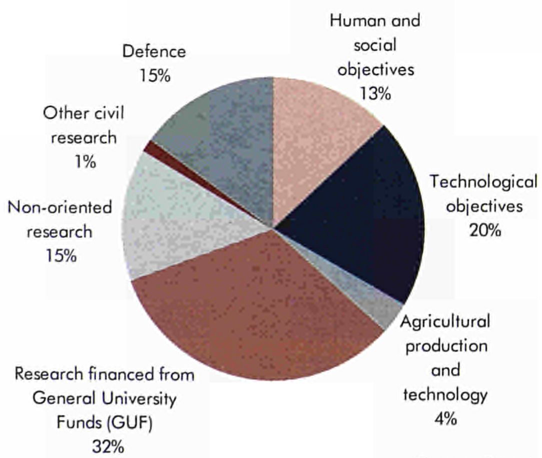
Comparison of GBAORD between current and constant prices — European Union 1985-99



Source: Eurostat.

Fig. 1.9.

GBAORD by NABS ([1]) — European Union 1999



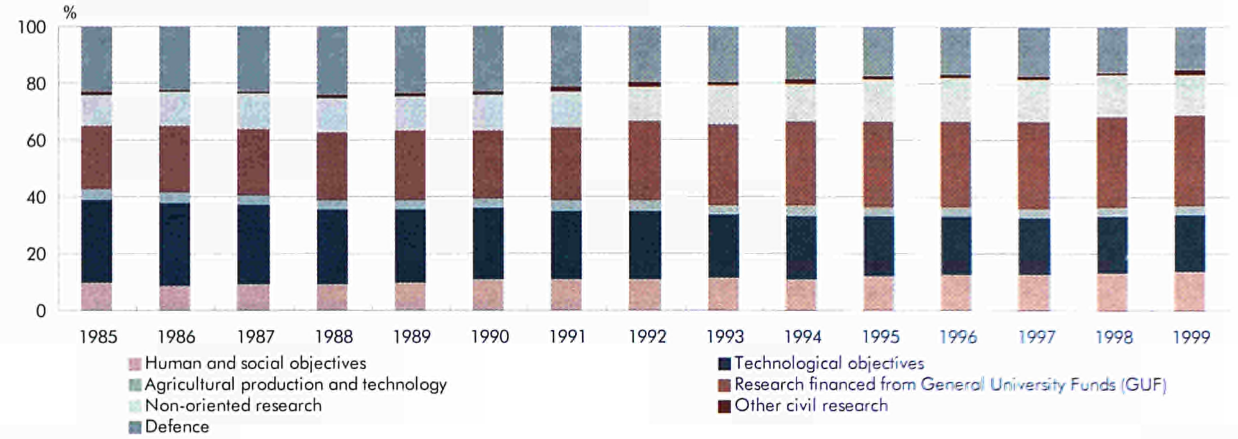
Source: Eurostat.

([1]) The categories 'Human and social objectives' and 'Technological objectives' are obtained by grouping other NABS.

- **'Human and social objectives' groups NABS:**
  No 2 — Infrastructure and general planning of land-use,
  No 3 — Control and care of the environment,
  No 4 — Protection and improvement of human health and
  No 8 — Social structures and relationships.
- **'Technological objectives' adds NABS:**
  No 1 — Exploration and exploitation of the Earth,
  No 5 — Production, distribution and rational utilization of energy,
  No 7 — Industrial production and technology and
  No 9 — Exploration and exploitation of space.

Fig. 1.10.

Distribution of GBAORD by NABS — European Union
1985-99 (1)

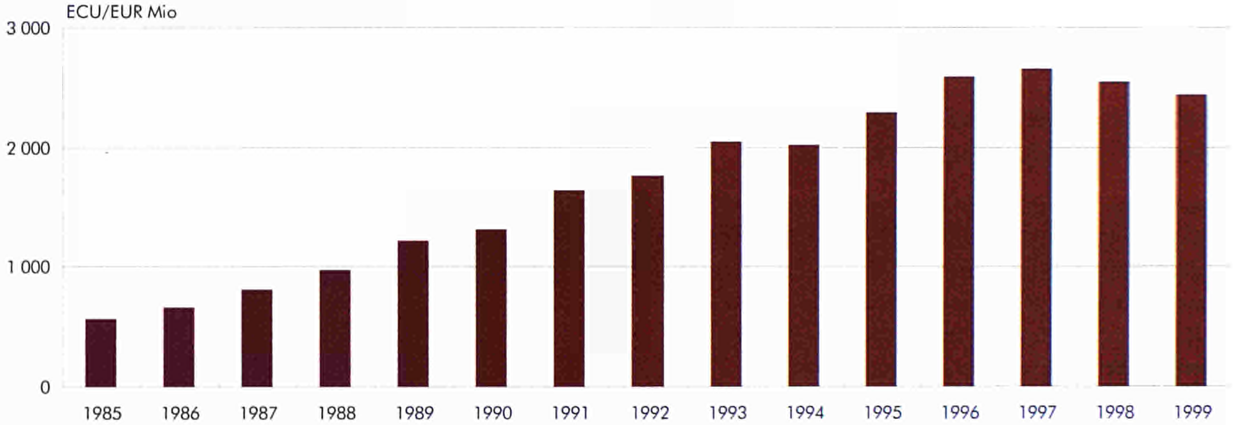


(1) Provisional data for 1999.

Source: Eurostat.

Fig. 1.11.

European Community appropriations on R&D at current prices
1985-99 (1)

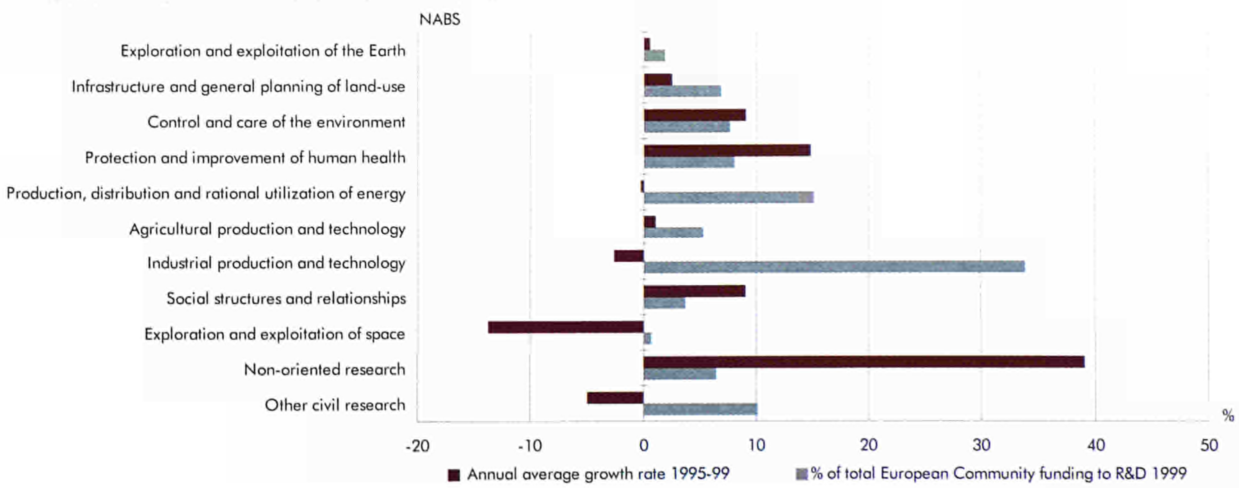


(1) Provisional data for 1999.

Source: Research DG.

Fig. 1.12.

European Community appropriations on R&D by NABS
as a % of total European Community funding to R&D in 1999 and annual average growth rate 1995-99



Source: Research DG.

1.3. EUROPEAN COMMUNITY FUNDING IN R&D (7)

Figure 1.11. shows the evolution of European Community R&D appropriations in ECU/EUR at current prices from 1985 until 1999 — 1999 figures being provisional.

Even if there is not a constantly increasing trend, growth was experienced until 1999. The upward trend is more consistent when we consider that from 1990 administrative costs are no longer included in the figures. The recent decrease in total R&D appropriations is mainly due to the fact that 1999 is the first year of operations for the Fifth R&D Framework Programme. Payment appropriations for R&D in 1999 represent only a small proportion of the total budget of the Fifth Framework Programme.

Figure 1.12. shows how the budget was divided during 1999 among different socio-economic objectives. 'Industrial production and technology' is by far the most important objective, but its relative weight has decreased in the last five years (as shown by the average annual growth rate). The high growth rate of the objective 'Non-oriented research' stands out, at almost 40 %, as well as the negative growth experienced by 'Exploration and exploitation of space'.

1.4. SPECIFIC DEVELOPMENTS IN THE EU MEMBER STATES

In this section we concentrate on the analysis of GBAORD in the Member States. The biggest performers of public funded R&D in absolute terms are the four biggest economies of the EU (Germany, France, Italy and the United Kingdom). Following these are Spain and the Netherlands, after which levels are much lower.

Figure 1.13. shows GBAORD as a percentage of GDP. The EU position is taken as a point of reference. This allows us to see for which countries the effort towards GBAORD is higher (or lower) than the average EU effort.

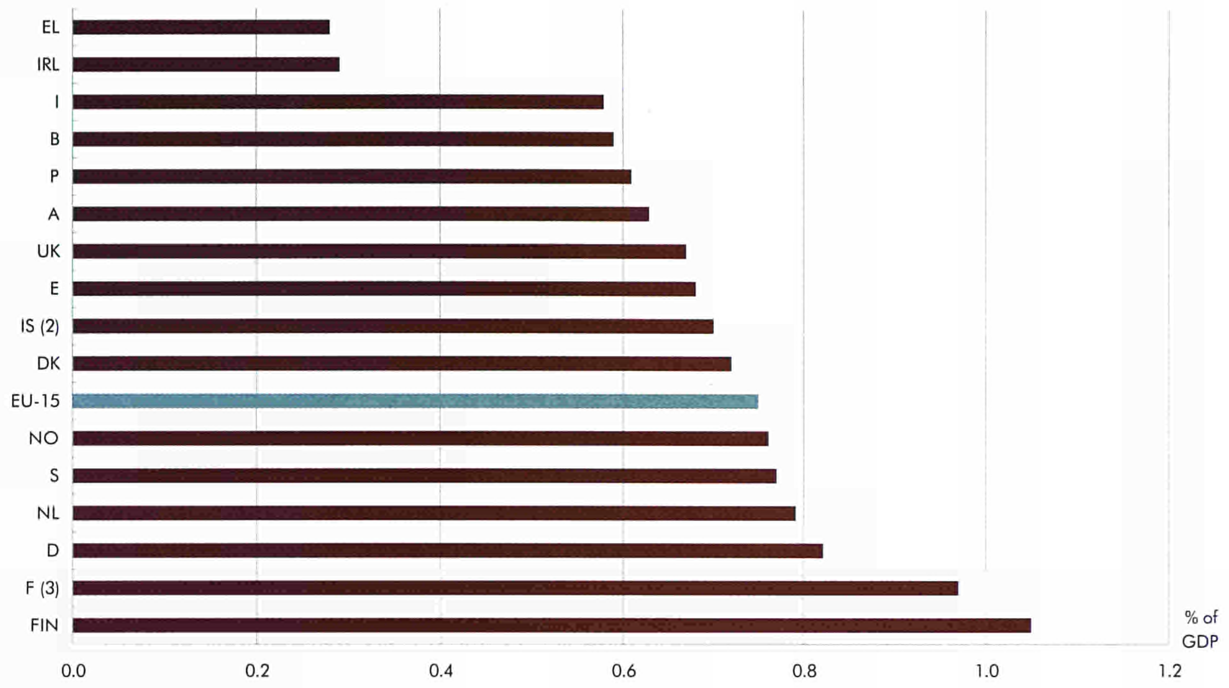
Since the indicator GBAORD as a percentage of GDP can be easily affected by changes in GDP, the analysis is complemented by an examination of the respective trends of GBAORD and GDP, considered separately. This is performed in Figure 1.14., where the annual average growth rates of GBAORD and of GDP in PPS 1990 are considered together for the years 1995-99.

From a combined analysis of Figures 1.13. and 1.14., four specific conclusions can be pointed out.

- Spain and Portugal are closing the gap with the other countries. GBAORD relative to GDP is still lower than the EU average, but the growth rate in the last five years is far higher than for the other countries, since GBAORD is growing at a faster rate than GDP.
- Sweden is earmarking fewer resources to R&D: even if it remains above the EU level of GBAORD as a percentage of GDP, the indicator is deteriorating.
- Two countries — Greece and Ireland — have values of GBAORD as a percentage of GDP that are far lower than the EU average (Figure 1.13.). As far as growth rated are concerned, in Greece and in Ireland both GBAORD and GDP are growing faster than the EU average.
- Finally, Finland is by far the country producing the biggest effort towards public funded R&D and the growth rates indicate that Finland is maintaining a concerted effort over time.

(7) For a more comprehensive analysis of Community R&D funding, see Chapter 2.

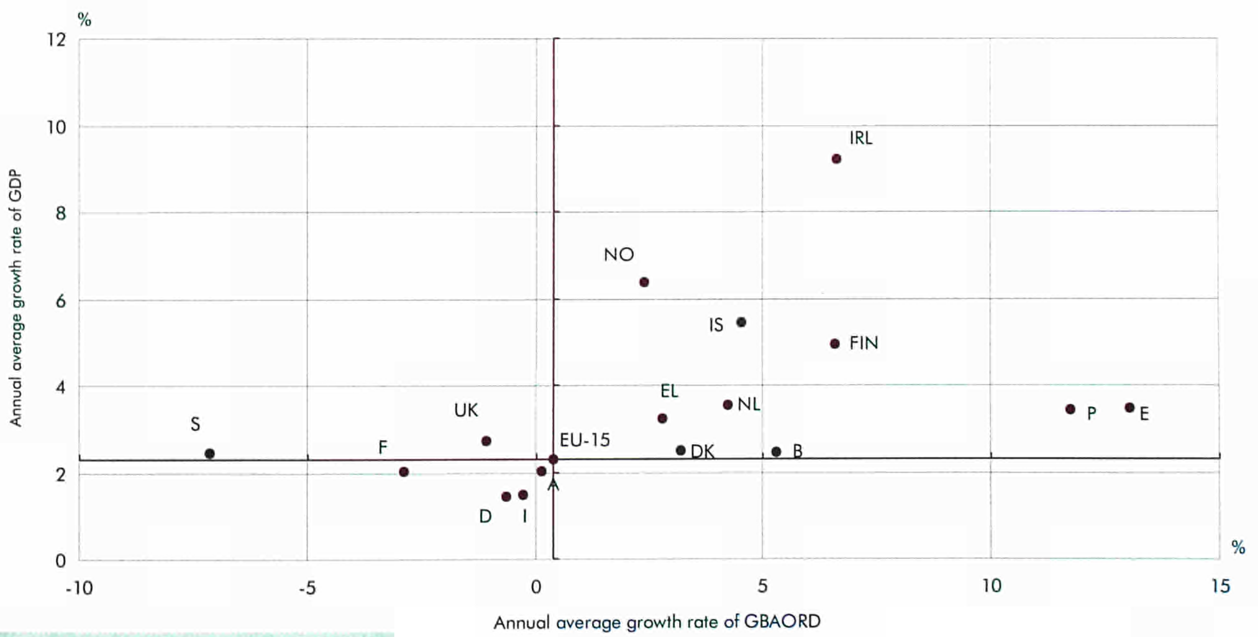
Fig. 1.13. GBAORD as a % of GDP by country 1999 (1)



(1) Provisional data for 1999.
(2) Exception to the reference period: 1997.
(3) Exception to the reference period: 1998.

Source: Eurostat.

Fig. 1.14. Annual average growth rates of GBAORD and GDP by country 1995-99 (1)



(1) Exception to the reference period — F: 1995-98.

Source: Eurostat.

When a consideration of the allocation of funds in the individual Member States is made (Table 1.1.), we can see that 'Research Financed from General University Funds' is in all countries among the three main priorities. Furthermore, in 8 out of 14 cases, it is by far the largest class of funding — Denmark, Germany, Greece, Italy, the Netherlands, Austria, Portugal and Sweden. Furthermore, Denmark, Greece, Austria and Sweden, where it represents more than 50 % of the entire budget, are particularly striking.

The category 'Human and social objectives', even being in all countries one of the most important destinations of budgets, is in no case the first priority. The category 'Technological objectives' is highly important in all countries and the first priority in the cases of Spain and France.

Finally it is in Ireland and Portugal that the largest amount of resources are devoted to 'Agricultural production and technology' while Spain, France and the United Kingdom devoted a large proportion of their GBAORD to the 'Defence' objective (respectively 30, 22 and 35 %).

Tab. 1.1.

GBAORD by NABS as a % of total GBAORD according to country
1999 (1)

In % of total GBAORD

	EUR Mio	GBAORD as a % of GDP	Human and social objectives	Technological objectives	Agricultural production and technology	Research financed from General University Funds (GUF)	Non-oriented research	Other civil research	Defence	Total
EU-15	59 177	0.76	13.0	20.1	3.6	32.1	14.6	1.0	15.4	100
B	1 387	0.65	9.4	39.2	3.0	19.3	23.2	5.3	0.6	100
DK	1 183	0.74	16.4	15.6	9.0	58.5	-	-	0.6	100
D	16 316	0.83	11.6	22.6	2.6	38.6	16.1	0.2	8.4	100
EL	334	0.29	15.9	15.1	8.9	52.0	6.5	0.2	1.4	100
E	3 819	0.54	8.7	26.8	4.2	21.8	7.3	1.2	30.0	100
F (2)	:	0.96	9.8	23.3	4.0	17.6	21.1	1.8	22.4	100
IRL	256	0.30	13.5	30.2	20.0	23.6	12.7	-	-	100
I	6 347	0.58	17.8	21.4	1.8	45.3	11.2	-	2.5	100
NL	2 911	0.76	14.0	20.6	3.0	44.2	11.0	4.2	3.1	100
A	1 230	0.64	8.9	8.1	3.2	65.9	13.8	0.2	0.0	100
P	644	0.54	16.7	21.6	13.1	35.0	7.4	4.3	2.0	100
FIN	1 275	1.08	16.7	38.4	5.7	25.4	12.5	-	1.4	100
S	1 725	0.81	15.6	15.2	1.9	50.9	-	9.1	7.4	100
UK	9 047	0.79	22.0	5.8	4.5	19.0	13.2	0.5	35.0	100
IS (3)	65	0.70	54.4	3.8	23.5	-	18.3	-	-	100
NO	1 088	0.76	19.5	19.2	8.7	39.1	8.2	-	5.3	100

(1) Provisional data for 1999.
(2) Exception to the reference period: 1998.
(3) Exception to the reference period for the indicator 'GBAORD as a % of GDP': 1997.

Source: Eurostat.

Notice to the reader

Analyses in this chapter refer to the data in the Eurostat database New Cronos at the time of writing. Because New Cronos is regularly updated as and when new data are received, it may be that data in extractions made or requested subsequently differ somewhat to those available at the time of writing.

This chapter takes into account changes brought about by the adoption of the new system of national accounts — the European System of Accounts (ESA) — with ESA '95 replacing ESA '79.

References

- *The Frascati Manual and identification of some problems in the measurement of Government R&D appropriations (GBAORD)*, document submitted to the NESTI meeting, OECD, Paris, 5-7 June 2000, (Ref DSTI/EAS/STP/NESTI (2000)31).
- Eurostat, *NABS, Nomenclature for the analysis and comparison of scientific programmes and budgets*, Office for Official Publications of the European Communities, Luxembourg, 1994.
- *Proposed Standard Practice for Surveys of Research and Experimental Development — Frascati Manual*, OECD, Paris, 1993.

PART 1

Community funded research and technological development

CHAPTER 2

INTRODUCTION

By Research DG

Until the beginning of the 1980s, European co-operation in R&D was considered to be a relatively marginal phenomenon, compared to the volume of activity conceived, financed and executed at the Member State level. However, the 1950s had seen not only the creation of CERN (Centre européen de la recherche nucléaire), but also the first steps in Community co-operation following the signature of the Euratom Treaty. During the next two decades, other intergovernmental and international institutions were founded including the European Southern Observatory, the European Molecular Biology Organisation, the European Space Agency, the European Molecular Biology Laboratory.

2.1. FRAMEWORK PROGRAMMES FOR RTD

From the mid-1980s onwards, European Community funding of R&D has been ever more concentrated in multi-annual Framework Programmes (FPs) for Research and Technological Development (RTD). There was an increasingly urgent need to have a mechanism for short to medium term scientific and technological planning, to co-ordinate the various Community research and technological development actions, and to obtain an overview of what was going on. This resulted in the 1984 decision to launch the First Framework Programme, covering the years 1984-87.

However, the first clear reference to RTD in the EEC Treaty was made with the adoption of the Single European Act in 1987. The Single European Act transformed and completed in many ways the Treaty of Rome. It introduced Article 130f (now Article 163), which gives the Community clear jurisdiction in RTD by describing its objectives and by establishing the general framework for implementation, as well as Article 130h (now Article 165) on the co-ordination of European R&D policies at the national and Community levels. It is in the Single European Act that the two basic mechanisms of current Community RTD policy were defined formally for the first time:

- the Framework Programme i.e. the general decision that defines the content, the objectives and the system of Community multi-annual RTD policy;
- specific programmes which implement the research activities described in the Framework Programme.

The Treaty of Maastricht added a number of new elements to Community research policy. It was clearly felt that the measures taken under the new Treaty would have a greater impact on the co-ordination of the research effort of the Member States of the Union and, moreover, would adapt to the closer economic relationships that the Member States would have in the future. Furthermore, the new decision-making mechanisms at the Union level, which gave greater powers to the European Parliament, were also applied to research policy. Thus the co-decision procedure (Article 189b, now Article 251), a joint European Parliament and Council decision, was introduced for the adoption of the framework programmes for RTD. The Treaty also introduced several new concepts in the structure and the content of the Community RTD policy, first and foremost the idea that the framework programme should include all RTD activities covered by the Treaty. In this respect all the RTD actions of the Community have to be included in the framework programme. These activities include basic research, technological development and demonstration activities. Another concept introduced by the Treaty of Maastricht is that rather than being limited to 'consolidating the science and technology bases of industry in the Community', its RTD activities can extend to other Community policies enshrined in the Treaty, such as energy, transport, environment, fisheries and agriculture.

The primary objective of the Framework Programmes for RTD (as expressed in Article 163 of the Amsterdam Treaty) is to strengthen the scientific and technological bases of Community industry and to encourage it to become more competitive at international level, while promoting all the research activities deemed necessary by virtue of the other Chapters of the Treaty.

R&D versus RTD

It should be noted that the European Commission uses the terminology Research and Technological Development, abbreviated to RTD, rather than the more classical Research and Development, R&D. This is a conscious decision given that Community RTD not only includes R&D but also demonstration, training, innovation and dissemination activities. From the statistical point of view it is important to understand that Community RTD is at one and the same time both wider and narrower in scope than R&D as defined by the OECD in the *Frascati Manual*. It is wider because RTD includes demonstration, training, dissemination, innovation activities, etc. It is narrower because of the macro and micro targeted nature of Community R&D. For this reason, and because in the past, Framework Programmes for RTD did not include all Community funded R&D, Community funding of R&D, as published for GBAORD (Government Budgetary Appropriations on R&D), does not equal Framework Programme budgets (1).

(1) For further information see http://europa.eu.int/comm/research/faq.html#tocref3_2.

2.2. IMPLEMENTATION OF COMMUNITY RTD POLICY

Community RTD policy is implemented through two types of actions: indirect measures (research carried out by teams of researchers in the Member States) and direct measures (Community's own research laboratories).

Indirect measures

At present, indirect measures are implemented in five ways: R&D projects (also called shared-cost projects and including demonstration projects, combined projects, support to infrastructures, co-operative research, exploratory awards), fellowships, support to networks, concerted actions and accompanying measures. Shared-cost contractual research, which is by far the most important element in financial terms, is put into effect through multi-annual projects implemented by multi-national consortia made up of firms (including small and medium-sized enterprises), research centres and universities from the European Union. The Commission pays for up to 50 % of the costs of a project and the members of the consortium share the rest (2).

Concerted actions, where co-ordination costs are paid for, and networks, where co-ordination costs and some research is paid for are becoming an increasingly important form of Community aid. Also the part taken by preparatory, accompanying and support measures is significant and includes substantial investment in innovation activities and SMEs, in training and mobility of scientists (mainly through post-doctoral fellowships), improving the utilisation of major research infrastructure, promotion of scientific and technological excellence, the support of the development of science and technology policies in Europe, and conferences, publications and studies.

Direct measures
The Joint Research Centre

The idea of bringing together scientists from different Member States to foster a common sense of belonging to Europe was already present as far as back as 1958, when the initial programme of the European Atomic Energy Commission (Euratom) was started. The Joint Research Centre (JRC) forms an integral part of the European Community's development within the field of scientific research and is a unique instrument, combining high level competence and a unique set of experimental installations. It has a large collaborative network within the Member States of the European Union. It is the JRC's natural vocation to address transfrontier problems (environment, risk analysis) or to perform research that is transnational in essence (e.g. basic reference materials or measurements, industrial standards).

The JRC's multiple activities are at the disposition of the Community as a whole and are run in close collaboration with research laboratories and industry in the Member States. They include the following:

- specific research programmes,
- S&T support to Community,
- work for third parties,
- competitive participation in shared cost actions,
- co-operation with national research organisations.

The JRC has its headquarters in Brussels and five other sites in Belgium, Germany, Spain, Italy and the Netherlands, which house the eight different institutes that make up the JRC:

- the Institute for Reference Materials and Measurements (IRMM) in Geel (B),
- the Institute for Transuranium Elements (ITU) in Karlsruhe (D),
- the Institute for Prospective Technological Studies (IPTS) in Seville (E),
- the Environment Institute (EI) in Ispra (I),
- the Institute for Health and Consumer Protection (IHCP), in Ispra (I).
- the Institute for Systems Informatics and Safety (ISIS) in Ispra (I),
- the Institute for Space Applications (SAI) in Ispra (I),
- the Institute for Advanced Materials (IAM) in Petten (NL).

The JRC's financial resources come from:

- the money directly allocated from the specific programmes budgets,
- other budget lines for work to S&T support activities for the Commission,
- contributions from the German, French and the Dutch Governments (for the operation of the High Flux Reactor),
- the JRC external customers for the execution of work at their request,
- FP4 onwards the JRC, as well as being allocated funding directly from the specific programmes, may also put in competitive bids for FP activities on the same basis as other organisations.

Table 2.1. shows the evolution of JRC funding during the periods covered by the 2nd, 3rd, 4th and 5th (partially) Framework Programmes.

(2) Universities, colleges and organisations that do not have cost accounting, making it possible to reveal total costs, receive up to 100 % of additional costs.

Tab. 2.1. Joint Research Centre financing for the periods of 2nd, 3rd, 4th and 5th Framework Programmes for RTD

	FP2 ECU Mio	FP3 ECU Mio	FP4 ECU Mio	FP5 EUR Mio
From framework programmes	531	712	958	1 020
S&T support to the Commission	87	230	71	0
Work for third parties	12	37	50	:
High flux reactor	52	71	80	:
Shared cost actions of framework programmes			160	:
Total	682	1 050	1 319	:

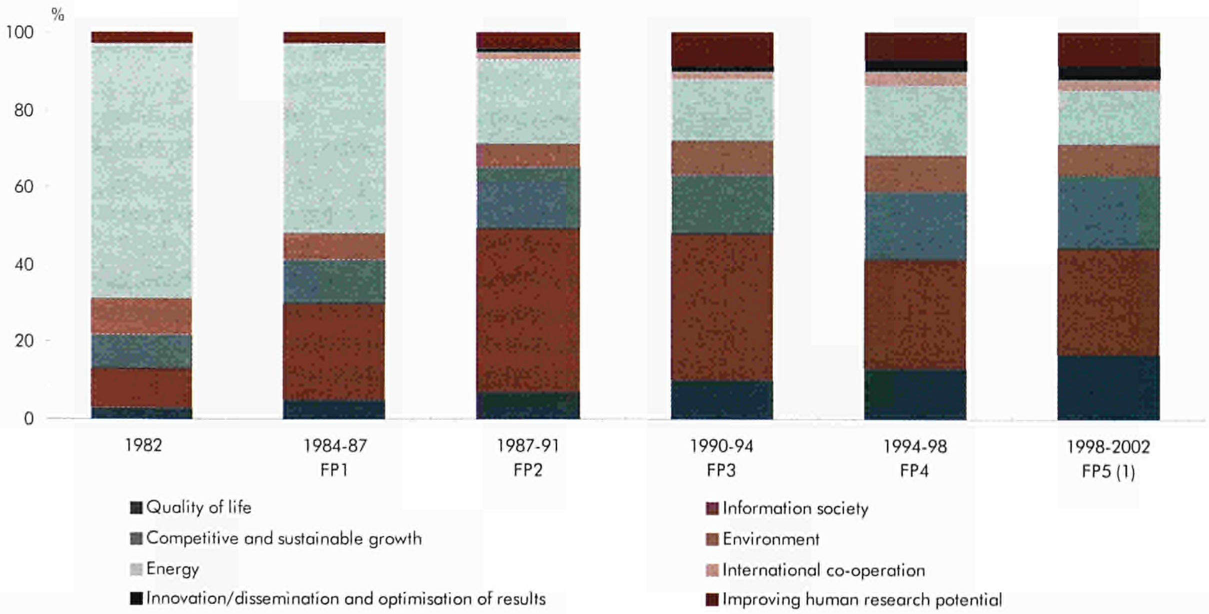
Sources: RESEARCH DG, data: JRC.

Tab. 2.2. Budgets accorded to the framework programmes for RTD

Framework progammes	Years covered	Financial commitments ECU/EUR Mio in current prices	% of Community budget
FP1	1984-87	3.7	2.4
FP2	1987-91	5.4	3.2
FP3	1990-94	6.6	4.0
FP4	1994-98	13.1	4.0
FP5	1998-2002	15.0	3.7

Sources: RESEARCH DG, data: European Commission Services.

Fig. 2.1. Changes in priorities of RTD activities from one framework programme to the next



(1) Budgeted.

Sources: RESEARCH DG, data: European Commission Services.

2.3. EVOLUTION OF THE FRAMEWORK PROGRAMMES FOR RTD

The budgets of the consecutive framework programmes for RTDs have risen in a rather non-linear way through a combination of real increase in resources, enlargement, and the gradual incorporation into their budgets of elements previously financed by appropriations from other budget headings. Successive framework programmes also overlap so as to preserve the continuity of the research effort and avoid any hiatus.

Changes in priorities from one framework programme to the next: 1984-2002

The framework programmes are the medium-term planning instrument for Community RTD policy. They determine the scientific and technological priorities as well as the financial scope of Community activity in the field of RTD. Changes in the structure for allocating budget appropriations also reflect the structure of priorities given to the various research fields. Large consultation exercises underpin the changes. The decision making procedure for the framework programmes involves the Commission, the Council of Ministers, the European Parliament and the Economic and Social Committee. Throughout the process there is widespread consultation with the scientific and industrial community.

The differences in grouping and content of research fields and specific programmes make it difficult to discern changes in priorities in the tables included above. A diachronic analysis of the priorities put forward in the five successive framework programmes has nevertheless been made possible thanks to harmonisation work carried out by Commission (see Figure 2.1.).

In order to get a feel for the philosophy and content of the recent and current framework programmes it is necessary to look in a little more detail at the Fourth Framework Programme, under which work is coming to a close, and the Fifth Framework Programme, which effectively started at the beginning of 1999.

The Fourth Framework Programme

The Fourth Framework Programme for RTD implemented from 1995 to 1998 was a major step forward in quantitative and qualitative terms:

- the annual budget available for Community RTD increased by half compared with the previous Framework Programme, rising from an average of ECU 2 100 to 3 300 million per year between 1995 and 1998;
- the Framework Programme has been considerably opened up to world research, both through the International Co-operation programme and by means of new scientific and technical association and co-operation agreements with our partners;
- the participation of SMEs has been substantially boosted by extending the scope for exploratory awards (schemes to support and encourage SME participation in collaborative and co-operative research projects) as well as co-operative research, itself;
- actions for the training and mobility of researchers have been stepped up thanks to the Marie Curie fellowships.

FP4 effectively finished in terms of launching new projects at the end of 1998 although many of the multi-annual projects funded under it are still running. Thus, between 1995 and 1998, the Fourth Framework Programme has resulted in:

- 13 500 RTD projects (shared-cost actions), each bringing together an average of 5 partners with Community funding averaging nearly ECU 700 000;
- more than 8 000 participations from third countries, representing 9 % of the total number of participations, of which more than 2 000 from Central and East European countries;
- more than 3 000 Marie Curie fellowships for the training and mobility of European scientists.

FP4 has been implemented through 22 000 contracts representing ECU 11.2 thousand million of funding. 93 % of the budget goes to RTD operations with only 5.0 % going on (Commission) staff, 1.4 % on other administrative costs and 0.4 % on information and publications. Nearly 90 % of this funding is dedicated directly to RTD projects.

RTD projects of thematic (non-nuclear) programmes associate an average of nearly 7 partners with, Community funding of projects (under non-nuclear programmes) averaging nearly ECU 900 000 per project.

Enterprises and research or higher education institutions have an equal share of participations in Community research with enterprises accounting for 49 % of participations and receiving 46 % of funding (thematic non-nuclear programmes) and SMEs in particular accounting for 29 % of participations and receiving 19 % of funding (thematic non-nuclear programmes).

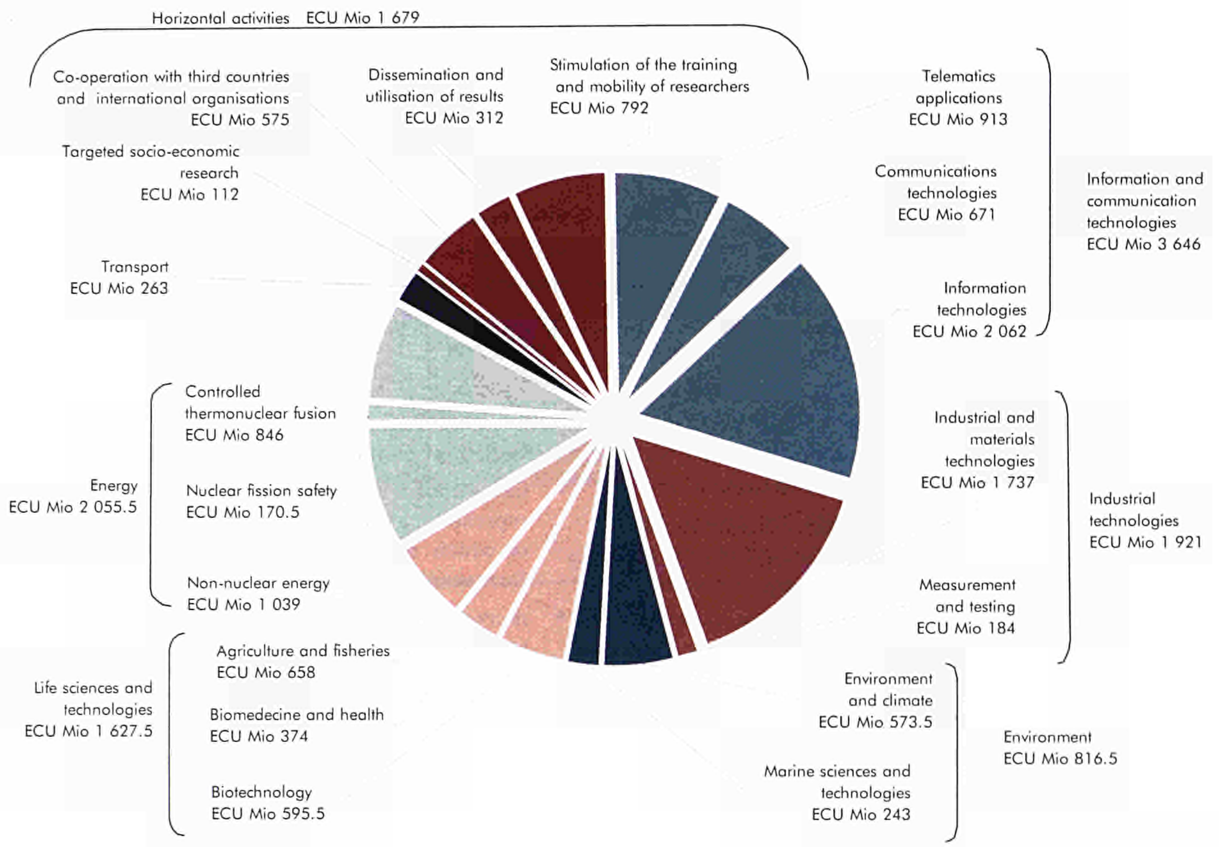
The International Co-operation Programme has linked EU research teams to researchers from 120 third countries, with 3 000 participations in the Union and 3 500 participations from third countries.

FP4 has resulted in 14 700 SME participations, with a large increase over the period due mainly to the exploratory awards and co-operative research projects specially designed for SMEs.

The JRC's competitive activities have allowed it to carry out work for a supplementary budget of ECU 160 million from 1995 to 1998, in addition to its institutional activities (FP4 budget of ECU 958.5 million).

Fig. 2.2.

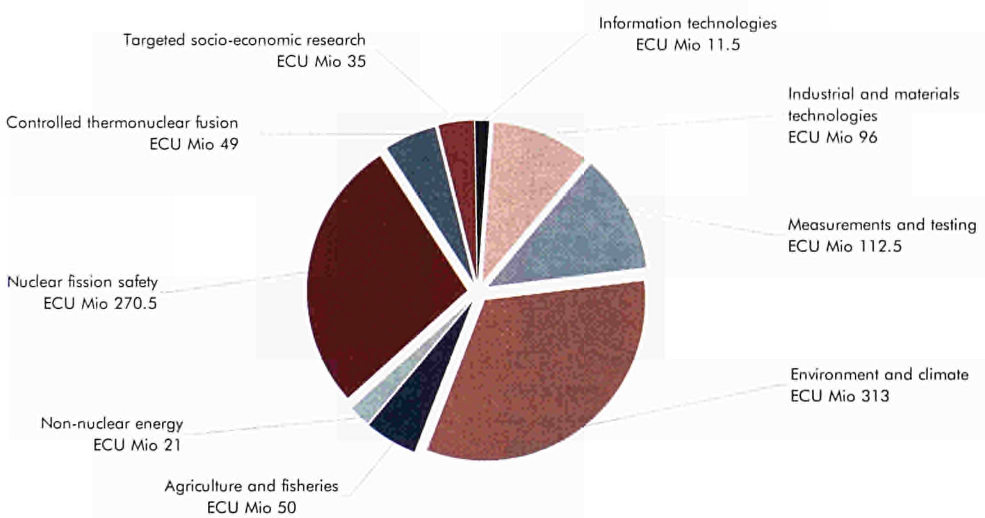
Breakdown of the FP4 indirect actions budget 1994-98



Sources: RESEARCH DG, data: European Commission Services.

Fig. 2.3.

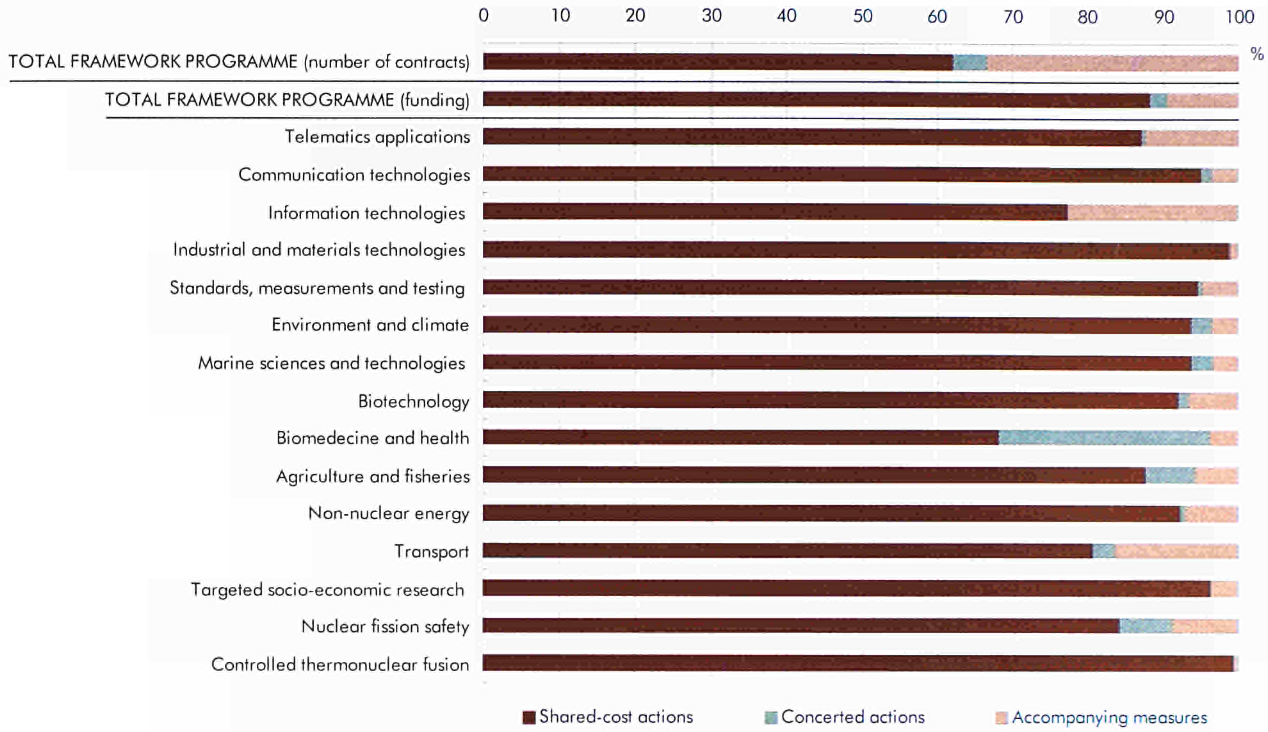
Breakdown of the Joint Research Centre FP4 direct actions 1994-98



Sources: RESEARCH DG, data: European Commission Services.

Fig. 2.4.

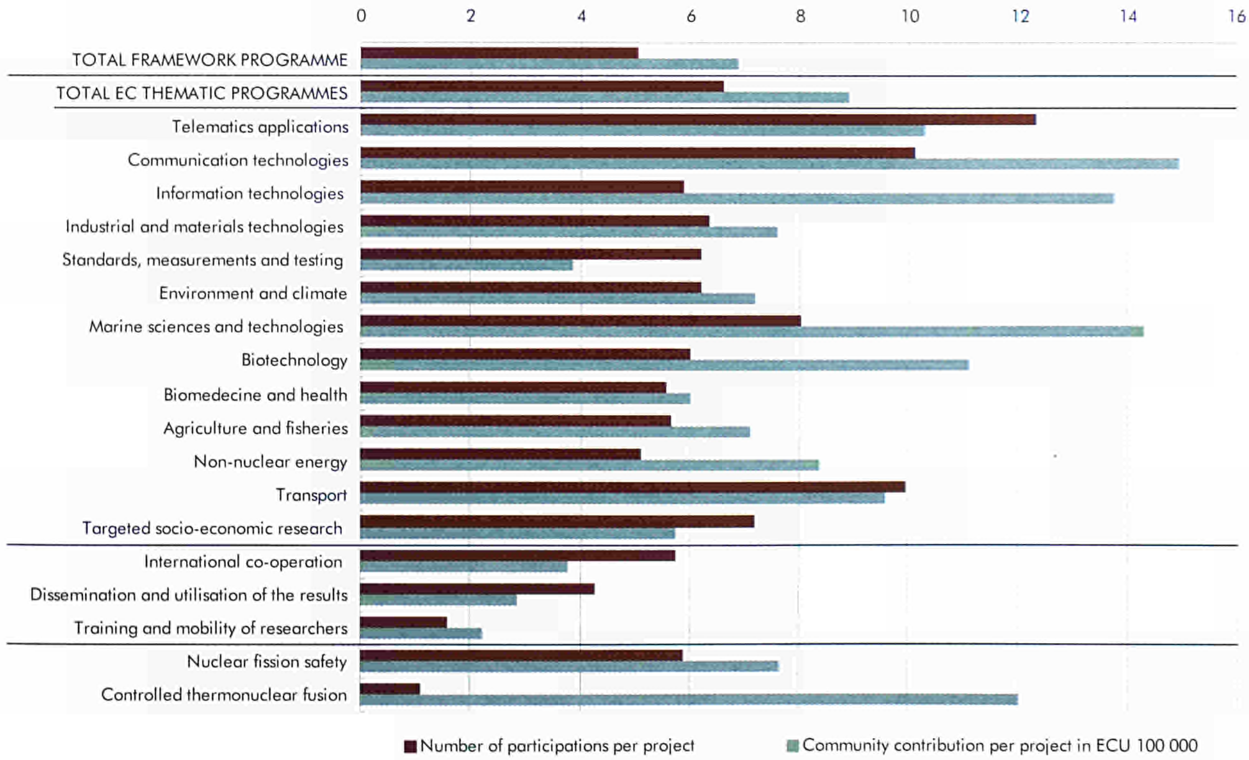
Breakdown of contracts and contractual Community contributions by types of actions 1995-98



Sources: RESEARCH DG, data: European Commission Services.

Fig. 2.5.

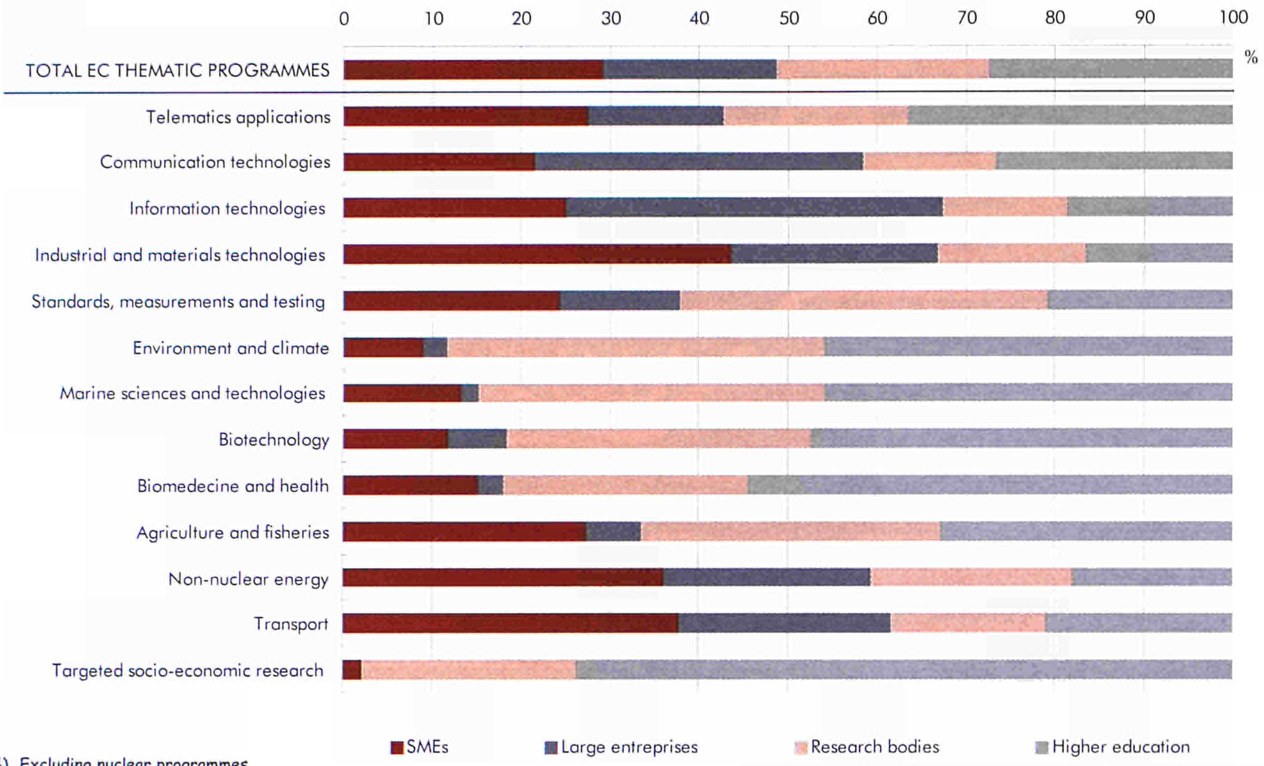
Average number of partners and average Community funding per project for shared-cost actions 1995-98



Sources: RESEARCH DG, data: European Commission Services.

Fig. 2.6.

Participation in thematic programmes (1) by type of organisation
1995-98

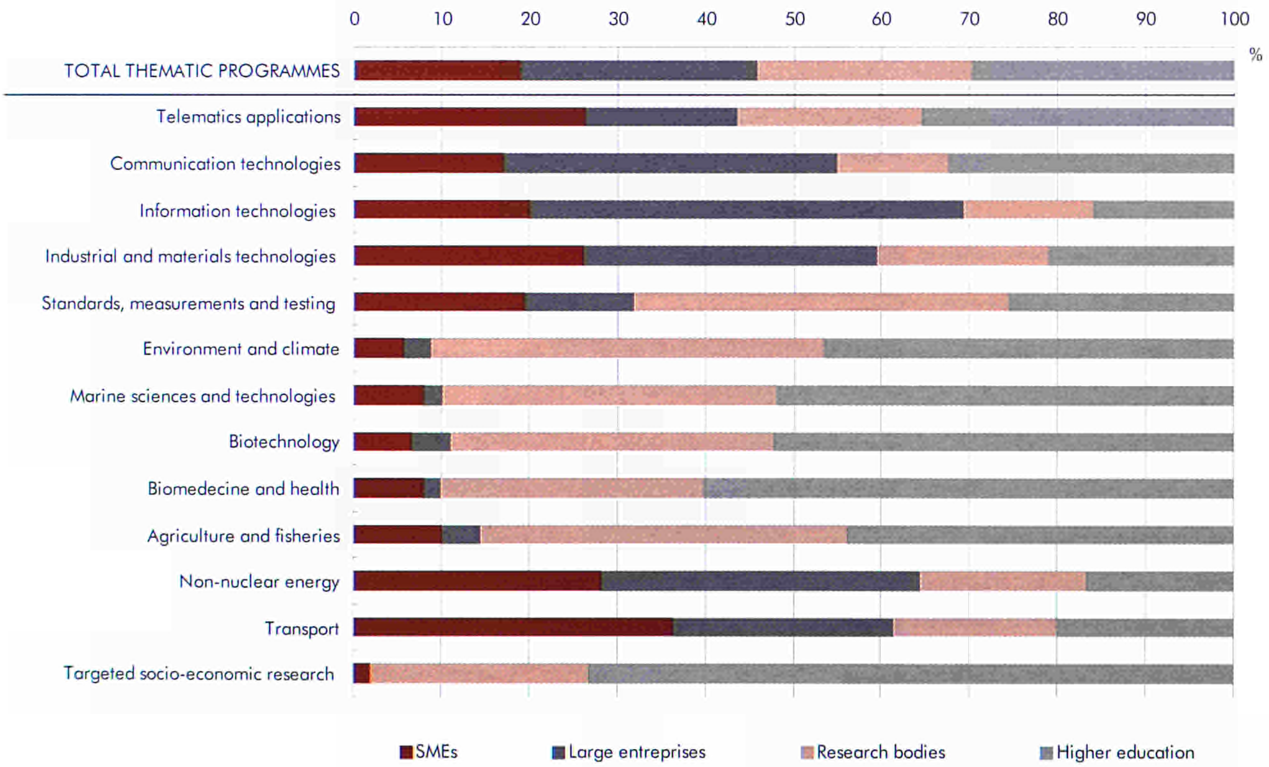


(1) Excluding nuclear programmes.

Sources: RESEARCH DG, data: European Commission Services.

Fig. 2.7.

Community funding by type of organisation
1995-98



Sources: RESEARCH DG, data: European Commission Services.

Fifth Framework Programme

Overview of the objectives and content

Building on the principles behind the success of Community research and on the experience gained in the course of the previous framework programmes, the Fifth Framework Programme provides appropriate responses to the challenges of the new millennium through innovation on several fronts, particularly:

- streamlined structure bringing together the RTD themes under 4 major specific programmes (excluding the Euratom part) instead of 13 in FP4;
- concentration of resources on integrated or co-ordinated RTD activities meeting the priority needs of citizens and society; the main means of achieving this is with 23 multidisciplinary key actions which account for over two thirds of the funding from FP5 and which cover all types of RTD, from basic research to demonstration activities; these key actions are backed up by generic RTD activities and support for research infrastructure;
- contribution of research to the Union's socio-economic objectives, by means of key actions to resolve specific issues, but also by encouraging participation by SMEs which will receive at least 10 % of the budget for the thematic programmes, plus revised rules for participation, laying down the selection criteria for projects funded by the Community, and attaching greater importance to take-up and dissemination of results;
- greater transparency and closer involvement of all interested parties, by improving the flow of information to the Council and the European Parliament and with the aid of continuing advice from the 17 external advisory groups for the key actions and/or programmes; FP5 will also benefit from advice on ethical issues from the European Group on Ethics in Science and New Technologies;
- association of 11 countries which have applied to join the Union, whose researchers will participate in FP5 on the same eligibility and funding conditions as EU Member States, in return for contributions from these countries to the Community budget;
- new strategy for the JRC, whose role of serving Union policies has been consolidated and reinforced, with a work programme consequently focusing on research serving the citizen, sustainability, European competitiveness and nuclear safety;
- management tools which have been fully revamped for higher efficiency.

Priorities and funding

Table 2.3. shows the relative priorities and funding levels of the different activities under the Fifth Framework Programme.

A very encouraging total response

As of October 1999 over 11 500 proposals had been received, which included almost 70 000 participations. 3 300 proposals, representing over 18 000 participations, were initially retained for negotiation.

Larger projects in order to achieve critical mass and socio-economic impact

First estimates show that the average number of participants and the requested funding per proposal has increased as compared to those for FP4. This has led to

Tab. 2.3. Breakdown of FP5 budgets by specific programmes 1998-2002

	EUR Mio	%
Quality of life and management of living resources	2 413	16.1
User-friendly information society	3 600	24.1
Competitive and sustainable growth	2 705	18.1
Energy, environment and sustainable development	2 125	14.2
Confirming the international role of Community research	475	3.2
Promotion of innovation and encouragement of participation of SMEs	363	2.4
Improving human research potential and the socio-economic knowledge base	1 280	8.6
Nuclear energy	979	6.5
Joint Research Centre	1 020	6.8
Total FP5	14 960	100.0

Sources: RESEARCH DG, data: European Commission Services.

larger and more integrated projects with greater multi-disciplinarity, a prerequisite for the success of the problem solving approach and the impact of programmes. The average number of participants per proposal (all types of actions included) is 5.5 for RTD actions retained for negotiation (as compared to an average of 4 in FP4). The average size of proposals retained for negotiation of contracts (all types of actions included) is in the order of one million euros in terms of Community funding as compared with a considerably lower figure for FP4 of less than ECU 700 000.

This tendency has been reinforced by project clustering in certain areas of the programmes. The clustering may, depending on the programme and the area considered, take the form of larger projects or may consist of more informal co-operation and exchange between individual projects.

Competition and high quality research

The estimated overall 'selection rate' is 22 % when expressed as the ratio between the Community funding earmarked and the funding requested. This implies a lower rejection rate than in the past, while maintaining a healthy degree of competition between projects and, ultimately, a high level of excellence for the projects selected.

Effective SME stimulation

SME participation (commercial sector alone) is around 13 % overall and 16 % in the thematic programmes. Among enterprises, SMEs represent a majority of participations. It is interesting to note that in the programmes 'Information society', 'Competitive and sustainable growth' and the 'Energy' part of 'Energy, environment and sustainable development', SME participation is well above 20 %. Around 700 SME specific measures were evaluated with selection rates of around 45 %.

Participation of women to be further enhanced

The overall representation of women in RTD actions ranges from 7 to 17 % in the thematic programmes (both in proposals received and in proposals retained for negotiation), showing that there is clearly room for improvement. However, in the Human Potential programme, female participation is significantly higher, with an overall figure of 26 % and with 37 % of women among fellows. It should also be noted that the presence of women in the project evaluation panels has substantially increased.

A substantial international dimension

A major feature of FP5 is the opening up of programmes to participation from outside the Union, first of all from 15 associated countries whose research organisations and enterprises may participate under the same conditions as those from Member States.

Third countries, including countries associated to FP5, account for 10 000 participations in the proposals received and over 2 200 in the proposals retained for negotiation, representing more than 12 % of the total in proposals retained.

Among associated countries, partners from the 11 candidate countries appear over 3 700 times in proposals received and more than 700 times in proposals retained for negotiation, representing 4 % of the total.

All specific programmes of FP5 are also open to project by project participation by partners from third countries (but without Community funding). These participations (around 1 000 or 5.5 % in proposals retained) are of value in many instances, particularly in projects addressing pre-normative or global issues.

Ethical aspects

This aspect is of particular importance in the programme 'Quality of life'. More than 500 projects entered into negotiation in 1999, 37 'ethically sensitive' projects were analysed by a specific ethical review panel, composed of scientists of the relevant disciplines, ethicists, philosophers, lawyers, experts, with an experience in animal protection, patient and consumer interests, etc. The panel recommendations were fully taken into account in the course of contract negotiation.

The future

Now as we are approaching the middle of the period covered by the Fifth Framework Programme, with the publication, in January 2000, by the Commission of the Communication *Towards a European Research Area* (3), the foundations are being laid for the future of European Research and Development.

(3) Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, *Towards a European research area*, 18 January 2000.

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- *The Amsterdam Treaty*, 1997.
- *The Treaty of Maastricht*, 1992.
- *Single European Act*, 1987.

R&D expenditure and personnel

CHAPTER 3

R&D activities require financing and qualified staff. Two variables are normally measured every year for statistical purposes: R&D expenditure and R&D personnel. They both have their strengths and weaknesses, and are both needed in order to obtain an accurate portrayal of the efforts devoted to R&D activities.

The basic measurement of R&D expenditure corresponds to 'intramural' expenditure, i.e. all expenditure on R&D within a statistical unit or sector of the economy, whatever the source of funds (*Frascati Manual*, paragraph 335). For statistical purposes, current expenditure and capital expenditure are included (1).

This chapter also takes into account changes brought about by the adoption of the new system of national accounts — the European System of Accounts (ESA) — with ESA '95 replacing ESA '79. This methodological change allows a better coverage of economic activities. Although for the most part minimal, the impact this has had on GDP is nevertheless sufficient to slightly reduce levels of R&D expenditure as a proportion of GDP. Its principal effect is at the European level, where, with the changeover to ESA '95, R&D expenditure as a percentage of GDP fell from 1.89 % to 1.86 % in 1998. Regional and national levels of expenditure are, with a few exceptions, less affected by this methodological change.

Data on R&D personnel measure the human resources directly devoted to R&D activities, i.e. all persons employed directly on R&D plus those who provide direct services such as R&D managers, administrators and clerical staff (*Frascati Manual*, paragraph 279). Data on R&D personnel are collected in terms of full-time equivalent (FTE) and head count (HC) (2).

Intramural R&D expenditure and R&D personnel are broken down by institutional sector, i.e. by sector engaged in R&D. In this publication, four sectors are used to calculate indicators of R&D activity: the business enterprise sector, the government sector, the higher education sector and the private non-profit sector (3). However, only the results for the first three of these sectors are given in the analyses below.

INTRODUCTION

(1) Data on R&D expenditure are based on expenditure actually committed, i.e. they refer to the R&D resources mobilised during a given year. In view of the time it takes to conduct such surveys and to process their results, data on R&D expenditure are not available until some time after the R&D has been carried out. Data on R&D expenditure are available at Eurostat for all the Member States of the European Union (except Luxembourg), Norway and Iceland from 1987 on.

(2) Data on R&D personnel are also based on resources actually committed, i.e. they refer to the number of staff employed on R&D during a given year. Data on R&D personnel, in terms of head count and FTE, are available at Eurostat for all the Member States of the European Union (except Luxembourg), Norway and Iceland from 1987 on.

(3) In other publications (e.g. of the OECD) in which data are also classified by source of funds, the 'foreign' sector should also be taken into account.

1 CHAPTER 3

3.1. R&D AT THE INTERNATIONAL LEVEL: EUROPE, JAPAN AND THE UNITED STATES

R&D expenditure

In 1998, gross domestic expenditure on R&D (GERD) in the United States was ECU 202 thousand million (4), or one and a half times domestic R&D expenditure in the EU-15 (ECU 141.2 thousand million) and twice that of Japan (ECU 102.5 thousand million) for the same year.

In that year, R&D expenditure increased in the EU-15 and the United States in terms of volume by 4.6 and 8 % respectively. They thus continued the global trend which had emerged over the previous five years. In contrast, Japan showed a decrease of 4.2 %.

The order is slightly different if R&D expenditure is measured in relation to GDP. The United States (2.58 % of GDP in 1998) and Japan (3.03 % in 1998) were in the lead and continued the upward trend which had been apparent since 1994. Japan even exceeded the previously highest level it had achieved at the beginning of the 1990s. Expenditure in the EU-15 (1.86 % of GDP in 1998) remained stable in relation to 1997 and continued the relative downward trend begun at the end of the 1980s (5).

R&D expenditure by institutional sector

An analysis of the distribution of domestic R&D expenditure among the three main institutional sectors (6) reveals a virtually identical structure in Japan and the United States, where the business enterprise sector accounted for three-quarters of total expenditure, the higher education sector one sixth and the government sector one tenth.

In the EU-15 the proportion of R&D expenditure committed by the public sector (higher education and government) was the highest among the triad countries. In contrast, the proportion committed by the business enterprise sector was only 64 % in the EU compared with more than 75 % in the United States and Japan.

It is worth noting that, for the EU, the United States and Japan, the distribution of expenditure among the various institutional sectors was broadly the same as in 1985.

R&D expenditure by institutional sector as a percentage of GDP shows a difference in the level of expenditure between the United States and Japan on one hand and the EU-15 on the other. This difference, observed at a global level, is due mainly to the difference recorded in the business enterprise sector. In the other two sectors, expenditure as a percentage of GDP remained much the same for the two countries and the EU, except in the government sector, where the proportion of R&D expenditure in the United States was virtually a tenth of a percentage point lower than that of EU-15 and Japan.

In the business enterprise sector, the United States and Japan continued the upward trend begun in 1994. In 1998, the United States achieved the same growth rate as Japan had achieved in 1995, i.e. almost 1.9 % of expenditure as a percentage of GDP. The difference in relation to the EU-15 was notable and continued to widen, with R&D expenditure in the EU almost half that in Japan and the United States.

There were uniform evolutions in the other two sectors. The level of R&D expenditure as a proportion of GDP in the government sector was similar for the EU-15 and Japan (0.28 % in 1998). This was a slight increase on the previous year for Japan, while there was a downward evolution for both the United States and the EU-15.

In the higher education sector, expenditure as a percentage of GDP was the same in the EU-15, the United States and Japan. Expenditure on R&D in the EU-15 and the United States has remained stable since the mid of this decade. After two years in which expenditure as a percentage of GDP had remained stable, there was again an upward trend in Japan (0.42 % in 1998).

R&D personnel (7)

R&D personnel estimated in terms of volume followed the same trends as those observed for R&D expenditure. In absolute terms, 1.63 million people (FTE) were employed on R&D activities in the EU-15 compared with 0.88 million in Japan in 1998 (8).

In terms of growth (9), Japan recorded an increase of 3.6 % between 1997 and 1998 compared with 2.5 % for the EU-15. Viewed over a longer period, between 1985 and 1998, the increases were 21 % for the EU-15 and 31 % for Japan.

(4) Source: OECD — EAS Division, MSTI database.

(5) Further to methodological changes in the European system of accounts (ESA). R&D expenditure as a proportion of GDP is henceforth calculated according to ESA '95 and not ESA '79.

(6) EU-15: our analysis does not include the sector of non-profit institutions (NPI) for the EU-15, since its R&D expenditure is very small in relation to the other sectors (it is estimated at under 1 % in 1997). Japan: the data are adjusted up to and including 1995.

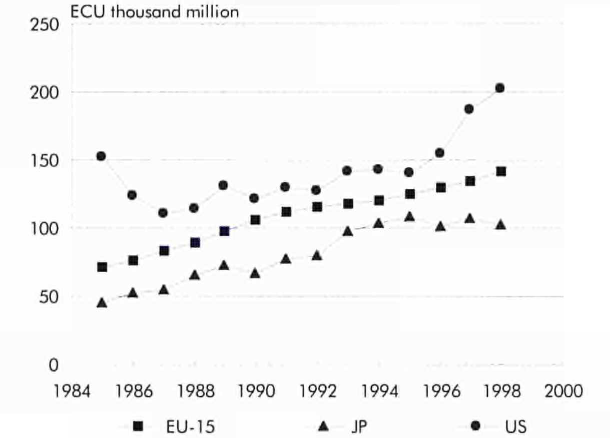
(7) Data on R&D personnel in Japan and the United States come from the OECD's MSTI database.

(8) The only data available for the United States relates to researchers, scientists and engineers (RSE), OECD database. In 1993 the number of such personnel (RSE) as a percentage of the active population was 0.74 %.

(9) On the basis of the data expressed in full-time equivalent (FTE).

Fig. 3.1. R&D expenditure in ECU at current prices 1985-98

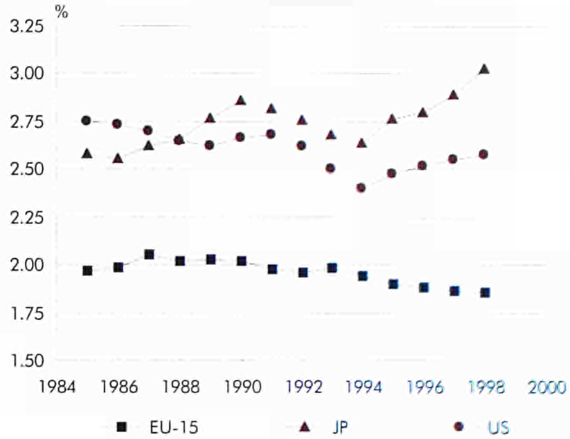
All sectors



Sources: Eurostat, OECD.

Fig. 3.2. R&D expenditure as a % of GDP 1985-98

All sectors



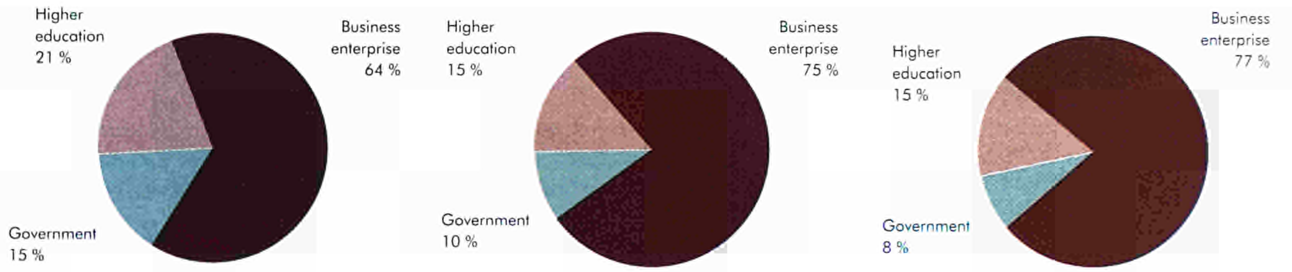
Sources: Eurostat, OECD.

Fig. 3.3., 3.4., 3.5. R&D expenditure in ECU at current prices by institutional sector 1998

EU-15
ECU 141 thousand million

Japan
ECU 103 thousand million

United States
ECU 202 thousand million



Source: Eurostat.

Source: OECD.

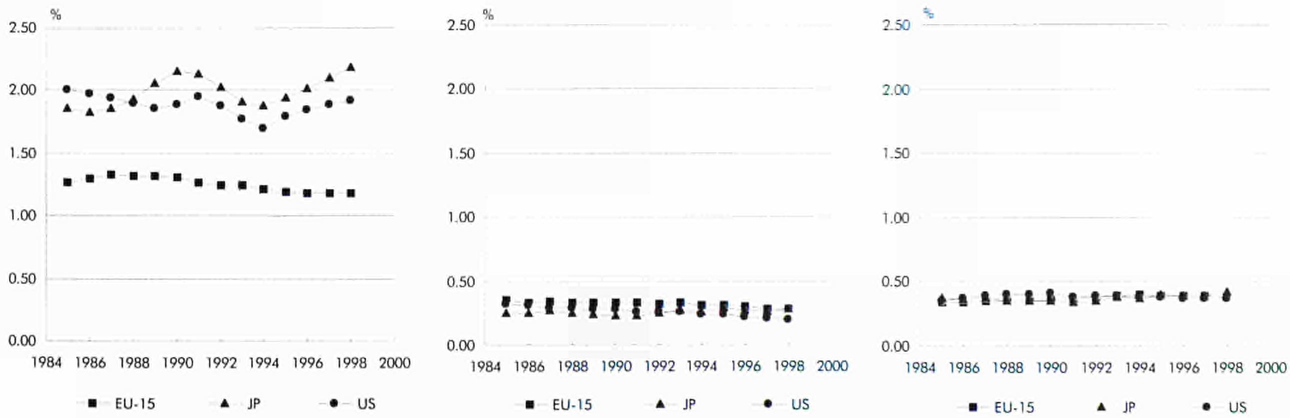
Source: OECD.

Fig. 3.6., 3.7., 3.8. R&D expenditure as a % of GDP by institutional sector 1985-98

Business enterprise

Government

Higher education



Sources: Eurostat, OECD.

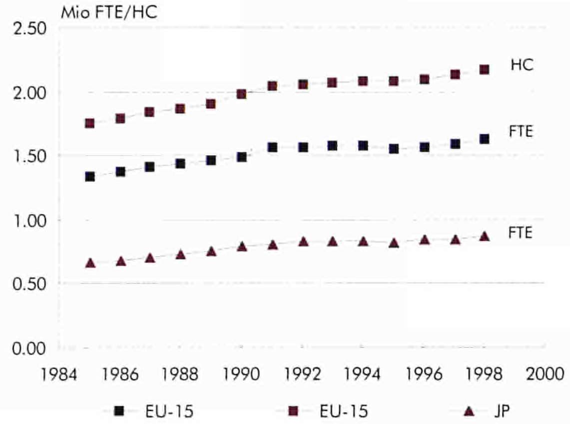
Sources: Eurostat, OECD.

Sources: Eurostat, OECD.

Fig. 3.9.

R&D personnel in FTE and HC
1985-98

All sectors

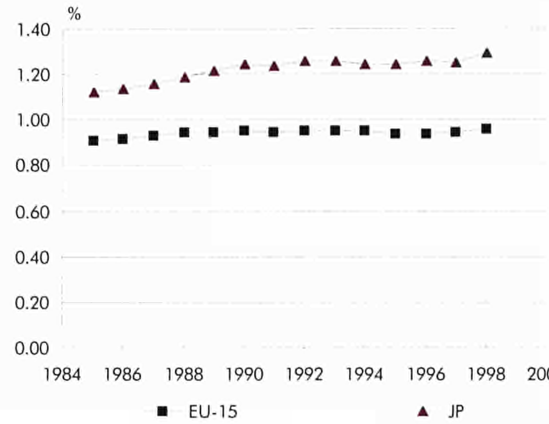


Sources: Eurostat, OECD.

Fig. 3.10.

R&D personnel in FTE
as a % of the labour force — 1985-98

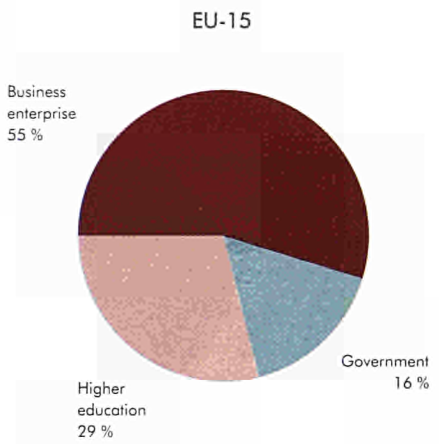
All sectors



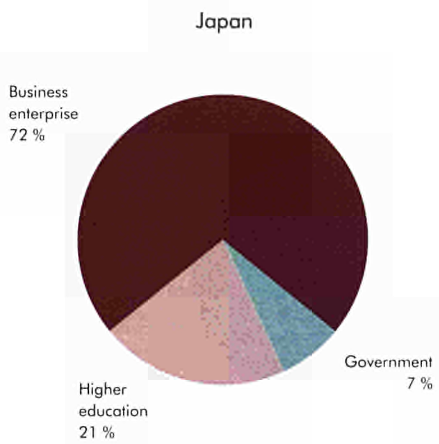
Sources: Eurostat, OECD.

Fig. 3.11., 3.12.

R&D personnel in FTE by institutional sector
1998



Source: Eurostat.

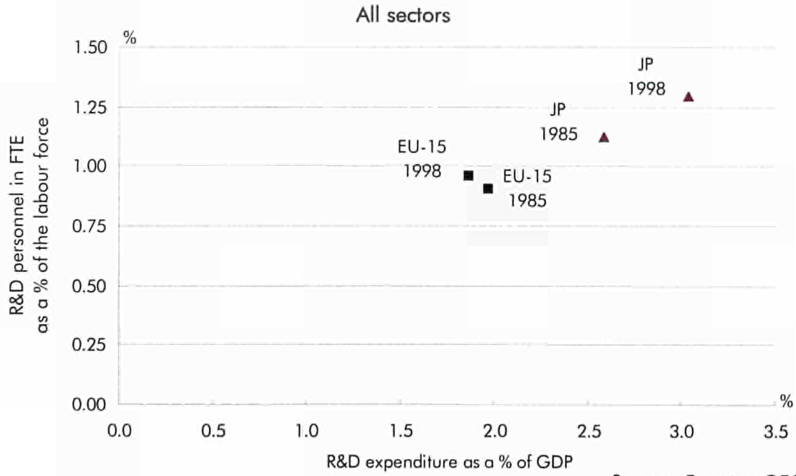


Source: OECD.

Fig. 3.13.

R&D expenditure and personnel in FTE
1985 and 1998

All sectors



Sources: Eurostat, OECD.

In 1998, 1.27 % of the EU population (HC) performed R&D activity, an increase of 0.02 points on the previous year. In Japan because HC data are not available, the same indicator is built up using FTE R&D personnel. These should therefore be treated with caution. The results show that in 1998, 1.3 % of the active population was engaged in R&D activity in Japan compared with only 0.96 % in Europe. Compared with the previous year, R&D personnel as a ratio of the active population was on the increase. It rose by about 0.05 percentage points for Japan and 0.02 points for the EU-15.

Over the longer period, between 1985 and 1998, there was a slight increase of 0.05 points in R&D personnel (FTE) as a ratio of the active population in the EU-15. This increase was, however, less marked than that in Japan, where there was a greater rise 0.18 points in the number of R&D personnel (FTE) in relation to the total active population over the same period.

R&D personnel by institutional sector

The distribution of R&D personnel by institutional sector is relatively in line with the results observed for R&D expenditure. Almost three out of four of all persons working on R&D in Japan work in the business enterprise sector, compared with only one in two in the EU-15.

Resources committed to R&D: expenditure and personnel

Total resources committed to R&D are presented on the basis of expenditure (as a percentage of GDP) and R&D personnel (in FTE). There was an overall increase in the gap between the EU-15 and Japan between 1985 and 1998. The increase in Japan, although very considerable, remained balanced between the R&D resources devoted to expenditure and those spent on personnel.

The situation in the EU-15 did not change greatly, since expenditure as a percentage of GDP decreased slightly while the number of personnel as a percentage of the active population increased slightly. This stagnation may be explained by the relative stability or decrease, in terms of resources committed to R&D, of the four major economies in the EU-15 (Germany, France, Italy and the United Kingdom), which accounted for approximately 75 % of R&D expenditure and personnel.

3.2. R&D IN THE EUROPEAN ECONOMIC AREA

R&D Expenditure

With expenditure of more than ECU 141 thousand million in 1998 [10], the EU showed an increase of 4.5 % on the previous year. This increase was, however, slightly below the annual average growth rate of 5.3 % recorded between 1985 and 1998.

Expressed in PPS [11], expenditure was 110 thousand million. The trend remained positive, and expenditure in the EU was 3.4 % up on 1998 in comparison to 1997, which was higher than the annual average growth rate of 2.2 % recorded during the same period (1985-98).

Four countries (Germany, France, Italy and the United Kingdom) accounted for 75 % of R&D expenditure in 1998. This is broadly similar to the situation observed in 1991 nevertheless with a slight decrease (see Figures 3.15. and 3.16.). Some countries, however, saw the share of their expenditure increase by more than 0.5 points in the total European R&D expenditure over the same period: Sweden (an increase from 4.9 in 1991 to 5.6 % in 1998) and Austria (1.8 to 2.3 %).

Measured as a percentage of GDP, R&D expenditure remained relatively stable in relation to the previous year. This is the case both at the EU level, where R&D expenditure as a proportion of GDP remained unchanged (1.86 %), and at the national level. The Nordic countries had a relatively high rate of expenditure: Finland and Sweden devoted almost 3 % of their GDP to R&D expenditure, which was close to the national average observed in Japan in 1998. At the top of the table, Finland and Iceland stepped up their R&D efforts considerably in relation to the previous year, from 2.72 to 2.89 % and from 1.84 to 2.02 %, respectively.

For a longer term perspective, the 1998 results are compared with the 1985 results. The small variations in R&D expenditure as a percentage of GDP [12] give us an initial idea of major trends between these two dates (see Figure 3.17. and Table 3.1.).

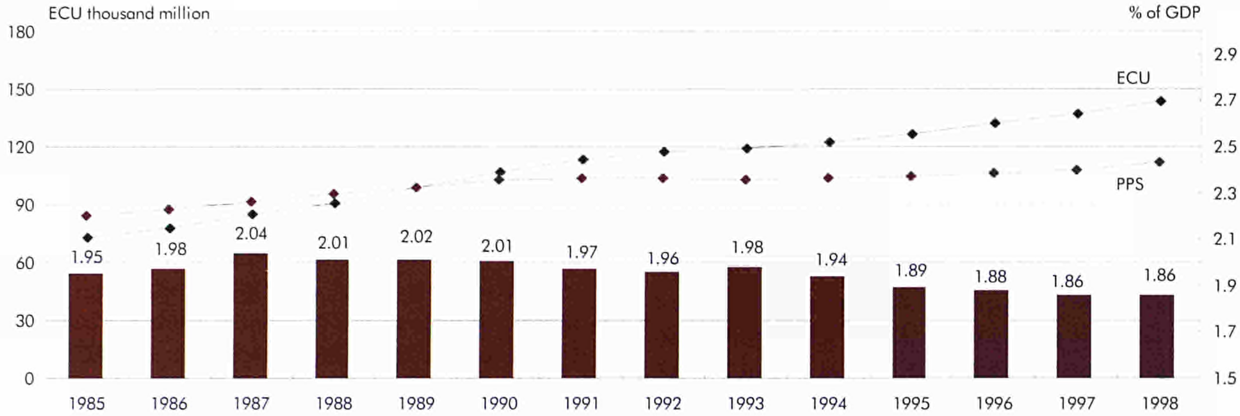
[10] R&D expenditure for the European Economic Area was ECU 143.7 thousand million in 1998.

[11] Purchasing Power Standard (PPS) at constant 1990 prices.

[12] The trends are broken down by country in: *Research and Development: annual statistics 1998*, Part A, Chapter 2 — Theme 9 Research and Development, Eurostat, Luxembourg, 1998.

Fig. 3.14.

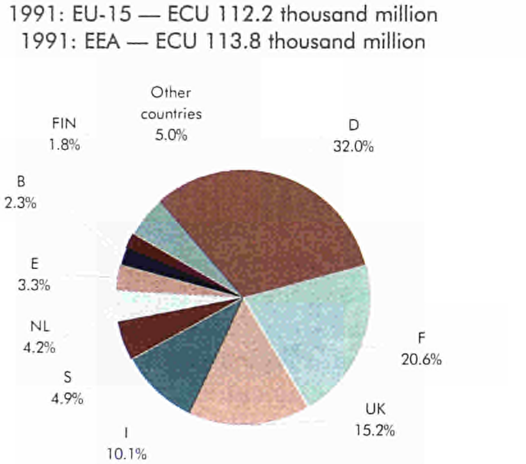
R&D expenditure in ECU at current prices, in PPS at 1990 prices and as a % of GDP
European Economic Area — 1985-98



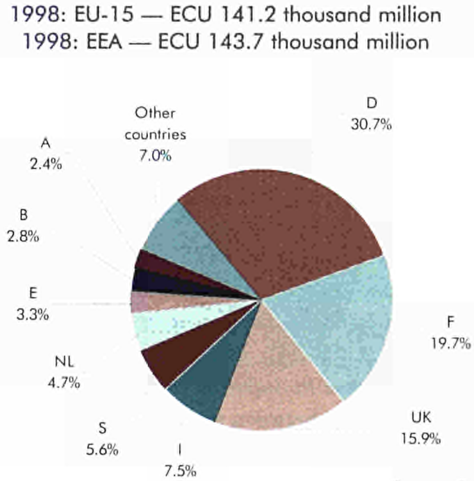
Source: Eurostat.

Fig. 3.15., 3.16.

R&D expenditure in ECU at current prices by country
1991 and 1998



Source: Eurostat.

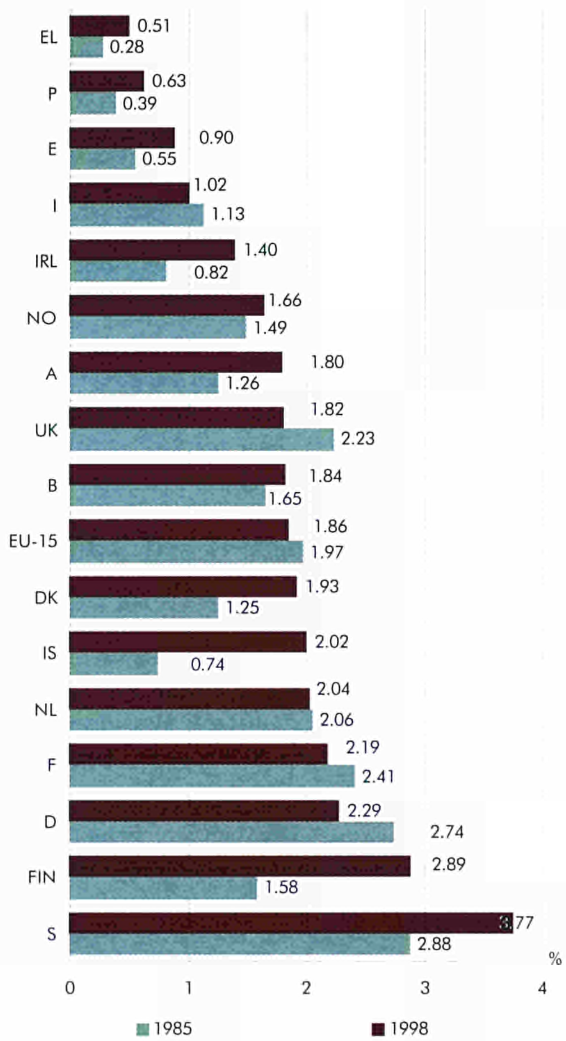


Source: Eurostat.

Methodological notes

- Exceptions to the reference period are:
  Figure 3.15. — P: 1990.
  Figure 3.16. — B, EL, IRL, NL, NO and P: 1997.
- Figure 3.16. — the heading 'Other countries' covers A, DK, EL, IS, IRL, P and NO.

Fig. 3.17. R&D expenditure as a % of GDP 1985 and 1998



Tab. 3.1. R&D expenditure in PPS at 1990 prices & in ECU at current prices — 1985 and 1998

	PPS Mio		ECU Mio	
	1985	1998	1985	1998
EL	223	499	133	542
P	276	663	135	582
E	1 880	4 747	1 203	4 693
I	8 365	9 721	6 307	10 822
IRL	235	855	205	968
NO	1 017	1 661	1 246	2 268
A	1 284	2 500	1 099	3 395
UK	15 800	17 900	13 490	22 865
B	2 197	3 174	1 778	3 953
EU-15	82 400	110 000	71 800	141 200
DK	886	1 928	959	2 993
IS	28	108	28	148
NL	3 915	5 600	3 485	6 789
F	22 200	22 767	23 399	28 319
D	25 700	31 459	22 472	44 051
FIN	1 002	2 515	1 119	3 335
S	3 477	5 800	3 833	8 000

CHAPTER 3

Methodological notes

Figure 3.17. and Table 3.1. — R&D expenditure as a % of GDP, in PPS million and in ECU million.

Exceptions to the reference periods are:

- **Reference period 1985**
  EL and P: 1986;
  F: 1991.
- **Reference period 1998**
  B, EL, IRL, P, NL and NO: 1997.

At the top of the range, R&D expenditure as a percentage of GDP was relatively stable for the four countries with the highest expenditure in absolute terms. With the exceptions of Italy and the United Kingdom, it was higher than the European average, which fell slightly between 1985 and 1998.

The lower threshold also rose considerably, from 0.28 % to over 0.51 %, during the reference period. There were marked increases in a number of countries, some of which virtually doubled their expenditure as a percentage of GDP over this period: Iceland (from 0.74 % to over 2.2 %), Finland (1.58 % to 2.89 %), Ireland (0.82 % to 1.40 %), Spain (0.55 % to 0.90 %), Denmark (1.25 % to 1.93 %), Greece (0.28 % to 0.51 %) and Portugal (0.39 % to 0.63 %).

These trends were not, however, uniform over time for all the countries mentioned above. Some had already reached the 1998 level by the beginning of the 1990s, while for others the increase reflected a more recent upward trend. This was particularly the case in Iceland and Sweden.

Table 3.1. and Figure 3.17. summarise the available information by EEA country on R&D expenditure as a percentage of GDP and R&D expenditure in PPS and ECU for 1985 and 1998.

R&D expenditure by institutional sector

In 1998, R&D expenditure totalled 110 thousand million PPS (at 1990 prices), broken down as follows among the three institutional sectors: 64 % in the business enterprise sector, almost 21 % in the higher education sector and over 15 % in the government sector.

At the national level, the breakdown of expenditure by sector reveals some disparities and a dominant trend (see Figure 3.18.). In over 13 EEA countries, expenditure in the business enterprise sector accounted for over 50 % of total R&D expenditure. There was a wide range between the two extremes: the share of the business enterprise sector was over 70 % in Belgium, Ireland and Sweden, but under 30 % in Greece and Portugal. In these two countries, the dominant sector was higher education, where the rates were 51 and 46 % respectively.

Iceland was the only country where R&D expenditure was highest in the government sector: with a rate of 38 %, it was one point higher than in the business enterprise sector.

Trends in R&D expenditure as a percentage of GDP between 1985 and 1998

Over the longer term, several trends are apparent. From an overall point of view and taking all sectors together, the Nordic countries were in the lead. There were marked increases in Denmark, Finland, Iceland and Sweden, to a lesser extent, Norway between 1985 and 1998. In Denmark and Finland, the increases were significant even in each individual sector.

In the business enterprise sector (see Figure 3.19.), the same countries again had the highest increases. In the other countries, the situation remained relatively stable except in Germany and the United Kingdom, where there were slight decreases.

In the government sector, the changes observed were within a narrower range. Increases in R&D expenditure as a percentage of GDP were most marked in the Nordic countries (Finland, Iceland, and Norway). There were significant decreases only in France and the United Kingdom, in line with the downward trend for Europe as a whole.

In the higher education sector, it was not only the Nordic countries which saw their expenditure increasing in line with the upward trend in the European average, since expenditure as a percentage of GDP also increased in Belgium, Greece, Spain, the Netherlands, Austria and Portugal.

Over a shorter period (between 1995 and 1998) ([13]), and in terms of the weight of the various sectors in the overall expenditure of the countries, a major trend emerged: R&D expenditure in the business enterprise sector as a percentage of the total expenditure rose in all countries but Greece.

R&D personnel

Over the past 15 years the number of R&D personnel in Europe has increased steadily: in 1998, almost 2.2 million people in head count (HC) were employed on R&D activities in the EU-15, or 1.6 million in full-time equivalent (FTE) ([14]). In terms of volume, the increase for both FTE and HC R&D personnel was over 2 % in relation to 1997.

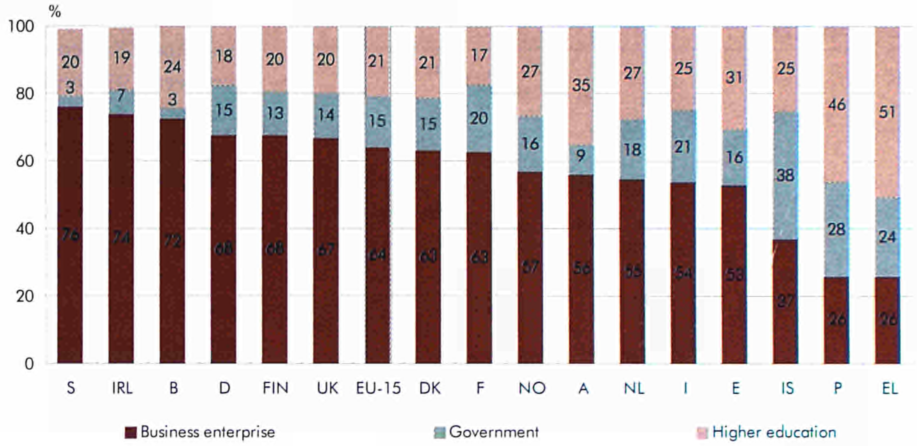
Analysed in terms of R&D personnel (HC) as a percentage of the active population, the trend was stable: the percentage rose from 1.25 % in 1997 to 1.27 % in 1998.

([13]) 1995 was selected according to the avalability of the data.

([14]) EEA data are estimated by Eurostat for 1998: over 2.2 million people (HC), or 1.65 million in full-time equivalent (FTE).

Fig. 3.18.

R&D expenditure in PPS at 1990 prices by institutional sector
1998



Source: Eurostat.

Methodological notes

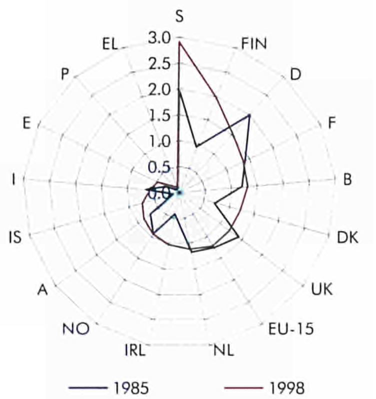
Exceptions to the reference period:

- A: 1993.
- B, EL, IRL, NL, NO and P: 1997.

Fig. 3.19., 3.20., 3.21.

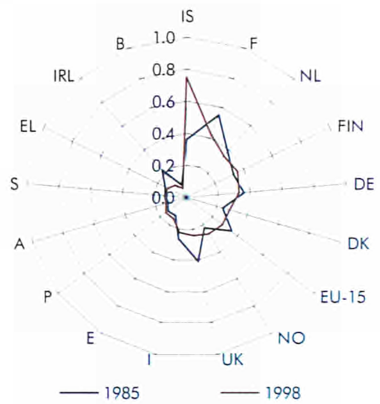
R&D expenditure as a % of GDP by institutional sector
1985 and 1998

Business enterprise



Source: Eurostat.

Government



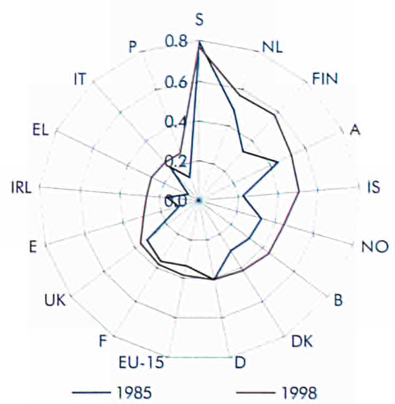
Source: Eurostat.

Methodological notes

Exceptions to the reference periods for Figures 3.19. to 3.21.:

- **Business enterprise**
  EL and P: 1986, 1997;
  A: 1993;
  B, IRL, NL and NO: 1997.
- **Government**
  P: 1986, 1997;
  A: 1993;
  B, EL, NL and NO: 1997.
- **Higher education**
  EL and P: 1986, 1997;
  F: 1991;
  A: 1993;
  B, IRL, NL and NO: 1997.

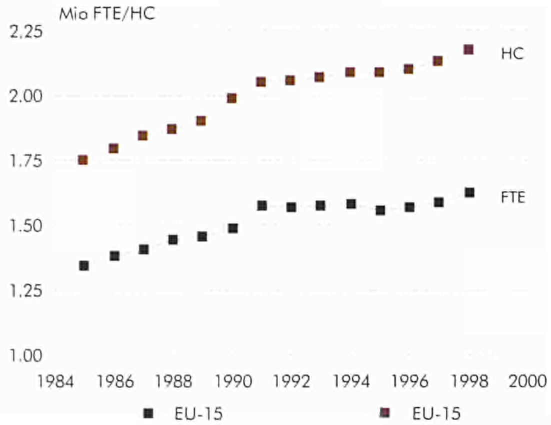
Higher education



Source: Eurostat.

Fig. 3.22. R&D personnel in FTE and HC 1985-98

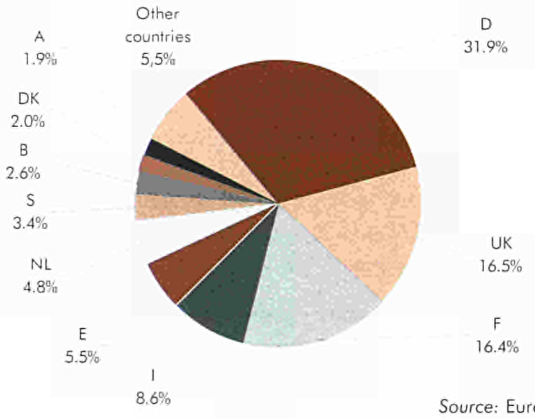
All sectors



Source: Eurostat.

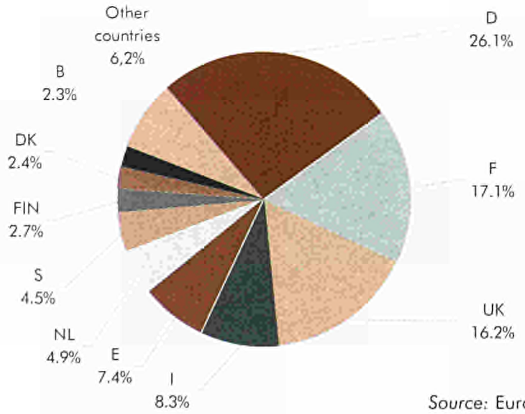
Fig. 3.23., 3.24. R&D personnel in HC by country 1991 and 1998

1991
EU-15 — 2.1 Mio HC



Source: Eurostat.

1998
EU-15 — 2.2 Mio HC



Source: Eurostat.

At the national level, five countries (Germany, Spain, France, Italy and the United Kingdom) accounted for over 75 % of R&D personnel in the EEA in both 1991 and 1998. This distribution of R&D personnel among the various EEA countries did not fundamentally change between 1991 and 1998 (see Figures 3.23. and 3.24.) with exception for Germany where the share decreased over 5 points. The decrease in the United Kingdom should, be interpreted with caution in view of the year in which the data became available (1993). The main increases were in Spain, where R&D personnel (HC) as a percentage of the European total rose from 5.5 % to 7.4 % over this period, Sweden (from 3.4 to 4.5 %), Finland (from 1.4 to 2.7 %) and Greece (from 0.5 to 1 %).

Trends in R&D personnel between 1985 and 1998

The Nordic countries lead the field by virtue of their numbers of R&D personnel expressed as a percentage of the economically active population. In Finland, Iceland and Sweden, R&D personnel represent more than 2 % of the economically active population, and Norway (1.91 %) and Denmark (1.99 %) are not far behind (see Figure 3.25. and Table 3.2.).

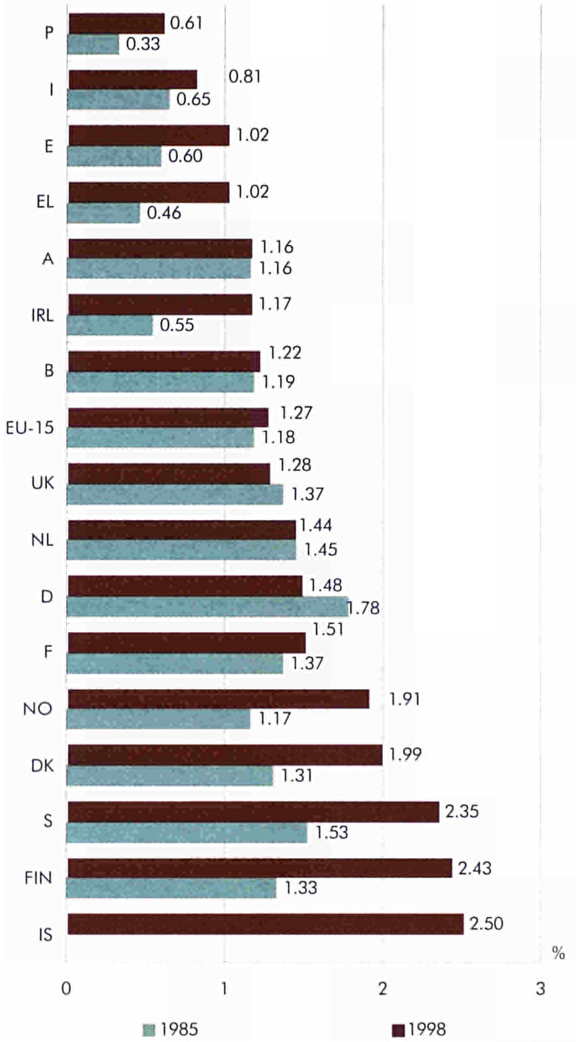
According to the latest available data by country, the most marked differences in recent years have been in Finland, with a difference of 0.46 points between 1995 and 1998 (rising from 1.97 to 2.43 %), Greece with a difference of 0.15 points (from 0.87 to 1.02 % between 1995 and 1997) and Portugal with a difference of 0.08 points (from 0.53 to 0.61 % over the same period).

Methodological notes

Exceptions for Figures 3.23. and 3.24.:

- **Figure 3.23.**
  Exception to the reference period:
  EL: 1990.
  'Other countries' means: FIN, EL, IS, IRL, NO and P.
- **Figure 3.24.**
  Exceptions to the reference period:
  A and UK: 1993;
  B and IRL: 1995;
  F, EL, I, NL, NO and P: 1997.
  'Other countries' means: A, EL, IS, IRL, NO and P.
- As a result, the estimated distribution of R&D expenditure by country is slightly biased.

Fig. 3.25. R&D personnel as a % of the labour force 1985 and 1998



Source: Eurostat.

Tab. 3.2. R&D personnel in HC and FTE 1985 and 1998

	Head count		Full time equivalent	
	1985	1998	1985	1998
P	15 107	29 413	10 570	18 035
I	146 976	185 354	117 887	142 956
E	87 797	165 582	40 654	97 099
EL	18 174	43 353	9 387	20 173
A	40 000	43 133	20 161	24 458
IRL	7 220	16 784	5 341	12 372
B	47 213	50 836	34 859	38 468
EU-15	1 750 900	2 174 700	1 342 400	1 625 500
UK	376 742	362 518	289 000	277 500
NL	82 738	109 416	61 400	83 967
D	499 596	584 909	390 938	463 002
F	330 041	384 053	283 747	313 151
NO	24 182	43 894	18 426	24 877
DK	35 945	54 321	19 914	32 107
S	66 862	101 913	49 599	68 405
FIN	34 312	60 890	23 550	46 519
IS	1 561	3 821	877	2 273

Source: Eurostat.

Methodological notes

Exceptions to the reference periods for Figure 3.25. and Table 3.2.:

- **Figure 3.25.**
  Reference period 1985
  P: 1986;
  FIN and S: 1987,
  E: 1988, EL,
  F and A: 1989.

  Reference period 1998
  A and UK: 1993;
  B and IRL: 1995;
  F, EL, I, NL, NO and P: 1997.

- **Table 3.2.**
  Reference period 1985
  P: 1986;
  IS 1987;
  E: 1988;
  F and EL: 1989.

  Reference period 1998
  A and UK: 1993;
  B and IRL: 1995;
  F, EL, I, NL, NO and P: 1997.

- As a result, the estimated distribution of R&D expenditure by country is slightly biased.

A medium-term analysis, between 1985 and 1998, reveals an overall increase in R&D personnel in the EU-15, rising from 1.18 to 1.27 % of the labour force.

The sizeable differences are largely found at either end of the table. In the countries where R&D personnel numbers are low (Greece, Spain, Italy, Ireland and Portugal), these increased significantly in proportion to the economically active population.

At the head of the table, the Nordic countries showed the most significant gains over the period 1985-98.

These results match those recorded in expenditure, in which the same trends are observed in the same countries: Greece, Spain, Italy and Portugal show the lowest expenditure, and Denmark, Finland, Iceland and Sweden the highest.

The female population in R&D personnel

The data on women's representation among R&D personnel appear in the annual publication for the first time, and are presented in Figure 3.26.

Women working in research represent between one-quarter and one-third of R&D staff in the countries for which these data are available.

This rate is relatively high in Portugal by comparison with those recorded in the Nordic countries or France, for example, where only one in every four people working in R&D is female. It would be interesting to be able to compare these first results with those for the other countries for which these data are unfortunately not yet available.

Furthermore, given that the data presented are not completely homogeneous in terms of the units observed, these results are to be interpreted with the usual caution [15].

R&D personnel by institutional sectors

The business enterprise sector is the leading employer of R&D personnel in Europe, contributing around 55 % of all R&D posts for the EU-15 in 1998. This rate is all but identical to the previous year's, following a period of uninterrupted decline since 1990 (51 %). The other R&D personnel in 1998 are employed in higher education (29 %) and in the government sector (16 %).

At the national level, employment in business is highest in Germany, at nearly 56 %. In the next six countries, the rates range higher than 50 %: Belgium, Denmark, Ireland, Finland, Sweden and the United Kingdom.

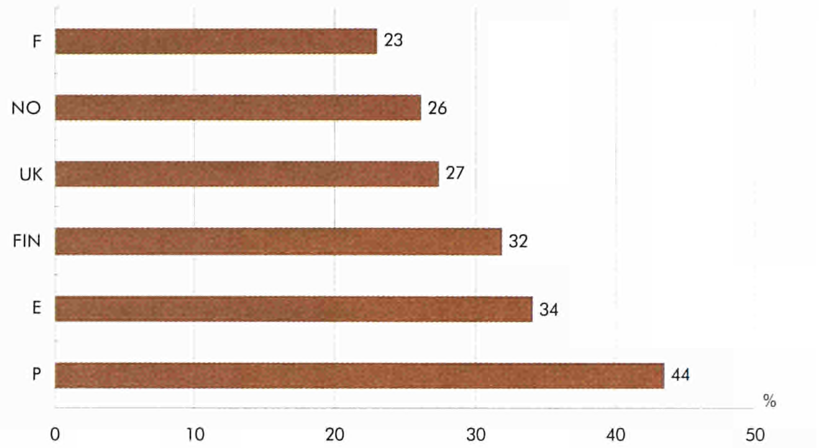
In Iceland and Italy, R&D personnel are almost evenly distributed over the three sectors. The reverse trend is observed in Greece, Spain and Portugal where more than 50 % of R&D personnel work in higher education.

The main results as percentages of the economically active population are shown in Figures 3.27., 3.28. and 3.29 [16].

(15) The references are as follows:
Finland (1998);
France (research personnel excluding those receiving grants, as well as those in the 'Defence' sector);
Norway (scientists and engineers);
Portugal (researchers — data for the government sector, the higher education sector and the private non-profit sector only — 1997) and
United Kingdom (scientists, engineers and technical experts, Scotland not included, 1998).

(16) The data for all sectors in 1998 are available for only few countries.
See 'Methodological notes', p. 63 for Figures 3.27. to 3.29.

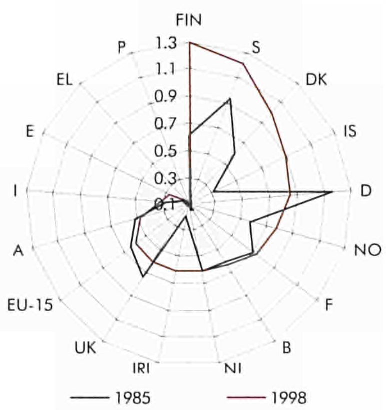
Fig. 3.26. Women as a % of total R&D personnel in HC
1997



Source: Eurostat.

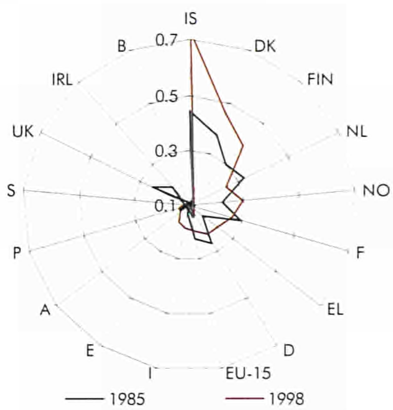
Fig. 3.27., 3.28., 3.29. R&D personnel in HC as a % of the labour force by institutional sector
1985 and 1998

Business enterprise



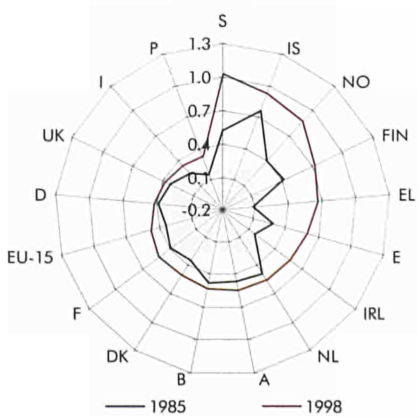
Source: Eurostat.

Government



Source: Eurostat.

Higher education



Source: Eurostat.

Methodological notes

Exceptions to the reference periods for Figures 3.27. to 3.29.:

- **Business enterprise**
  - **Reference period 1985**: EL and P: 1986; FIN and S: 1987; A: 1989; IS: 1991.
  - **Reference period 1998**: A: 1993; B: 1995; NL: 1996; F, EL, IRL, I, NO and P: 1997.
- **Government**
  - **Reference period 1985**: P: 1986; EL, FIN and S: 1987; F: 1989; IS: 1991.
  - **Reference period 1998**: A: 1993; IRL: 1995; B, F, EL, I, NL, NO and P: 1997.
- **Higher education**
  - **Reference period 1985**: P: 1986; EL, FIN and S: 1987; E: 1988; F: 1989; IS: 1991.
  - **Reference period 1998**: A and UK: 1993; IRL: 1995; B, F, EL, I, NL, NO and P: 1997.

Tab. 3.3., 3.4., 3.5., 3.6.

Regions with high R&D expenditure by institutional sector 1997

All sectors

Region	Country	R&D expenditure As a % of GDP	In PPS at 1990 prices Mio	%
EU-15		1.86	106 400	100.0
Braunschweig	D	4.87	1 204	1.1
Stuttgart	D	4.76	3 628	3.4
Oberbayern	D	4.29	4 251	4.0
Tübingen	D	4.02	1 156	1.0
Uusimaa (Suuralue)	FIN	3.74	1 072	1.0
Rheinhessen-Pfalz	D	3.63	1 098	1.0
Midi-Pyrénées	F	3.55	1 297	1.2
Île de France	F	3.28	9 656	9.0
Karlsruhe	D	3.25	1 743	1.6
Berlin	D	3.24	1 845	1.7

Source: Eurostat.

Business enterprise

Region	Country	R&D expenditure As a % of GDP	In PPS at 1990 prices Mio	%
EU-15		1.18	66 800	100.0
Stuttgart	D	4.24	3 235	4.8
Stockholm	S	4.23	1 501	2.2
Oberbayern	D	3.32	3 285	4.9
Tübingen	D	3.29	945	1.4
Braunschweig	D	2.96	732	1.1
Rheinhessen-Pfalz	D	2.89	875	1.3
Sydsverige	S	2.67	521	0.8
Uusimaa (Suuralue)	FIN	2.39	685	1.0
Östra Mellansverige	S	2.33	536	0.8
Île de France	F	2.26	6 655	10.0

Source: Eurostat.

Government

Region	Country	R&D expenditure As a % of GDP	In PPS at 1990 prices Mio	%
EU-15		0.28	16 400	100.0
Flevoland (1996)	NL	2.47	81	0.5
Midi-Pyrénées	F	1.29	470	2.9
Braunschweig	D	1.06	261	1.6
Berlin	D	0.99	563	3.4
Karlsruhe	D	0.97	520	3.2
Lazio	I	0.93	882	5.4
Köln	D	0.77	566	3.4
Languedoc-Roussillon	F	0.77	227	1.4
Utrecht (1996)	NL	0.73	149	0.9
Uusimaa (Suuralue)	FIN	0.71	203	1.2

Source: Eurostat.

Higher education

Region	Country	R&D expenditure As a % of GDP	In PPS at 1990 prices Mio	%
EU-15		0.38	22 300	100.0
Gießen	D	0.95	146	0.7
Wien (1993)	A	0.95	357	1.6
Braunschweig	D	0.86	212	0.9
Steiermark (1993)	A	0.83	123	0.6
Berlin	D	0.75	427	1.9
Halle	D	0.72	69	0.3
Tirol (1993)	A	0.71	73	0.3
Pohjois-Suomi	FIN	0.69	53	0.2
Languedoc-Roussillon	F	0.62	181	0.8
Uusimaa (Suuralue)	FIN	0.62	177	0.8

Source: Eurostat.

Methodological notes

As a result of the switch to NUTS 98, certain changes can be observed in the year-on-year ranking of the regions.

- The main ones are that East-Anglia (UK), Uusimaa and Etelä-Suomi (FIN) and Sachsen (D) no longer appear.
- Ireland, which was classified in NUTS 2 (1995) is now in NUTS 1 (1998).

The regions for which data are not available at NUTS level 2 are the United Kingdom (except Northern Ireland, which is classified at NUTS levels 1 and 2), Belgium and the Netherlands for the higher education sector, and Sweden and Norway for all institutional sectors.

For the regions for which no data are available for the reference year 1997, the percentage share of expenditure in PPS is slightly biased because it is calculated on the basis of expenditure at EU-15 level for 1997.

3.3. REGIONAL R&D

Regional R&D expenditure

The top 10 regions in terms of expenditure as a percentage of GDP

Taking all sectors together, seven out of the top ten regions are in Germany. Overall, more than one-half of the regions where R&D expenditure amounts to more than 1.5 % of GDP are in Germany, one-quarter are in France, and the last quarter is spread over five countries: Austria, Denmark, Iceland, Italy and Spain.

At the other end of the table, one-half of the regions for which data are available apply less than 1 % of their GDP to R&D expenditure.

More specifically, few of the ten highest ranking regions record employment in all three institutional sectors. Sectoral specialisation tends to be the rule. Some regions, however, are exceptional: Braunschweig (D) and Uusimaa (Suuralue; FIN) feature in the business enterprise (BES), government (GOV) and higher education (HES) sectors; Berlin (D) and Languedoc-Rousillon (F) appear in GOV and HES.

Regional disparities in R&D expenditure over all sectors

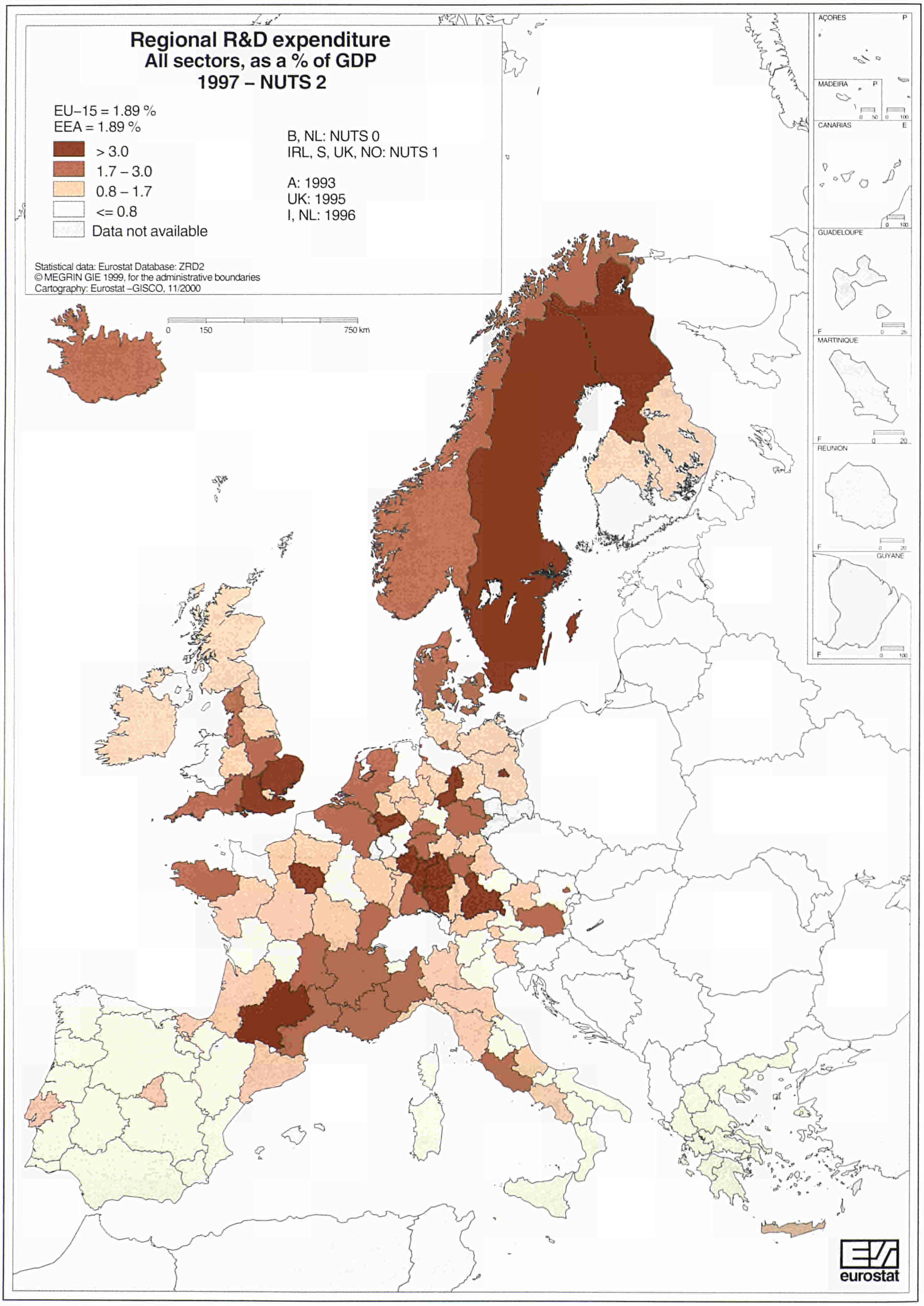
The regions with the highest R&D expenditure at national level reveal marked disparities between countries. Thus, the difference between the leading German region, Braunschweig, and the highest-spending Greek region, Kriti, is of the order of 3 points. The reverse is true of the regions with low rates of R&D expenditure, where the differences are less distinct: less than 0.4 points separates Weser-Ems (D) from Åland (FIN).

Tab. 3.7. Disparities in R&D expenditure by region for all sectors 1997

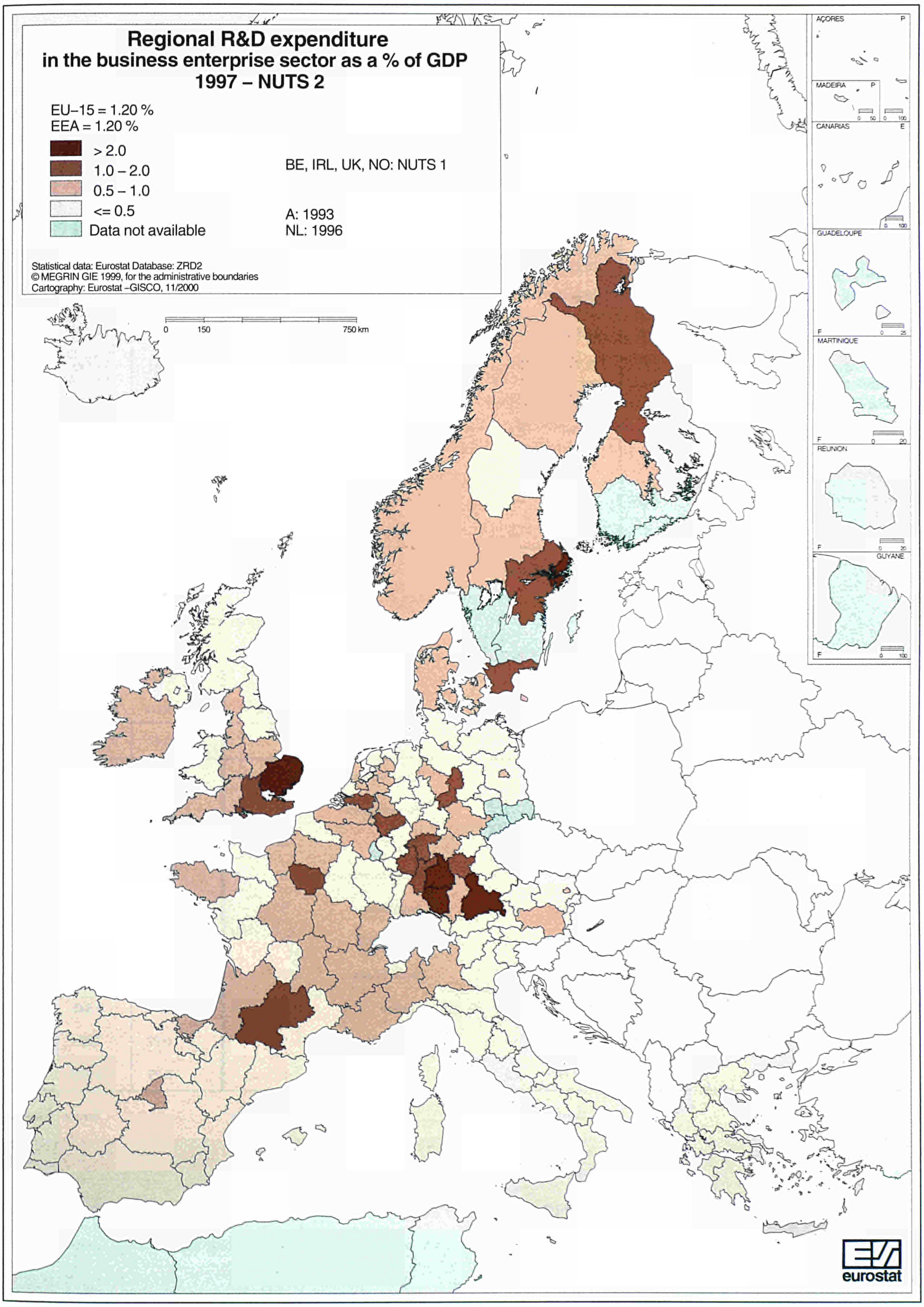
Regions with high R&D expenditure			PPS at 1990 prices		Regions with low R&D expenditure			PPS at 1990 prices	
Country	Region	% of GDP	Mio	%	Country	Region	% of GDP	Mio	%
EU-15		1.86	106 400	100.0	EU-15		-	-	-
DK	Denmark ([1])	1.94	1 899	1.8	DK	Denmark ([1])	-	-	-
D	Braunschweig	4.87	1 204	1.1	D	Weser-Ems	0.39	143.0	0.1
EL	Kriti	0.87	49	0.0	EL	Notio Aigaio	0.07	2.0	0.0
E	Comunidad de Madrid	1.64	1 339	1.3	E	Islas Baleares	0.22	27.0	0.0
F	Midi-Pyrénées	3.55	1 297	1.2	F	Corse	0.27	10.0	0.0
I	Lazio (1996)	1.92	1 786	1.7	I	Valle d'Aosta (1996)	0.18	4.0	0.0
A	Wien (1993)	2.62	985	0.9	A	Burgenland (1993)	0.34	9.0	0.0
P	Lisboa e Vale do Tejo	0.86	379	0.4	P	Algarve	0.29	11.0	0.0
FIN	Uusimaa (Suuralue)	3.74	1 072	1.0	FIN	Åland	0.05	0.3	0.0
UK	Northern Ireland (1995) ([2])	0.79	162	0.2	UK		-	-	-
IS	Iceland	1.87	93	0.1	IS	Iceland	-	-	-

([1]) The nomenclature of territorial units for statistics (NUTS) places Denmark at the NUTS 2 level.
([2]) Data at the NUTS 2 level is not available for any UK region except Northern Ireland (1995 data), which is classified at both the NUTS 1 and NUTS 2 levels.

Source: Eurostat.


Regional R&D expenditure
All sectors, as a % of GDP
1997 – NUTS 2
EU–15 = 1.89 %
EEA = 1.89 %
> 3.0
1.7 – 3.0
0.8 – 1.7
<= 0.8
Data not available
B, NL: NUTS 0
IRL, S, UK, NO: NUTS 1
A: 1993
UK: 1995
I, NL: 1996
Statistical data: Eurostat Database: ZRD2
© MEGRIN GIE 1999, for the administrative boundaries
Cartography: Eurostat –GISCO, 11/2000
0
150
750 km
AÇORES
MADEIRA
CANARIAS
GUADELOUPE
MARTINIQUE
REUNION
GUYANE
eurostat

Map 3.1.


Regional R&D expenditure
in the business enterprise sector as a % of GDP
1997 – NUTS 2
EU–15 = 1.20 %
EEA = 1.20 %
> 2.0
1.0 – 2.0
0.5 – 1.0
<= 0.5
Data not available
BE, IRL, UK, NO: NUTS 1
A: 1993
NL: 1996
Statistical data: Eurostat Database: ZRD2
© MEGRIN GIE 1999, for the administrative boundaries
Cartography: Eurostat –GISCO, 11/2000
0 150 750 km
AÇORES
MADEIRA
CANARIAS
GUADELOUPE
MARTINIQUE
REUNION
GUYANE
eurostat

Map 3.2.

Tab. 3.8.,3.9., 3.10., 3.11.

Regions with high R&D personnel by institutional sector 1997

All sectors

Region	Country	R&D personnel As a % of labour force	R&D personnel HC Number	R&D personnel HC %
EU-15		1.25	2 129 400	100.0
Stockholm	S	3.65	32 642	1.5
Uusimaa (Suuralue)	FIN	3.59	25 974	1.2
Oberbayern	D	3.33	68 465	3.2
Braunschweig	D	3.18	23 968	1.1
Wien (1993)	A	2.91	22 931	1.1
Île de France	F	2.85	150 484	7.1
Östra Mellansverige	S	2.70	20 185	0.9
Stuttgart	D	2.67	51 289	2.4
Övre Norrland	S	2.51	6 544	0.3
Karlsruhe	D	2.47	31 431	1.5

Source: Eurostat.

Business enterprise

Region	Country	R&D personnel As a % of labour force	R&D personnel HC Number	R&D personnel HC %
EU-15		0.59	989 100	100.0
Oberbayern	D	2.32	47 714	4.8
Stuttgart	D	2.23	42 898	4.3
Stockholm	S	1.92	17 157	1.7
Uusimaa (Suuralue)	FIN	1.79	12 953	1.3
Tübingen	D	1.64	13 753	1.4
Braunschweig	D	1.61	12 176	1.2
Darmstadt	D	1.58	28 368	2.9
Île de France	F	1.58	83 228	8.4
Rheinhessen-Pfalz	D	1.38	12 815	1.3
Mittelfranken	D	1.34	11 164	1.1

Source: Eurostat.

Government

Region	Country	R&D personnel As a % of labour force	R&D personnel HC Number	R&D personnel HC %
EU-15		0.19	321 100	100.0
Flevoland (1996)	NL	1.22	1 603	0.5
Uusimaa (Suuralue)	FIN	0.85	6 179	1.9
Lazio	I	0.77	16 039	5.0
Braunschweig	D	0.75	5 629	1.8
Islande	IS	0.71	1 036	2.6
Karlsruhe	D	0.67	8 480	0.3
Berlin	D	0.61	10 860	3.4
Köln	D	0.59	11 222	3.5
Kriti	EL	0.58	1 328	0.4
Zuid-Holland (1996)	NL	0.58	9 119	2.8

Source: Eurostat.

Higher education

Region	Country	R&D personnel As a % of labour force	R&D personnel HC Number	R&D personnel HC %
EU-15		0.47	793 900	100.0
Övre Norrland	S	1.97	5 127	0.6
Voreio Aigaio	EL	1.74	1 019	0.1
Ipeiros	EL	1.69	1 843	0.2
Östra Mellansverige	S	1.56	11 660	1.5
Stockholm	S	1.41	12 651	1.6
Wien (1993)	A	1.34	10 567	1.3
Dytiki Ellada	EL	1.20	3 027	0.4
Gießen	D	1.01	4 845	0.6
Kentriki Makedonia	EL	0.92	7 051	0.9
Sydsverige	S	0.92	5 442	0.7

Source: Eurostat.

Methodological notes

- As the data are presented on the basis of NUTS 98, certain regions which appeared in previous years no longer feature as such in the classification (e.g. Uusimaa, Etelä-Suomi for Finland).
- Austrian data (in particular Wien): the reference year for R&D personnel (HC) is 1993, whereas the reference year for the economically active population is 1995.

R&D personnel in Europe's regions

The top ten regions in terms of R&D personnel

In regional terms, R&D personnel (as a percentage of the labour force) as well as expenditure bring the main centres of R&D in Europe into sharper focus.

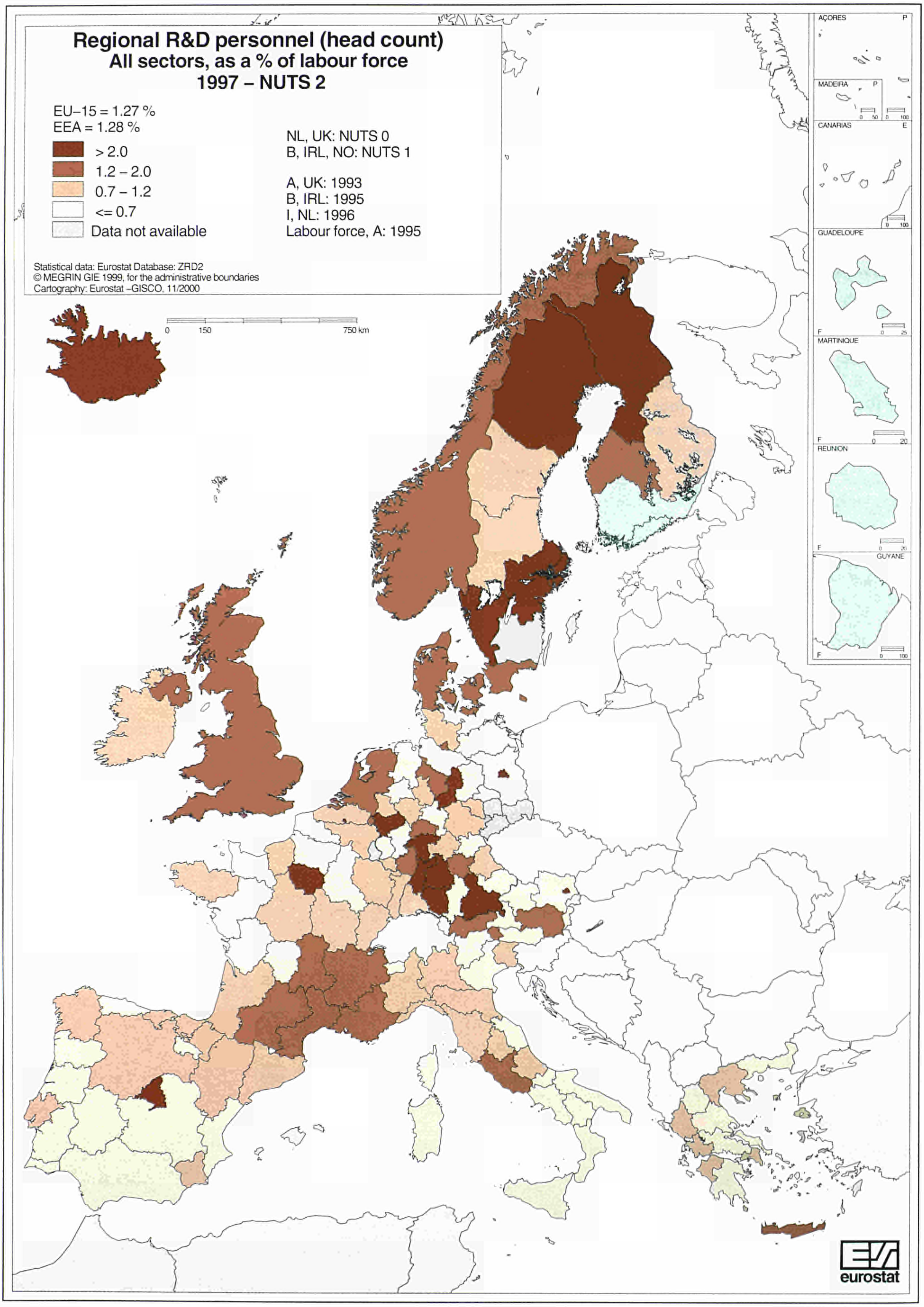
German regions are well represented in all institutional sectors, and particularly so in the business enterprise sector (Germany has seven regions in the top ten in the EEA). In the government sector, two Dutch regions, for which regional data for 1996 are available this year for the first time, are among the dominant regions. One Greek and one Finnish regions are, too.

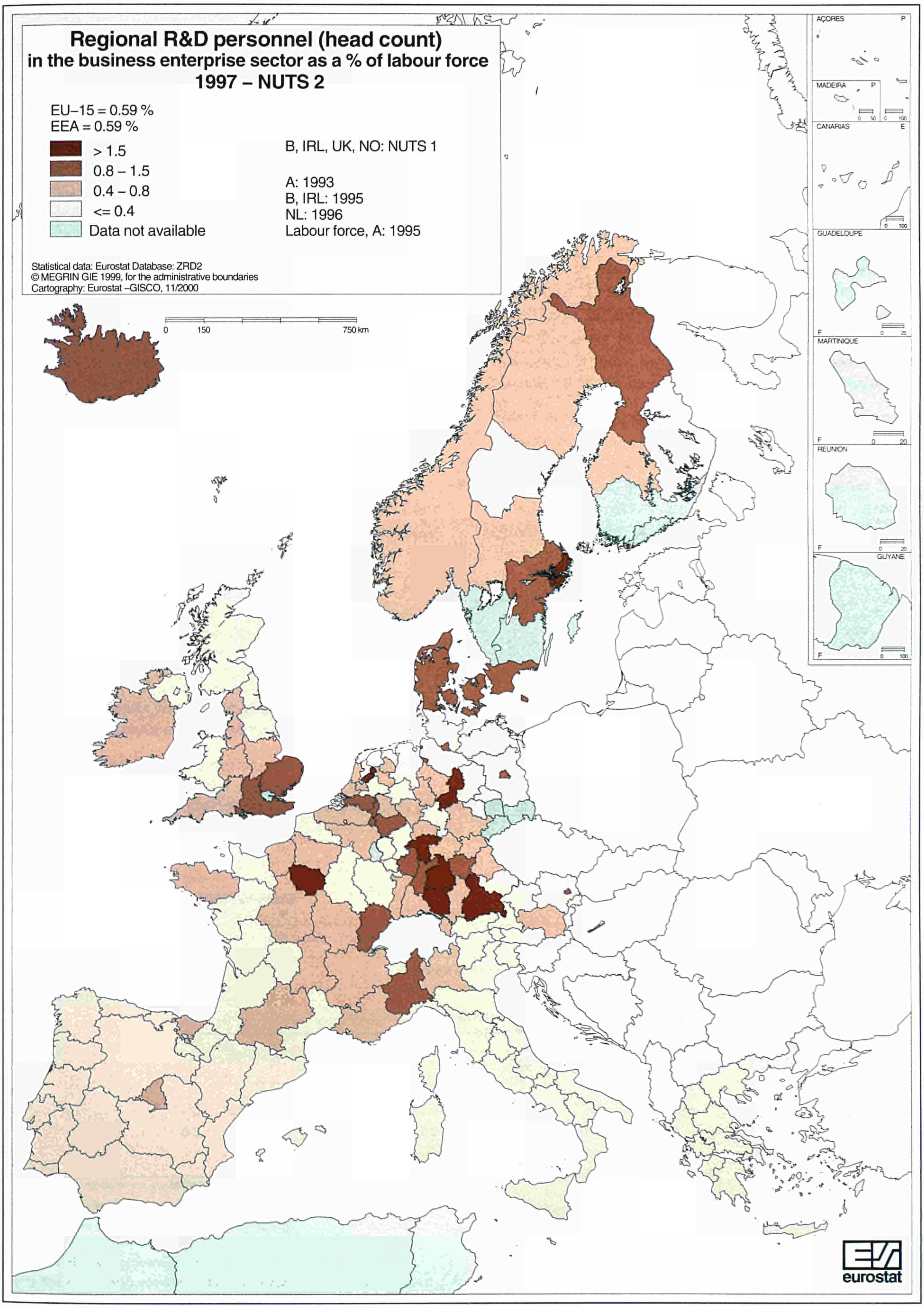
Greece stands out particularly in the higher education sector, in which R&D staff numbers soared between 1995 and 1997, which explains why four Greek regions appear among the top eight in Europe as a percentage of the economically active population.

Comparison of the ranking of regions' expenditure as a percentage of GDP and their R&D staff numbers as a percentage of the economically active population reveals the following:

- Few changes are in evidence in the business enterprise sector. Eight regions appear in the top ten by virtue of expenditure and personnel. These are Oberbayern (D), Stuttgart (D), Stockholm (S), Tübingen (D), Braunschweig (D), Île de France (F), Uusimaa (Suuralue; FIN) and Rheinhessen-Pfalz (D).
- The situation in the government sector is also relatively stable: Flevoland, Utrecht (NL), Uusimaa (Suuralue; FIN), Lazio (I) and the German regions of Braunschweig, Karlsruhe, Berlin and Köln are in the top ten regions from the point of view of expenditure and R&D personnel.
- The higher education sector presents a different picture in that Giessen (D) is the only region featuring in the top ten in terms of both expenditure and personnel.

Map 3.3.

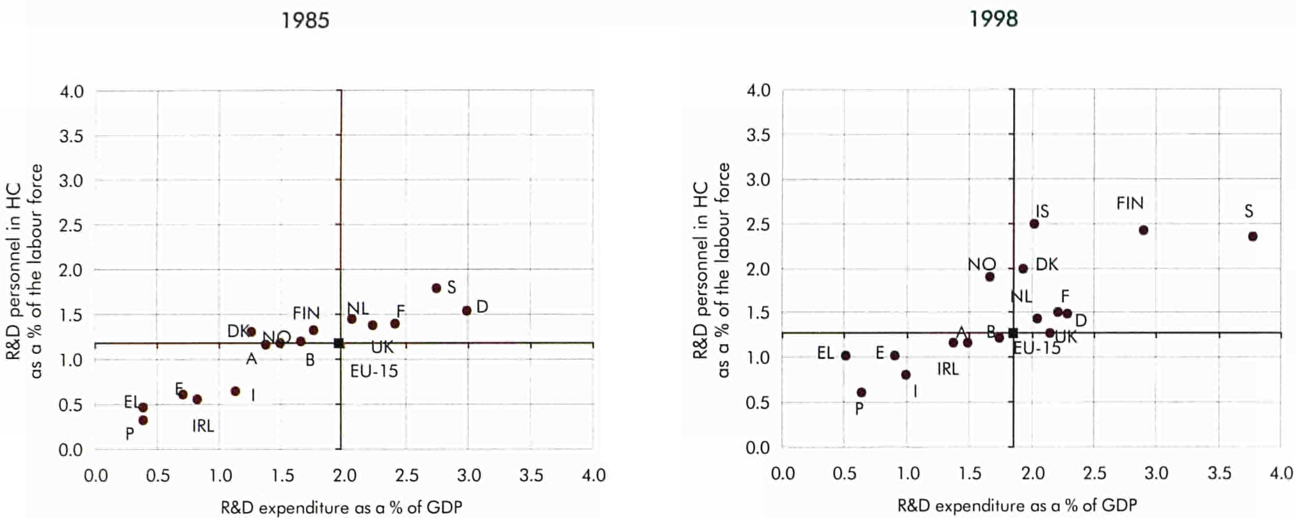

Regional R&D personnel (head count)
All sectors, as a % of labour force
1997 – NUTS 2
EU–15 = 1.27 %
EEA = 1.28 %
> 2.0
1.2 – 2.0
0.7 – 1.2
<= 0.7
Data not available
NL, UK: NUTS 0
B, IRL, NO: NUTS 1
A, UK: 1993
B, IRL: 1995
I, NL: 1996
Labour force, A: 1995
Statistical data: Eurostat Database: ZRD2
© MEGRIN GIE 1999, for the administrative boundaries
Cartography: Eurostat –GISCO, 11/2000
0
150
750 km
AÇORES
P
MADEIRA
P
CANARIAS
E
GUADELOUPE
F
MARTINIQUE
F
REUNION
F
GUYANE
F
eurostat


Regional R&D personnel (head count)
in the business enterprise sector as a % of labour force
1997 – NUTS 2
EU–15 = 0.59 %
EEA = 0.59 %
> 1.5
0.8 – 1.5
0.4 – 0.8
<= 0.4
Data not available
B, IRL, UK, NO: NUTS 1
A: 1993
B, IRL: 1995
NL: 1996
Labour force, A: 1995
Statistical data: Eurostat Database: ZRD2
© MEGRIN GIE 1999, for the administrative boundaries
Cartography: Eurostat –GISCO, 11/2000
0
150
750 km
AÇORES
P
MADEIRA
P
CANARIAS
E
GUADELOUPE
F
MARTINIQUE
F
REUNION
F
GUYANE
F
eurostat

Map 3.4.

Fig. 3.30., 3.31.

Commitments to R&D for all sectors 1985 and 1998



Source: Eurostat.

Source: Eurostat.

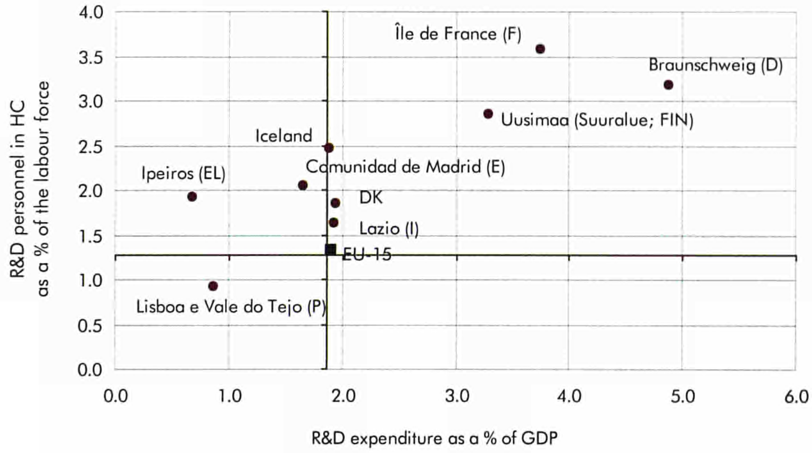
Methodological notes

Exceptions to the reference periods for Figures 3.30. and 3.31.:

- **Reference period 1985**
  P: 1986;
  FIN and S: 1987;
  E: 1988
  A and EL: 1989;
  F: 1991.
- **Reference period 1998**
  A and UK: 1993;
  B and IRL: 1995;
  F, EL, I, NL, NO and P: 1997.

Fig. 3.32.

Regions with a high commitment to R&D by country for all sectors 1997



Source: Eurostat.

Methodological note

Exception to the reference period:

- Lazio (I): 1996.

The overall commitment to R&D

The term 'overall commitment to R&D' covers expenditure on R&D as a percentage of GDP and R&D personnel as a percentage of the economically active population. The results are given for 1985 and 1998 in order to identify how these two indicators change in each country in the medium term (17). The results for all sectors as a whole are also given at the regional level and for the highest performing region in each country.

The overall commitment in all sectors

The figures 3.30. and 3.31. summarise the results presented in the preceding sections. There was little change at the EU-15 level between 1985 and 1998. Four countries (Denmark, Finland, Iceland and Sweden) increased their R&D commitments considerably above the average European levels of R&D expenditure and personnel (18). Iceland also stands out by virtue of its particularly high level of R&D personnel by comparison with its expenditure.

On the other hand, countries with limited R&D commitments (Greece, Spain, Ireland and Portugal) came considerably closer to the European averages.

Of the countries making the largest commitment to R&D by volume, France, Italy and the United Kingdom remained stable, while Germany recorded a relatively substantial reduction.

The commitment to R&D of the dominant regions in each country in the EU-15 in 1997 (19)

The disparities between countries, and between regions in particular, remain when the regions with the heaviest commitment to R&D activities in each country are compared.

The differences between the dominant regions are still substantial: more than 2 points for R&D personnel as a percentage of the labour force, and 4 points for expenditure on R&D as a percentage of GDP between Lisboa e Vale do Tejo (P) and Braunschweig (D).

Furthermore, only four regions (20) out of nine show an overall commitment to R&D above the level achieved for the EU-15 in 1998.

R&D intensity and GDP growth

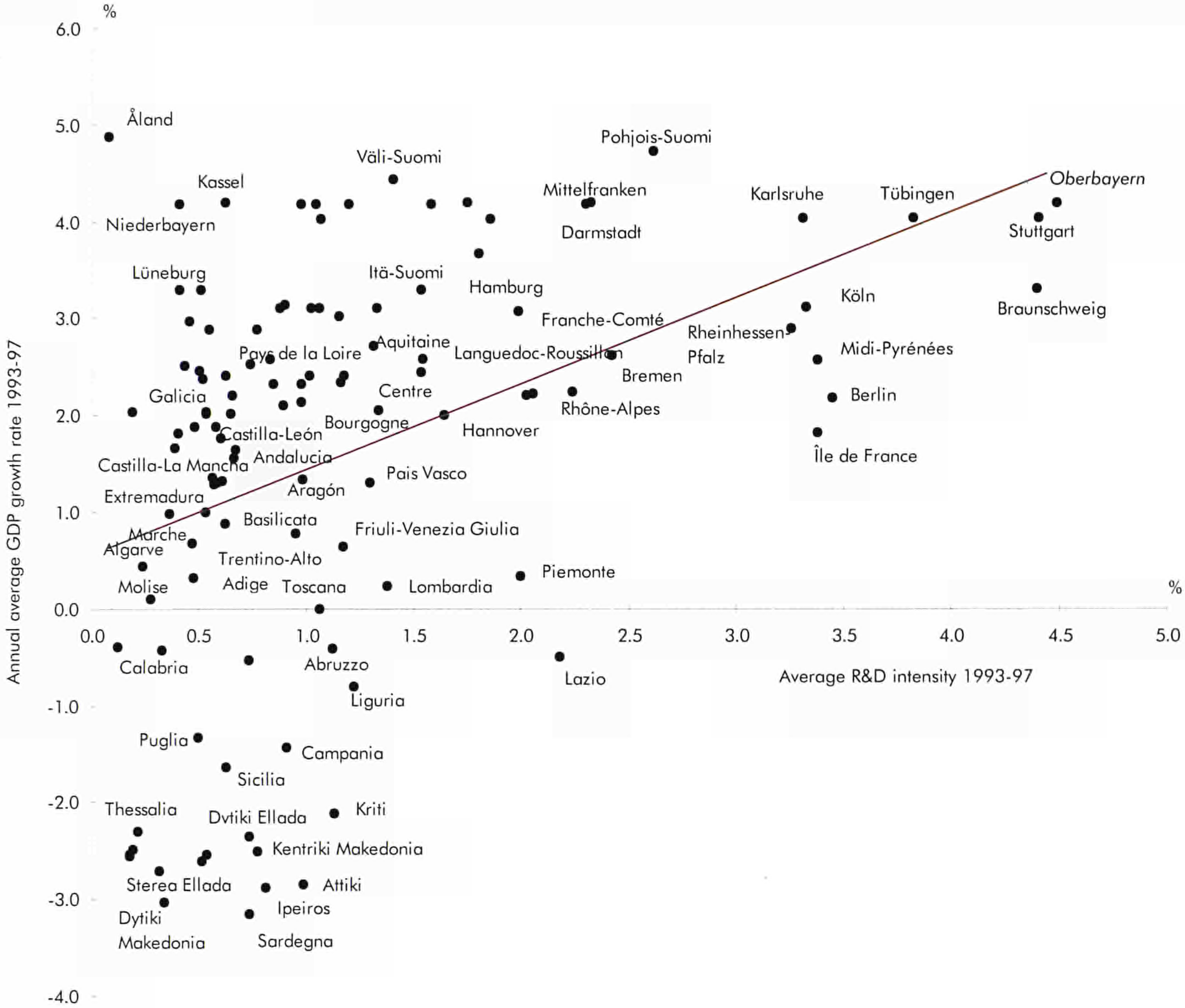
Figures 3.33. shows the average intensity of R&D as a percentage of GDP (21) compared to the average annual growth rate of GDP over the period 1993-97 ($R^2 = 0.17$). Several regions in Germany, including Upper Bavaria, Stuttgart, Braunschweig and Tübingen combine very intensive R&D and a very high annual GDP growth rate.

Most European regions show positive values for these two indicators. Thus, most regions with an average annual GDP growth rate of more than 1 % demonstrate average R&D intensity of more than 0.5 %. On the other hand, it is interesting to note that R&D remains above a certain threshold in spite of negative year-on-year GDP growth rates.

(17) Insofar as data are available.
(18) The data for 1985 are not available.
(19) Countries for which regional data are available.
Including Denmark, which Eurostat classifies at NUTS level 2.
(20) Excluding Denmark and Iceland.
(21) The average R&D intensity is the ratio between the average R&D expenditure over the period 1993-97 and the average GDP over the equivalent period.

Fig. 3.33.

R&D intensity and GDP growth by selected regions
1993-97



Source: Eurostat.

Methodological notes

- **Reference periods** for countries for which regional data at NUTS level 2 are available:
  D: 1995-97 (except Berlin, Bremen and Hamburg: 1993-97);
  EL: 1993-97;
  E: 1993-97;
  F: 1993-97;
  I: 1994-96;
  P: 1992-97;
  FIN: 1995-97.
- **Reference units**
  R&D expenditure: expenditure in PPS at 1990 prices;
  GDP: PPS (constant).

Notice to the reader

The periods under analysis presented in this chapter were chosen according to availability. Whenever possible, data included in the time series cover the period 1985 to 1998.

For the analysis, the general aim was to keep the year that ensured the greatest degree of harmonisation between countries. For this reason it was not possible in some cases to present all the data for all countries. The complete data time series are available from Eurostat on the New Cronos database.

General remark for this chapter

- Data for both R&D expenditure and personnel are estimated for EU-15 and EEA.
- 1998 data for the US are provisional.

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European patent applications

CHAPTER 4

INTRODUCTION

This chapter analyses the technological situation of the Member States and regions of the European Union on the basis of patents, which serve as indicators of the level of innovative activity. The state of technological activity is described using temporal criteria (evolution of indicators), thematic criteria (patent density, specialisation etc.) and geographical criteria (EU, country, region).

The basic data on applications for European patents which are used in this study are taken from the European Patent Office (EPO) database and relate to the period 1989-98. A European patent can be applied for through European channels or via the Euro-PCT (Patent Co-operation Treaty) (1). Patent applications filed through the Euro-PCT are published by the EPO 18 months after the priority date. For this reason, data for 1998 are to be considered provisional.

The first section of this chapter outlines the main developments in patents as indicators of innovative activity. The second section describes technological activity in Europe and in the various EU Member States. Using the indicators developed, it is possible to monitor the position of the EU relative to Japan and the United States, and also the position of the individual Member States. The third section highlights the disparities in technological activity between European regions.

(1) For more information on patent application procedures, see OECD, *The Measurement of Scientific and Technological Activities: Using Patent Data as Science and Technology Indicators — Patent Manual*, 1994, pp. 18-25, OECD.

4.1. PATENT INDICATORS

A patent is a public title of industrial property conferring on its owner the exclusive right to use his invention for a limited number of years. The patent applies to an invention i.e. a new solution to a technical problem which satisfies the criteria of novelty, inventiveness and industrial applicability.

The use of patents as an indicator of technological activity has been widely discussed in the literature (for example: Pavitt, 1988; Griliches, 1990; OECD, 1994). These indicators are alternatives to direct measurements of the output of scientific and technological research activity. They do, however, have certain advantages and disadvantages which need to be highlighted.

Advantages and disadvantages

Patent data have a number of advantages which make them good indicators for analysing technological activity. As well as being available over long periods of time, patents generally cover almost every field of technology and embrace a global geographical area. Given the highly detailed information in patent documents, it is possible to categorise patents according to various criteria.

The limitations of the patent as an indicator of technological activity are also discussed in the literature (Basberg, 1987). Not every patent gives rise to an innovation. Not all patents are of equal value and they do not all reach the market. There are, in particular, marked disparities between the various procedures for using technologies in industry: firms do not all patent according to the same system and they differ in their propensity to apply for patents (Scherer, 1983). This propensity also varies according to the area of technology, reflecting sectoral differences in the relative importance attached to the filing of patents as a form of protection against imitation, as compared with other types of ownership.

Indicators

Patent data can be used in two ways which are not necessarily mutually exclusive. The first approach, which is essentially quantitative, considers the patent as the output of a knowledge production function. In this context, R&D expenditure is an important explanatory variable (cf. Licht and Zoz, 1998). The second approach is to regard the patent as an indicator of technological skills. According to the manner in which patents are classified, simple counting is the most elementary indicator. Hence, the number of patent applications filed by an economy, the evolution in the number of applications over time and the relative proportions of the various technological fields, allow a characterisation of the technological activity of the economy in question.

On the basis of the classification of patent applications adopted by the International Patent Classification (IPC) (2), it is possible to determine technological specialisation indicators. The first indicator is the specialisation index. This measures the performance of an economy in a particular IPC section in relation to its overall performance (see 'Methodology' Section, p. 88). For any given IPC section, an index greater than 1 means that the economy is specialised (relative strength). Conversely, the closer the index is to zero, specialisation decreases (relative weakness).

In order to analyse sectoral strengths and weaknesses, it is necessary to describe how the economies spread or concentrate their technological activities. This behaviour can be described using the degree of specialisation (Archibugi and Pianta, 1992). This indicator is derived by comparing the structure of the technological activities of one economic unit with the structure of all units as a whole (see 'Methodology' Section, p. 88). Thus, if an economy has the same distribution as that of all of its constituent units, its degree of specialisation is zero. The indicator increases where an economy shows evidence of strengths or weaknesses in its technological activities.

Data on the number of patent applications can be related to other economic or institutional variables, such as population, employment, GDP, R&D expenditure and so on, allowing the data to be expressed in terms of density. This provides indicators independent of the size of economic units and thus allows a comparison of the inventive capacity of the various units.

4.2. CHARACTERISATION OF TECHNOLOGICAL ACTIVITIES IN THE EUROPEAN UNION

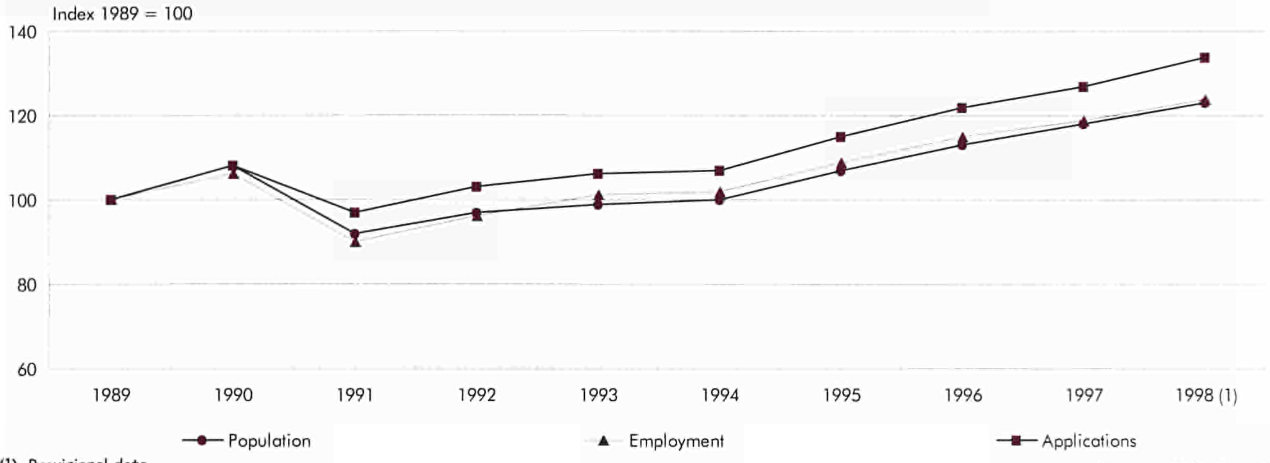
Europe

An analysis of the evolution in applications for European patents in the EU between 1989 and 1998 reveals an annual average increase of 3.2 %. Densities in relation to population and employment (3), which were lower than the 1989 level during the period 1991-93, have shown a regular positive evolution since 1994 (see Figure 4.1.).

(2) The IPC, which entered into force in 1975, is a system for classifying inventions. It is based on the criteria of 'application' and 'function'. The first criterion is used for an invention where the use described is specific to an industrial activity and the 'function' criterion is used when the invention involves a number of industries. The IPC is structured hierarchically into several levels: 8 sections, 118 classes, 620 subclasses, and 66 000 groups and subgroups.

(3) Calculations of densities in relation to employment do not include Austria, Finland and Sweden for 1989-94.

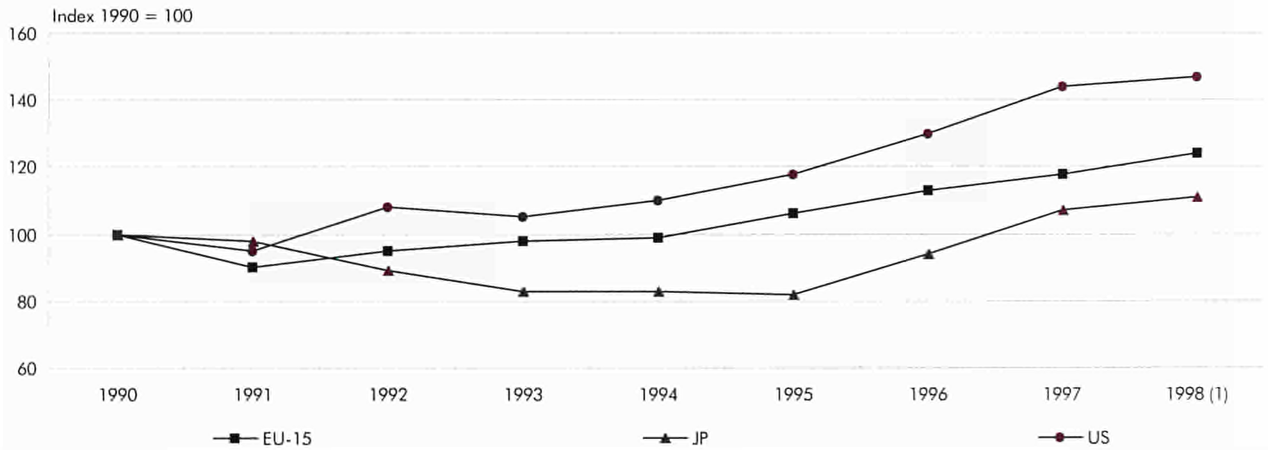
Fig. 4.1. Index of growth in applications for European patents and their density in relation to population and employment in the European Union — 1989-98



(1) Provisional data.

Sources: EPO, Eurostat.

Fig. 4.2. Evolution in applications for European patents European Union, Japan and United States — 1990-98



(1) Provisional data.

Sources: EPO, Eurostat.

Tab. 4.1. Applications for European patents by IPC section — European Union, Japan and United States Averages for 1990-98

IPC section	Annual average growth rate %			Average proportion %		
	EU-15	JP	US	EU-15	JP	US
A Human necessities	3.3	3	6.3	15	8	14
B Performing operations; transporting	2	1.5	6.1	23	16	16
C Chemistry; metallurgy	0	- 1.1	2.7	17	19	24
D Textiles; paper	0.6	0.2	3.7	3	1	2
E Fixed constructions	2.2	- 3	7	5	1	2
F Mechanical engineering; lighting; heating; etc.	2.8	5.7	4.8	10	6	7
G Physics	2.8	- 1	1.2	13	25	18
H Electricity	6.3	4.2	8.7	14	23	18
Total	-	-	-	100	100	100

Sources: EPO, Eurostat.

In 1998, 82 969 EPO patent applications were filed by Europeans, Japanese or Americans. The EU predominates with 48 % of applications. Japan and the United States account for 18 and 34 % respectively. Relative to 1990, when 64 838 patents were applied for, the shares of the EU and Japan have fallen by 2 and 3 points respectively to the benefit of the United States. This is explained by vigorous growth in the number of applications filed by the United States, which averaged 4.8 % between 1990 and 1998 as against 2.7 and 1.3 % respectively for Europe and Japan (see Figure 4.2.).

A breakdown by IPC section shows that certain activities predominate (see Table 4.1.). Chemistry and metallurgy, Physics and Electricity together account for 44 % on average of all EU applications. These same sections account for 60 % and 67 % of applications from the United States and Japan. The strongest growth in the number of applications filed is found in the Electricity section, where the share of patents rose by four points for Europe and by six points for Japan and the United States between 1990 and 1998. Chemistry and metallurgy, on the other hand, fell by four points for all three during the same period.

EU countries

Within the EU, Germany, France and the United Kingdom predominate with a combined average of 72 % of patent applications between 1989 and 1998, despite growth levels below the European average (see Table 4.2.). Germany and France saw their share fall slightly, whereas for the United Kingdom the fall was more pronounced, down from 15.2 % in 1989 to 12.1 % in 1998. The strongest growth was seen in Ireland, Spain, Finland and Greece, where the percentage of applications doubled in the space of ten years.

Data on patents are related to population and employment, in millions and as an index (EU-15 = 100) respectively, in order to compare indicators of technological activity which are independent of the size of the country. From the indicators obtained it is possible to distinguish four groups of countries (see Table 4.2.). The first group comprises Germany, the Netherlands, Finland and Sweden and is characterised by technology densities that are well above the European average. Denmark, France, Luxembourg and Austria constitute the second group, in which densities are level with the European average. The third group consists of Belgium and the United Kingdom, with densities slightly below the European average, plus Italy and Ireland, which have significantly lower densities. Greece, Spain and Portugal make up the last group, which is characterised by extremely low technology densities.

An examination of the technological specialisation indices by IPC section shows that the leading countries in terms of the number of patent applications filed, i.e. Germany, France and the United Kingdom, spread their technological activities uniformly among the various IPC sections. In these countries, the indices are between 0.67 and 1.31 and the levels of specialisation, measured by the degree of specialisation, are the lowest (see Table 4.3.). Conversely, the concentration of technological activities within a small number of IPC sections is particularly marked in Greece, Luxembourg, Portugal and Finland, where the indices vary between 0.22 and 3.27 and the levels of specialisation are at their highest. In between these two groups, specialisation indices range from 0.36 to 1.87 for Belgium, Denmark, Spain, Ireland and the Netherlands.

Tab. 4.2.

Indicators of technological activity by country
Averages for 1989-98

	Number of patents 1998 (1)	Annual average growth rate %	Average proportion %	Technology densities Population (2)	(3)	Employment (4)	(5)
EU-15	40 025	3.2	100.0	88	100	222	100
B	1 106	6.7	2.5	79	90	219	98
DK	629	4.9	1.6	101	115	206	93
D	17 090	3.1	41.5	176	199	399	180
EL	50	9.1	0.1	4	4	10	5
E	618	11.3	1.2	10	11	32	14
F	6 227	2.4	16.5	94	106	247	111
IRL	144	11.7	3.1	27	30	82	37
I	3 104	4.2	7.8	44	50	125	56
L	48	4.1	0.1	88	100	224	101
NL	2 167	2.9	5.5	116	132	274	123
A	997	3.7	2.3	94	107	224 (a)	92 (a)
P	20	7.8	0.0	1	2	3	1
FIN	998	10.3	2.1	132	150	432 (a)	178 (a)
S	1 977	6.3	4.5	162	184	478 (a)	196 (a)
UK	4 850	0.7	13.8	78	89	174	79

(1) Provisional data.
(2) Per million inhabitants; average 1989-96.
(3) Densities are calculated from base EU-15 = 100; average 1989-96.
(4) Per million employed persons; average 1989-97.
(5) Densities are calculated from base EU-15 = 100; average 1989-97.
NB: '(a)': densities in relation to employment are determined for the period 1995-97 in these countries.

Sources: EPO, Eurostat.

Tab. 4.3.

Specialisation indices and degree of specialisation of technological activities by country
Averages for 1989-98

	Specialisation indices A	B	C	D	E	F	G	H	Degree of specialisation
EU-15	1.23	1.00	0.99	1.13	1.16	0.95	0.87	0.85	19
B	0.90	0.78	1.82	1.41	0.76	0.46	1.13	0.75	19
DK	1.74	0.88	1.20	0.79	1.16	0.97	0.64	0.49	16
D	0.78	1.11	1.06	0.98	1.01	1.13	0.93	0.95	2
EL	1.62	0.96	0.84	0.60	1.86	1.35	0.72	0.37	32
E	1.64	1.06	0.90	1.19	1.24	0.94	0.63	0.60	13
F	1.10	0.89	0.88	0.71	0.94	1.01	1.13	1.17	2
IRL	1.87	0.80	0.72	0.36	0.59	0.56	1.31	0.98	23
I	1.26	1.18	0.80	1.78	1.02	0.96	0.76	0.78	6
L	0.42	1.66	1.31	1.57	1.56	1.21	0.50	0.22	49
NL	1.08	0.74	1.12	0.42	0.87	0.59	1.22	1.44	9
A	1.08	1.15	0.87	1.13	1.78	1.20	0.68	0.70	8
P	1.82	0.87	0.99	0.68	1.49	1.05	0.56	0.63	61
FIN	0.71	0.95	0.67	3.27	1.06	0.73	0.78	1.72	33
S	1.23	1.11	0.50	1.35	1.19	1.17	0.82	1.04	10
UK	1.17	0.79	1.11	0.67	0.90	0.85	1.31	0.94	4

NB: A specialisation index higher than 1 means that the country is specialised in the specific IPC section (relative strength); where the index is closer to zero, the country has relative weaknesses in the section.
A high (low) degree of specialisation denotes a concentration (diversification) of technological activities in a small number of sections.

- Section A: human necessities
- Section B: performing operations; transporting.
- Section C: chemistry; metallurgy.
- Section D: textiles; paper.
- Section E: fixed constructions.
- Section F: mechanical engineering; lighting; heating; weapons; blasting.
- Section G: physics.
- Section H: electricity.

Sources: EPO, Eurostat.

Tab. 4.4.

European regions with high technological activity
Averages for 1989-98

Region	Country	Number of patents 1998 (2)	Proportion % (3)	Technological densities (1) in relation to: Population	Employment	European ranking (4)
EU-15		40 025	100.00	100	100	-
Oberbayern	D	2 082	5.14	493	392	1
Darmstadt	D	1 289	3.70	384	330	2
Stuttgart	D	1 812	3.96	367	317	3
Rheinhessen-Pfalz	D	694	1.84	346	318	4
Freiburg	D	754	1.94	350	302	5
Noord-Brabant	NL	809	2.02	327	303	6
Stockholm	S	678	1.44	291	313 (b)	7
Karlsruhe	D	855	2.21	318	277	8
Tübingen	D	598	1.40	308	264	9
Düsseldorf	D	1 233	3.57	257	249	10
Köln	D	1 011	2.81	258	243	11
Île de France	F	2 482	6.84	238	216	12
Vorarlberg	A	114	0.21	215	204 (b)	13
Brabant Wallon	B	70	0.17	192	219 (a)	14
Schwaben	D	438	1.05	229	190	15
Koblenz	D	182	0.76	223	192	16
Sydsverige	S	276	0.64	180	211 (b)	17
Berkshire, Bucks & Oxfordshire	UK	409	1.14	214	163 (c)	18
Rhône-Alpes	F	1 054	2.69	180	182	19
Unterfranken	D	334	0.71	192	171	20
Cheshire	UK	150	0.49	194	153 (c)	21
East Anglia	UK	424	1.05	185	157	22
Östra Mellansverige	S	324	0.70	162	175 (b)	23
Mittelfranken	D	570	0.93	169	158	24
Vlaams Brabant	B	192	0.42	149	167 (a)	25
Antwerpen	B	237	0.67	151	161	26
Gießen	D	202	0.47	164	155	27
Pohjois-Suomi	FIN	119	0.21	128	198 (b)	28
Hamburg	D	313	0.72	152	136	29
Alsace	F	247	0.65	148	139	30

(1) Densities are calculated on base EU-15 = 100 for the period 1989-98 except for:
(a) 1993-97,
(b) 1995-97 and
(c) 1996.
(2) Provisional data.
(3) Average European share.
(4) The European classification is determined on the basis of the minimum rankings in terms of densities in relation to population and employment respectively.

Sources: EPO, Eurostat.

4.3. CHARACTERISATION OF TECHNOLOGICAL ACTIVITIES IN EUROPEAN REGIONS

This section compares the structure of technological activities measured on the basis of patents in 228 European regions (4) at NUTS 2 level, from 1989 to 1998.

Indicators of technological activities in the European regions

Table 4.4. shows the first 30 regions classified according to technological density indicators, in relation both to population and employment, and expressed relative to the European average (EU-15 = 100). Over 50 % of patent applications were concentrated in these regions between 1989 and 1998. They include 15 German regions and 3 regions from Belgium, France, Sweden and the United Kingdom. The Netherlands, Austria and Finland each account for one region.

As regards technological activity in relation to population and employment respectively, German regions are dominant: 9 regions have technological densities of at least twice the European average. In amongst them are Noord-Brabant (NL) and Stockholm (S). The Île de France (F) region, despite being extremely active in terms of patent applications and leading the European regions with 6.84 % of patent applications per year on average — is still only in 12th place. On the other hand, the Vorarlberg (A) region is in 13th position despite the fact that its activity in terms of absolute number of patent applications is low. The regions that are developing most strongly are Mittelfranken (D), Pohjois-Suomi (FIN), Vorarlberg (A), Unterfranken (D) and Vlaams Brabant (B).

An analysis of the applications for patents relative to the labour force (in millions) for 1997 reveals densities that are higher than the European average (227 patents per million labour force] in 56 regions (see Map 4.1.). Of these regions, 20 have densities in excess of 400 and most of these are German regions. Indeed, the first four places are taken by Stuttgart (892), Oberbayern (884), Rheinhessen-Pfalz (835) and Freiburg (764). Following them, three Swedish regions occupy 5th, 16th and 19th place respectively: they are Stockholm (760), Sydsverige (476) and Östra Mellansverige (433). Two Dutch regions — Noord-Brabant (715) and Limburg (405) — are in 7th and 20th position. Lastly, the regions Vorarlberg (A) and Île de France (F), with 570 and 438 patent applications per million of active population respectively, are relegated to 11th and 18th place.

Regions with densities between the European average and 400 applications per million of active population include: Vlaams Brabant (395) and Antwerp (392) for Belgium, Berkshire-Bucks & Oxfordshire (381) and East Anglia (380) for the United Kingdom (5), Pohjois-Suomi (378) for Finland, Lombardia (266) and Friuli-Venezia Giulia (263) for Italy.

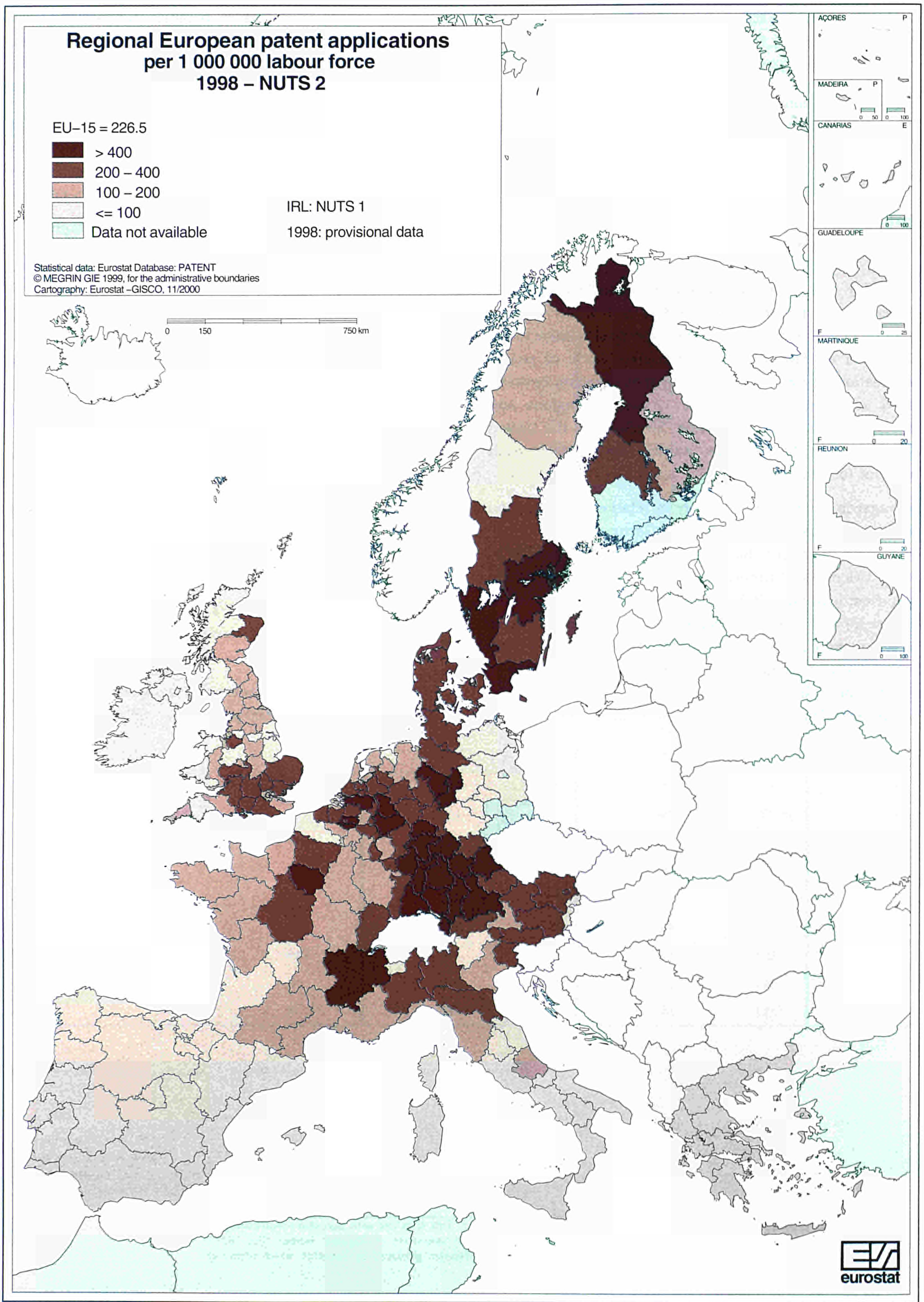
Finally, all Spanish, Greek and Portuguese regions have densities of less than 100 patents per million labour force.

(4) The regional breakdown of patents is based on the address of the inventor. This is in line with Eurostat's methodological recommendations of 1996, *The regional dimension of R&D statistics and innovation — Regional manual*. The NUTS (Nomenclature of Territorial Units for Statistics) is a hierarchical classification produced by Eurostat, which starts at country level (NUTS 0) and goes down to municipality level (NUTS 5).

(5) The densities for UK regions are calculated for 1996.

CHAPTER 4

Map 4.1.



Strengths and weaknesses of technological activities in the European regions

A study of the specialisation indices shows that textiles and paper, chemistry and metallurgy, and electricity figure most prominently as both strong sections (18 regions) and weak sections (23 regions) in the most active European regions (see Table 4.5.).

Specialisation is particularly pronounced in the regions of Pohjois-Suomi (FIN) and Noord-Brabant (NL) in the electricity section; Tübingen (D), Schwaben (D) and Alsace (F) in the textiles and paper section Rheinhessen-Pfalz (D), Brabant-Wallon (B), Vlaams-Brabant (B) and Cheshire (UK) in the chemistry and metallurgy section; Stuttgart (D) for mechanical engineering; Koblenz (D) for fixed constructions and Antwerp (B) in the physics section. Conversely, the lowest levels of specialisation are found in the Stuttgart region (D) in chemistry and metallurgy; Rheinhessen-Pfalz (D) in the electricity section and East Anglia (UK) and Antwerp (B) in the textiles and paper section.

The degrees of technological specialisation point to a diversification of technological activity especially in the regions of Karlsruhe (D), Freiburg (D), Rhône-Alpes (F) and Île de France (F).

Conversely, the concentration of technological activities is particularly strong in Pohjois-Suomi (FIN), Rheinhessen-Pfalz (D), Noord-Brabant (NL) and Brabant-Wallon (B). However, the concentration is decreasing in these regions, with the exception of Pohjois-Suomi (FIN) and, to a lesser extent, Brabant-Wallon (B).

Table 4.6. shows the five most active regions for each Member State of the EU. It is evident that regional disparities in technological activities are still important, particularly in Belgium, France, the Netherlands, Austria, Finland and Sweden, when it comes to the ranking of the first to the fifth regions. However, despite the relative under-performance of Spanish and Italian regions overall, the disparities there are less pronounced. Lastly, the Greek and Portuguese regions are characterised by the highest levels of specialisation, a feature which points to a strong concentration of technological activities.

Tab. 4.5. Strengths and weaknesses of the European regions with high technological activities
Averages for 1989-98

Region	Country	Strengths IPC section	Strengths Specialisation index	Weaknesses IPC section	Weaknesses Specialisation index	Degree of specialisation
Oberbayern	D	H	1.89	D	0.52	23.18
Darmstadt	D	C	1.78	H	0.60	15.79
Stuttgart	D	F	2.06	C	0.17	34.17
Rheinhessen-Pfalz	D	C	3.15	H	0.24	99.00
Freiburg	D	D	1.23	C	0.83	4.30
Noord-Brabant	NL	H	3.02	D	0.33	92.33
Stockholm	S	H	1.75	C	0.56	21.36
Karlsruhe	D	B	1.14	D	0.53	4.15
Tübingen	D	D	2.36	C	0.38	23.44
Düsseldorf	D	C	1.96	H	0.37	30.19
Köln	D	C	1.90	H	0.55	20.91
Île de France	F	G	1.41	D	0.27	9.01
Vorarlberg	A	E	1.83	C	0.34	36.16
Brabant Wallon	B	C	2.81	F	0.46	76.18
Schwaben	D	D	2.34	C	0.50	24.04
Koblenz	D	E	2.13	H	0.34	27.99
Sydsverige	S	A	1.61	D	0.55	18.49
Berkshire, Bucks & Oxfordshire	UK	G	1.53	D	0.27	15.88
Rhône-Alpes	F	D	1.65	F	0.70	7.41
Unterfranken	D	B	1.53	G	0.52	17.33
Cheshire	UK	C	2.04	F	0.47	33.16
East Anglia	UK	G	1.80	D	0.07	24.86
Östra Mellansverige	S	F	1.49	D	0.47	14.46
Mittelfranken	D	H	1.66	C	0.37	26.88
Vlaams Brabant	B	C	2.48	F	0.41	49.31
Antwerpen	B	G	2.48	D	0.25	44.82
Gießen	D	E	1.58	D	0.69	16.91
Pohjois-Suomi	FIN	H	3.97	A	0.39	190.50
Hamburg	D	H	1.48	D	0.31	15.78
Alsace	F	D	2.11	F	0.52	17.91

NB: An index greater than 1 means that the region is specialised in the corresponding sections (relative strength); when the index tends towards zero, the region has relative weaknesses.
A high (low) degree of specialisation denotes a concentration (diversification) of technological activities in a small number of section.

- Section A: human necessities.
- Section B: performing operations; transporting.
- Section C: chemistry; metallurgy.
- Section D: textiles; paper.
- Section E: fixed constructions.
- Section F: mechanical engineering; lighting; heating; weapons; blasting.
- Section G: physics.
- Section H: electricity.

Sources: EPO, Eurostat.

Tab. 4.6. Strengths and weaknesses of technological activities for the top five regions per country
Averages for 1989-98

	Region	European ranking ([1])	Strengths	Weaknesses	Degree of specialisation		Region	European ranking ([1])	Strengths	Weaknesses	Degree of specialisation
B	Brabant Wallon	14	C	F	76	I	Lombardia	45	D	E	5
	Vlaams Brabant	25	C	F	49		Emilia-Romagna	56	B	H	30
	Antwerpen	26	G	D	45		Friuli-Venezia Giulia	61	D	C	66
	Reg. Bruxelles Cap.	53	C	F	51		Piemonte	64	B	C	18
	Liège	66	C	H	60		Veneto	67	A	H	30
DK	Københavns amt	-	C	F	43	NL	Noord-Brabant	6	H	D	92
	Frederiksborg amt	-	A	D	29		Limburg	46	C	H	47
	Københavns O. F. K.	-	C	H	28		Zuid-Holland	47	A	D	26
	Århus amt	-	A	H	40		Overijssel	50	F	D	9
	Roskilde amt	-	E	H	47		Gelderland	54	E	H	9
D	Oberbayern	1	H	D	23	A	Vorarlberg	13	E	C	36
	Darmstadt	2	C	H	16		Oberösterreich	41	D	H	31
	Stuttgart	3	F	C	34		Wien	52	E	D	13
	Rheinhessen-Pfalz	4	C	H	99		Steiermark	55	E	H	9
	Freiburg	5	D	C	4		Tirol	65	F	D	20
EL	Attiki	75	E	H	55	P	Lisboa E. Vale do Tejo	79	A	H	83
	Kriti	76	G	(a)	281		Alentejo	80	H	(a)	525
	Dytiki Ellada	77	E	D	394		Algarve	82			(a)
	Kentriki Makedonia	78	A	G	233		Norte	83	E	H	161
	Dytiki Makedonia	81	D	(a)	1 363		Madeira	84	F	(a)	628
E	Cataluña	70	D	G	23	FIN	Uusimaa	-	D	F	27
	Comunidad Foral de Navarra	71	G	D	57		Etelä-Suomi	-	D	C	39
	Comunidad de Madrid	72	A	D	18		Pohjois-Suomi	28	H	A	191
	Pais Vasco	73	E	H	45		Väli-Suomi	62	D	C	371
	Comunidad Valenciana	74	A	H	66		Itä-Suomi	69	D	H	57
F	Île de France	12	G	D	9	S	Stockholm	7	H	C	21
	Rhône-Alpes	20	D	F	7		Västsverige	-	D	C	22
	Alsace	30	D	F	18		Sydsverige	17	A	D	18
	Bourgogne	58	B	D	13		Östra Mellansverige	23	F	D	14
	Franche-Comté	59	E	D	32		Norra Mellansverige	31	D	C	75
IRL	Dublin	-	A	D	39	UK	Berkshire, Bucks & Oxfordshire	18	G	D	16
	Mid East	-	A	C	128		Cheshire	21	C	F	33
	Mid West	-	H	D	240		East Anglia	22	G	D	25
	South West	-	D	B	191		Bedfordshire, Hertfordshire	32	A	D	24
	South East	-	A	E	129		Gloucestershire, Wiltshire	35	G	D	28

([1]) The European classification is determined on the basis of the minimum rankings in terms of density in relation to population and employment respectively. (-) Densities are not calculated for these regions because data for population and persons employed are not available on a regionalised basis. The regions shown are those which are most active in terms of patent applications.

NB: '(a)' A number of sections have specialisation indices equal to their overall specialisation — see Table 4.5. for the definition of the sections.

Sources: EPO, Eurostat.

4.4. Methodology

Specialisation index

Let n_{ij} denote the number of patent applications filed by the i-th economic unit in the technological section j, and $n = \sum_i \sum_j n_{ij}$ is the total number of applications; then

$n_i = \sum_j n_{ij}$ is the total number of patent application in the i-th economic unit;

$n_j = \sum_i n_{ij}$ is the number of patent application in section j in the overall economy;

$d_{ij} = \frac{n_{ij}}{n_j}$ is the share of patents applied for by this economic unit in section j over the total of section applications (weight of i-th economic unit in the technological section j);

$d_i = \frac{n_i}{n}$ is the share of patents applied for by this economic unit over the total number of applications (weight of the economic unit in the whole economy).

The technological specialisation index (6) IS_{ij} of the i-th economic unit in the technological section j is defined as the ratio between the percentage share of patents applied for by this economic unit in section j (d_{ij}) and the percentage share of patent applications filed for all sections by the economic unit:

$$IS_{ij} = \frac{d_{ij}}{d_i} = (n_{ij} / \sum_i n_{ij}) \, / \, (\sum_j n_{ij} / \sum_i \sum_j n_{ij}).$$

This index has the property of being equal to 1 if the economic unit holds the same share in the j-th section as in the total of the economy's patents. It is below (respectively, above) 1 if there is a relative weakness (respectively, strength) in the j-th technological section.

Degree of specialisation

The degree of technological specialisation is a general indicator of *technological concentration* of an economic unit. For the i-th economic unit, it indicates if the distribution of its technological activities among the various sections is similar to the distribution of the whole economy. A measure proposed by Archibugi and Pianta (7) is obtained by analogy with the chi-square statistics: it is denominated *degree of specialisation*, DS_i. Let $p_{ij} = n_{ij} / n$ be the percentage of patents applied for the section j by the i-th economic unit, and $p_j = n_j / n$ be the percentage of the whole economy patents application for the section j. Then DS_i is calculated by comparing the two percentages according to the formula:

$$DS_i = \sum_j \frac{(p_{ij} - p_j)^2}{p_j}.$$

If an economic unit has the same distribution of technological activities as all units taken as a whole, its DS_i is zero. The greater it differs from the whole economy, the greater the value of DS_i.

(6) Archibugi and Pianta, 1992, p. 50. This index was proposed by Balassa, B., 1965 is known as the 'Technology Revealed Comparative Advantage index', 1992, p. 104 or TRCA.

(7) Archibugi and Pianta, 1992, p. 104.

Notice to the reader

Analyses in this chapter refer to the data on the Eurostat database New Cronos at the time of writing. Because New Cronos is regularly updated as and when new data are received, it may be that data in extractions made or requested subsequently differ somewhat to those available at the time of writing.

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PART 2

PART 2

CHAPTER 5

INTRODUCTION

Innovation is a complex and systemic phenomenon and has until recent years remained insufficiently understood. However, now a substantial body of evidence shows that innovation is a dominant factor in national economic growth and international patterns of trade, with innovation policies today being most of the time a combination of science, technology and industrial policies. The *1997 Oslo Manual* (1) describes innovation as being 'at the heart of a knowledge-based economy', where knowledge in all its forms is seen to play a crucial role in economic processes. One can go to great lengths to describe the innovation process, but for the purposes of the Community Innovation Survey (CIS), technological innovation is defined as: 'the introduction onto the market of a technologically new or significantly improved product or the implementation of a technologically new or significantly improved process' and innovation is said to occur as a result of an interaction between market opportunities and the enterprise's knowledge base and capabilities (2).

The Community Innovation Survey, organised by the European Commission and conducted in 1992, was the first large-scale international survey of innovation, based on the *1992 Oslo Manual* guidelines for collecting and interpreting technological data. Based on the experience gained from the first CIS, the second CIS2 was conducted during 1997/98 in 17 EEA countries. It followed the revised guidelines of the *1997 Oslo Manual*, which had been extended to incorporate survey experience and to cover innovation in a wider range of industries. The focus of CIS2 is mainly on the firm, with emphasis on the innovations in the manufacturing industry. However, it also extends to cover the service sector, which is now considered as the main user of innovation generated from the manufacturing industries (3).

The aim of this chapter is to present some general results produced from CIS2. In terms of coverage, it should be noted that the results presented in this chapter refer to EU-15 countries (excluding Greece) plus Norway. In Table 5.1. and Tables 5.4. to 5.7., the 'Total' figure represents the total for available EU countries. The total for EEA countries with the addition of Norway remains more or less the same as the EU total.

(1) *Proposed Guidelines for Collecting and Interpreting Technological and Innovation Data — Oslo Manual*, Eurostat and OECD, revised version, Paris, 1997.

(2) Archibugi, D., Cohendet, P., Kristensen, A. and Schäffer, K. A., *Evaluation of the Community Innovation Survey — Phase 1*, DG XIII, European Commission, EIMS Publication 11, Luxembourg, 1994.

(3) *Oslo Manual*, p. 44, Section 4.2.3.

5.1. METHODOLOGY

The second Community Innovation Survey (CIS2) was launched in all the EEA countries (except Liechtenstein) in 1997/98 based on the *1997 Oslo Manual*. All the participating countries agreed on a common methodology and a core questionnaire aimed at providing comparable, harmonised and representative data on a pan-European scale. In general, it is either the National Statistical Institute or a Ministry that is directly responsible for the survey at the national level.

This Chapter presents results for the EU countries (excluding Greece): Belgium, Denmark, Germany, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, the United Kingdom as well as Norway for the manufacturing sector. The data for Norway and Portugal refer to 1997, for the other countries the reference year is 1996. The results may deviate from national published results, mainly due to different target populations.

The target population

The statistical unit is the enterprise.

The following economic activities have been included in the target population: all manufacturing industries, electricity, gas and water supply, wholesale trade, transport, telecommunications, financial intermediation, computer and related activities and engineering services. For Spain and Italy, only the manufacturing sector is covered; for France the wholesale sector has not been surveyed. The cut-off point for inclusion in the target population is 20 employees in the manufacturing sector and 10 employees in the service sector. The sampling frames are business registers with as good quality as possible. Official statistical business registers have been used whenever available.

The survey method

A combination of sampling and census has been used; census down to a certain threshold of employees depending upon the country's enterprise population, and sampling for the rest. The samples have been selected by using a simple random selection in each stratum (defined by size class of employees and economic activity based on NACE Rev.1). A full census is applied if the total number of enterprises in the frame population in a particular stratum is less than 5.

The results are based on answers from 39 500 enterprises, thus yielding a response rate of 57 %. Nationally the response rate varies from 24 % to over 90 %.

The results presented are grossed-up figures for the whole population. The weighting factors are based on shares between the number of enterprises in each stratum of the frame population (combined non-response correction and weighting).

A non-response analysis has been carried out whenever the national response rate is below 70 %. In these cases the results of non-response analysis are used in the calculation of weighting factors.

Definitions

Innovation

Innovation is defined as the introduction on to the market of a technologically new or significantly improved product or the implementation of a new or significantly improved process.

Technological innovations

Technological innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes. It requires an objective improvement in the performance of a product or in the way in which it is produced or delivered. An innovation has been implemented if it has been introduced or used on the market.

The following size bands, based on number of employees, have been used to characterise enterprises.

- Manufacturing
  Small: 20 to 49 employees,
  Medium: 50 to 249,
  Large: 250 or more.
- Services
  Small: 10 to 49,
  Medium: 50 to 249,
  Large: 250 or more.

Export intensity

Export intensity has been measured as the ratio of export sales over turnover for 1996.

- The levels of intensities are:
  Low: less than 10 %,
  Medium: between 10 % and 40 %,
  High: above 40 %.

Innovation co-operation

Innovation co-operation means active participation in joint R&D and other innovation projects with other organisations. It does not necessarily imply that both partners derive immediate commercial benefit from the venture. Work which is purely on a contract basis, with no active participation, is not regarded as co-operation.

Patents

Patents are legal documents issued by a national or supranational body (e.g. the European Patent Office). It confers on its holder (the licensor) a monopoly on the invention, on its industrial and commercial use for a limited period (usually ranging from 15 to 20 years) and on a geographical area in which the patent has been requested.

CHAPTER 5

5.2. INNOVATING ENTERPRISES

Innovating enterprise by sector and size class

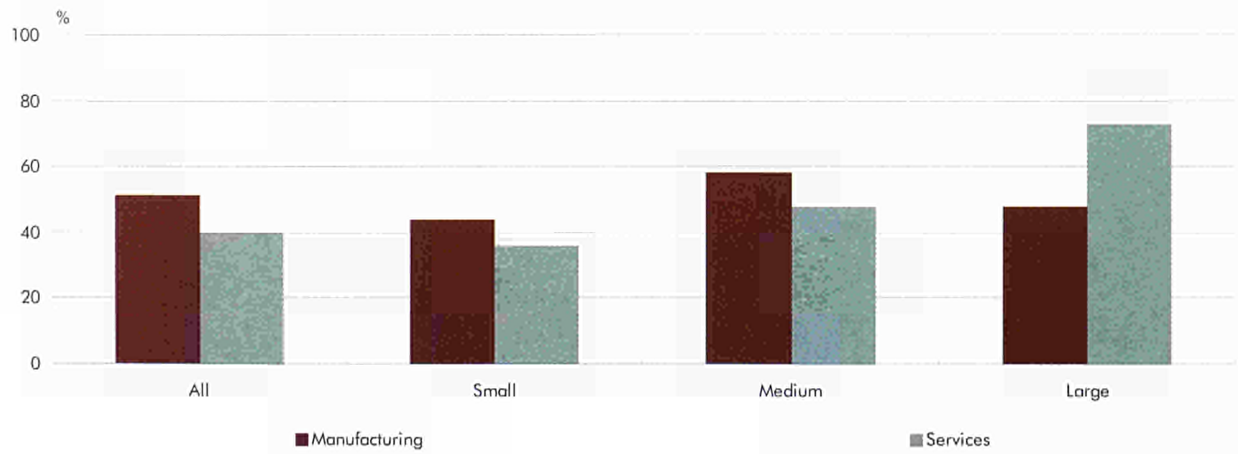
The results of CIS2 show that on average 51 and 40 % of enterprises in the manufacturing and service sectors respectively were innovative in the period 1994-96 (1995-97 for Norway and Portugal). These firms have either introduced a technologically new or improved product or introduced a new or improved technological process in their production system. Countries with the highest proportions of innovating enterprises in the manufacturing sector were Ireland (73 %), Denmark (71 %), Germany (69 %) and Austria (67 %), whereas Portugal (26 %) and Spain (29 %) had the lowest proportions. In the service sector, the countries with the highest proportion of innovators were Ireland (58 %), Austria (55 %), Luxembourg (48 %) and Germany (46 %); the lowest proportions of innovators were Belgium (13 %), Norway (22 %) and Finland (24 %).

The proportion of innovating enterprises increases with size class in both the manufacturing and service sectors. Table 5.1. shows that in the manufacturing sector, on average 79 % of large enterprises were innovative as compared to 58 and 44 % for medium-sized and small enterprises respectively. This general trend holds true for all the countries. However, this increase in the proportion of innovating enterprises from small to large enterprises is more marked in countries with a low proportion of innovating enterprises (Belgium, Spain and Finland). The countries with the highest proportion of innovating enterprises (Denmark, Germany, Ireland and Austria) have relatively high proportions in all three size classes anyway.

In the service sector, 73 % of the large enterprises were innovative compared to only 48 and 36 % in the medium-sized and small size classes. This is illustrated in Figure 5.1.

Comparing the figures by economic activity, it can be seen that the highest proportions of innovators in the manufacturing sector are within activities of Machinery and equipment n.e.c., and Electrical and optical equipment (68 %) followed by Chemicals (56 %). The highest proportion of service innovators was in Computer, engineering and related activities (59 %) whereas the lowest proportion could be found in Transport and Telecommunications (25 %).

Fig. 5.1. Innovating enterprises as a % of total enterprises in manufacturing and service sectors by size class in the European Union — 1996



Source: Eurostat — Community Innovation Survey 1997/98.

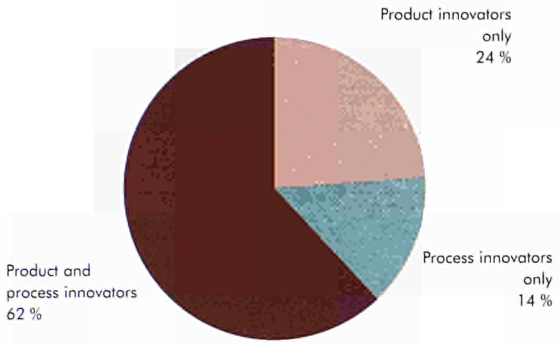
Tab. 5.1. Innovating enterprises (1) as a % of total enterprises in manufacturing and service sectors by country, size class and NACE — 1996

Code	Breakdown	B	DK	D	E	F	IRL	IT	L	NL(2)	A	P	FIN	S	UK	NO	Total
	Manufacturing																
	Total	34	71	69	29	43	73	48	42	62	67	26	36	54	59	48	51
	Size class																
20-49	Small	33	64	63	21	34	68	44	21	54	59	22	26	43	54	39	44
50-249	Medium	34	76	70	43	48	78	57	52	71	73	30	40	61	59	56	58
250+	Large	51	91	85	76	75	85	73	85	84	88	52	77	79	81	77	79
	NACE																
15-19	Food, beverages and tobacco, textile and leather	27	65	66	20	38	62	38	14	56	62	20	30	40	57	47	41
20-22	Wood, pulp and printing	21	70	59	21	32	68	45	43	53	62	23	30	45	51	36	45
23-26	Coke and chemicals, rubber and other non-metallic	39	72	69	40	55	79	48	50	73	50	45	49	58	62	60	56
27-28	Basic and fabricated metals	39	58	59	25	31	69	54	44	53	68	19	31	41	56	48	48
29-33	Machinery and equipment, electrical and optical equipment	47	83	81	50	62	88	59	61	78	83	49	44	74	70	64	68
34-37	Transport equipment, n.e.c. and recycling	30	69	70	30	43	77	51	0	58	82	17	28	58	52	47	51
40-41	Electricity, gas and water distribution	60	49	38	37	24	:	36	:	58	22	36	19	23	65	24	36
	Services																
	Total	13	30	46	:	31	58	:	48	36	55	28	24	32	40	22	40
	Size class																
20-49	Small	11	24	41	:	25	60	:	45	32	54	28	22	29	40	20	36
50-249	Medium	21	45	60	:	33	49	:	55	45	58	27	30	48	37	26	48
250+	Large	55	71	83	:	73	87	:	83	71	74	52	43	45	55	50	73
	NACE																
51	Wholesale trade	10	27	39	:	:	52	:	37	36	58	26	15	29	33	18	34
60-62, 64.2	Transport and telecommunications	9	16	26	:	12	38	:	57	22	54	29	22	20	36	7	25
65-67	Financial intermediation	13	48	69	:	45	67	:	43	40	55	43	28	56	49	44	54
72, 74.2	Computer and related activities; engineering services	42	57	63	:	46	75	:	83	58	41	38	44	50	56	42	59

(1) An innovating enterprise is an enterprise that has introduced new or improved products/processes on the market.
(2) In the Netherlands, medium-sized is defined as 50 to 199, and large is defined as more than 200 employees.

Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.2. Type of innovation by innovating enterprises in the EU — 1996



Source: Eurostat — Community Innovation Survey 1997/98.

Tab. 5.2. Innovating enterprises as a % of total enterprises by innovation type in the EU — 1996

Innovation type	%
Total innovating enterprises	51
Product innovators	44
Innovators with products new to the market	21
Process innovators	39

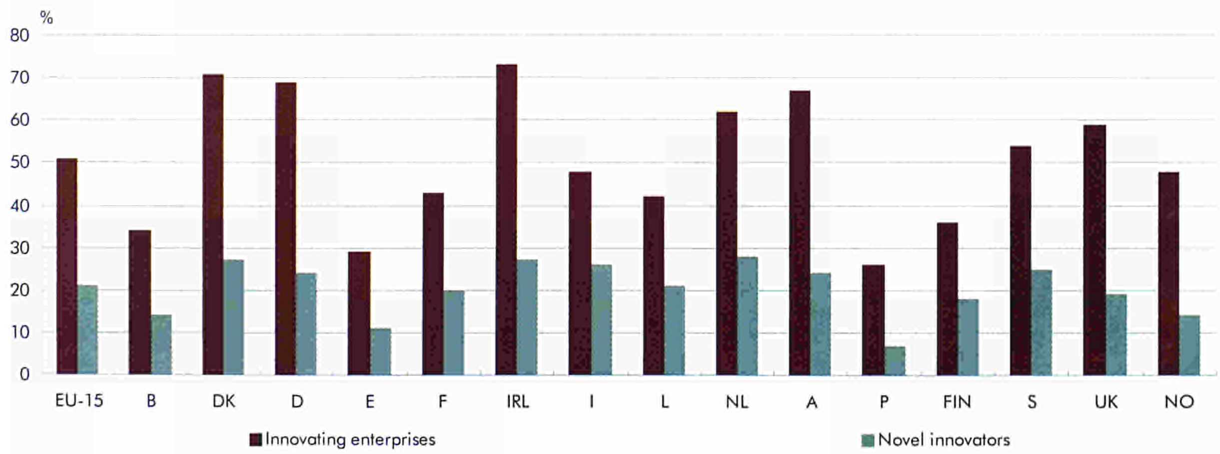
Source: Eurostat — Community Innovation Survey 1997/98.

Tab. 5.3. Novel innovators as a % of total enterprises in the manufacturing sector by NACE in the EU 1996

Code	NACE	%
	Total manufacturing	21
15-16	Food, beverages and tobacco	17
17-19	Textile and leather	13
20-22	Wood, pulp and printing	10
23-24	Coke and chemicals	35
25-26	Rubber and other non-metallic	22
27-28	Basic and fabricated metals	17
29	Machinery and equipment	33
30-33	Electrical and optical equipment	36
34-36	Transport equipment	24
36-37	N.e.c. and recycling	20

Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.3. Innovating enterprises and novel innovators as a % of total enterprises in the manufacturing sector by country — 1996



Source: Eurostat — Community Innovation Survey 1997/98.

In the EU countries, 62 % of innovating enterprises are both product and process innovators (Figure 5.2.); 24 % are product innovators only and 14 % are process innovators only.

Novel innovators in the manufacturing sector

By economic activity

As shown in Table 5.2., among all the enterprises in the manufacturing sector, 44 % developed new products and 39 % developed new processes. Of the enterprises, 21 % were novel innovators, that is, their products were not only new to the firm but also new to the market. The corresponding figure for the service sector is not available.

Examining the data in the manufacturing sector by economic activity (Table 5.3.), the proportion of novel innovators varies widely on average according to economic sector. This ranges from 36 % for the manufacture of Electrical and optical instruments to 10 % in the case of the manufacture of Wood and Paper Products and Publishing, printing and reproduction of recorded media.

By country

Figure 5.3. shows that the share of novel innovators also varies widely at the country level. The lowest proportions of novel innovators are in Portugal (7 %) and Spain (11 %). However at least one in four enterprises is a novel innovator in Sweden (25 %), Italy (27 %), Ireland (27 %), Denmark (27 %) and the Netherlands (28 %).

Tab. 5.4. Novel innovators as a % of total enterprises in the manufacturing sector by country, size class and NACE — 1996

Code	Size class	B	DK	D	E	F	I	IRL	L	NL	A	P	FIN	S	UK	NO	Total
20-49	Small	12	22	19	7	15	23	23	9	21	14	4	12	21	15	8	16
50-249	Medium	13	32	22	17	22	32	28	28	33	31	11	17	24	19	17	23
250+	Large	29	42	46	39	42	50	50	41	53	42	17	46	43	37	37	42
	NACE																
15-16	Food, beverages and tobacco	15	15	17	8	13	28	29	15	24	24	6	15	13	21	11	17
17-19	Textile and leather	10	34	33	5	14	14	11	0	26	17	3	20	18	15	18	13
20-22	Wood, pulp and printing	6	21	8	6	10	18	18	15	14	12	8	9	12	6	5	10
23-24	Coke and chemicals	23	45	28	29	33	40	23	42	43	32	5	43	34	48	25	35
25-26	Rubber and other non-metallic	19	22	23	9	26	27	25	30	31	22	12	23	36	18	16	22
27-28	Basic and fabricated metals	12	26	15	8	14	26	28	9	21	19	8	11	22	15	10	17
29	Machinery and equipment	21	16	39	20	36	42	34	40	47	33	20	23	37	17	24	33
30-33	Electrical and optical equipment	27	53	37	27	33	37	48	41	35	42	26	23	39	37	32	36
24-36	Transport equipment	12	18	30	20	29	29	22	0	36	37	3	21	19	19	15	24
36-37	N.e.c. and recycling	7	43	18	9	18	32	14	:	24	32	4	5	25	13	15	20

Source: Eurostat — Community Innovation Survey 1997/98.

Innovators by export intensity

By sector and by country

Table 5.5. shows that on average the proportion of innovators is higher among exporters than non-exporters in both sectors. In the manufacturing sector, 57 and 40 % are innovators among exporters and non-exporters respectively, while the corresponding figures in the service sector are 49 and 39 %. This is a general trend for all countries in both sectors.

It can also be observed that as the export intensity (enterprise exports as a ratio of sales) increases from low to high, the proportion of innovators in the manufacturing sector increases for all countries, with an average of 52, 58 and 61 % of innovators among the low, medium and high exporters, respectively. However, this trend tends to reverse in the service sector (where Wholesale and Financial intermediation are not included), with the proportion of innovators decreasing with export intensity, being 53, 46 and 44 % among the low, medium and high exporters, respectively. It should be noted though that this pattern does not hold true for all countries in the service sector.

Tab. 5.5. Innovating enterprises according to their export intensity in manufacturing and service sectors by country in % — 1996

		B	DK	D	E	F	I	IRL	L	NL	A	P	FIN	S	UK	NO	Total
Manufacturing																	
Non-exporters		18	61	61	18	26	36	46	:	45	49	16	15	34	53	37	40
Exporters	Total	37	75	72	40	50	54	78	:	68	69	27	45	59	65	58	57
of which:	Low	31	50	67	35	42	52	70	:	55	67	26	35	51	60	49	52
	Medium	27	63	73	44	53	53	73	:	70	64	32	40	56	64	60	58
	High	45	89	79	44	62	57	83	:	79	76	26	59	68	72	65	61
Services																	
Non-exporters		17	27	42	:	31	:	71	:	38	24	16	26	32	40	17	39
Exporters	Total	19	33	62	:	26	:	50	:	27	58	35	44	36	68	56	49
of which:	Low	30	30	69	:	24	:	47	:	25	100	34	42	39	68	66	53
	Medium	14	73	54	:	24	:	45	:	31	56	45	53	42	63	46	46
	High	19	14	53	:	36	:	54	:	27	28	36	36	22	72	54	44

Source: Eurostat — Community Innovation Survey 1997/98.

5.3. INNOVATION CO-OPERATION

Innovators with innovation co-operation by country and sector

Figure 5.4. shows that on average at least a quarter of the innovators in the EU countries have established a co-operation with another partner in developing new products and processes. The actual proportion stands at 28 % in the manufacturing sector with a marginally lower proportion of 26 % in the service sector. Note that the highest proportions of innovators with co-operation are in the Scandinavian countries (Denmark, Finland, Norway and Sweden). Spain and Italy have the lowest proportion of innovators with co-operation.

Innovators with innovation co-operation by type of partner

Among innovators with co-operation, the highest proportion in both sectors (58 % for manufacturing and 67 % for service) have established a joint partnership with enterprises within a group (Figure 5.5.). Vertical co-operation in the manufacturing sector is most common with clients and customers (47 %) and suppliers of equipment (46 %), whereas in the service sector, the highest proportion of vertical co-operation occurs with competitors (41 %) and suppliers (39 %). In both sectors, roughly one third of innovating enterprises have innovation co-operation with either government or private non-profit institutions or universities.

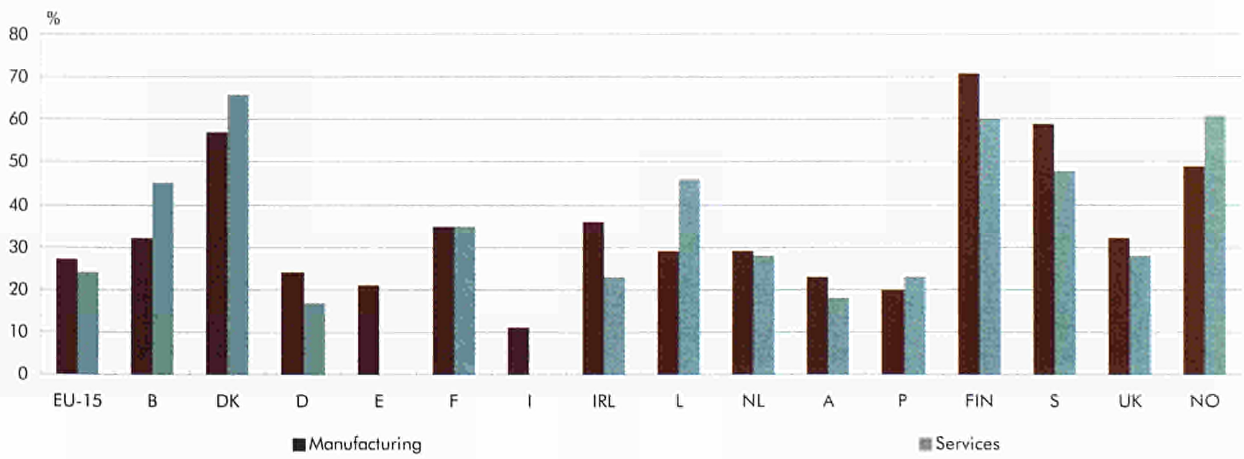
Innovators with innovation co-operation by location

In both sectors, the highest proportion of enterprises with innovation co-operation is with a national partner: 84 and 74 % in the manufacturing and service sectors, respectively (Figure 5.6.). With multiple responses possible, after a national partner, most innovators choose to establish co-operation with an EU partner (50 % in manufacturing and 38 % in the service sector). A quarter of the innovation co-operation occurs with the United States in both sectors, whilst the corresponding proportion is lowest with Japan for both sectors.

A cursory inspection of Figure 5.7. reveals that, on average, in the manufacturing sector, half (51 %) of the innovators with innovation co-operation have commercialised an innovation that was new to the market. The corresponding proportion for the innovators without a co-operation agreement is only about a third (36 %).

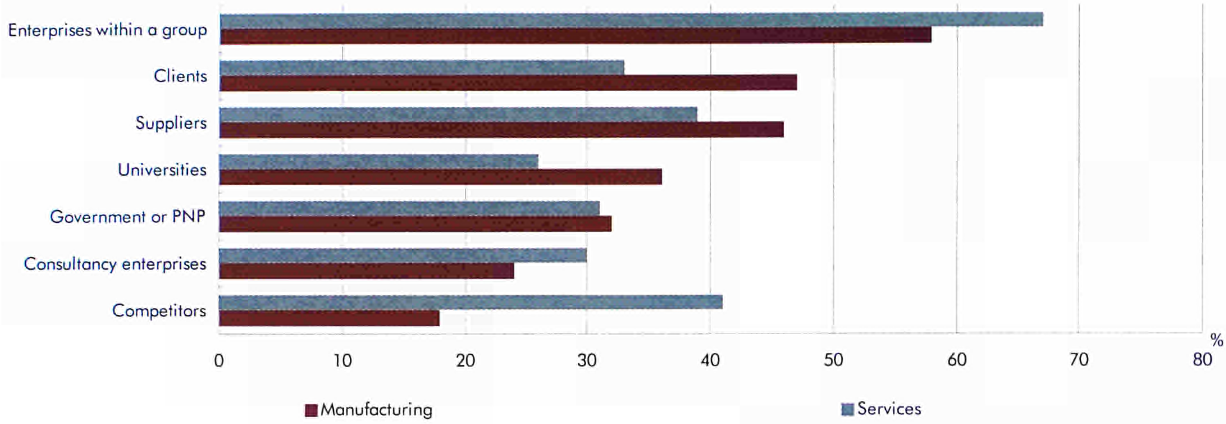
It can also be seen that for each size class, the proportion of novel innovators with innovation co-operation is higher than the proportion of those without the co-operation. Moreover, the proportion of novel innovators with innovative co-operation increases with the size of the enterprises.

Fig. 5.4. Innovators with co-operation as a % of total innovators in the manufacturing and service sectors by country — 1996



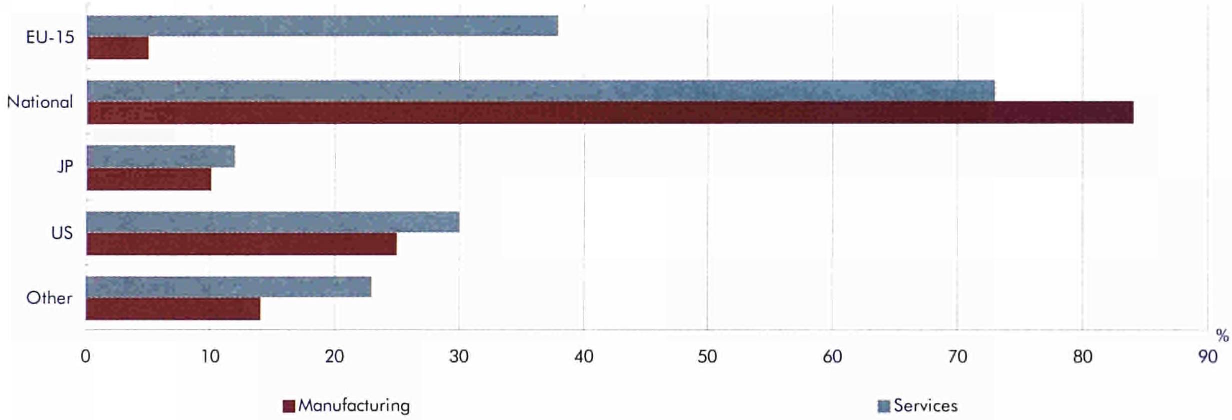
Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.5. Innovating enterprises with co-operation by type of partner in the manufacturing and service sectors in the EU in % — 1996



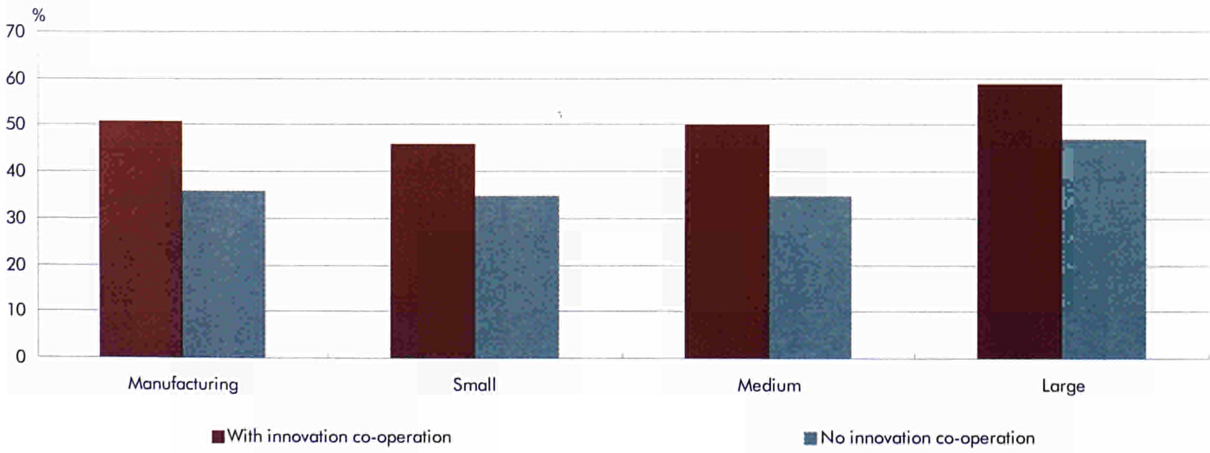
Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.6. Innovating enterprises with co-operation by location of partner in the manufacturing and service sectors in the EU in % — 1996



Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.7. Novel innovators with/without co-operation in manufacturing by size class in the EU in % 1996



Source: Eurostat — Community Innovation Survey 1997/98.

5.4. INNOVATION EXPENDITURE AND TURNOVER OF NEW PRODUCTS

Innovation expenditure

The *1997 Oslo Manual* states that expenditure on innovation includes all expenditure related to those scientific, technological, commercial, financial and organisational steps which are intended to lead, or actually lead, to the implementation of technologically new or improved products and processes. For the purposes of CIS2, the total expenditure refers to expenditure on innovation activities for the enterprise in a given year. In this section, the indicators measured are the innovation intensity and the structure of innovation expenditure by type and sector.

Innovation intensity by sector and economic activity

Innovation intensity is defined as innovation expenditure as a percentage of turnover. Referring to Table 5.6., the average expenditure on innovation activities in the manufacturing enterprises represented 3.7 % of the turnover in that sector. The data also show that the innovation intensity in the manufacturing sector is highest for all countries in the large enterprises (4.2 % on average), with minimal differences between the small and medium enterprises (on average 2.5 and 2.3 % respectively for small and medium enterprises). In terms of economic activity in this sector, the innovation intensity is highest in Machinery and equipment n.e.c., and Electrical and optical equipment (6.3 % on average).

In the service sector, the average expenditure on innovation activities represented 2.8 % of the turnover with expenditure on Computer, engineering and related services representing the highest turnover (4.4 %). Note that Wholesale trade and Financial intermediation is excluded. No apparent pattern could be seen in the innovation intensity between countries and size class, as is the case for the manufacturing sector.

Structure of innovation expenditures

Figure 5.8. shows the breakdown of expenditure by three categories of innovative activity. Intramural R&D comprises expenditure on R&D performed within the firm. Acquisition of disembodied technology and know-how includes extra-mural R&D, patents, non-patented inventions, licences, know-how, trademarks etc. Machinery and equipment refers to embodied technology, and includes machinery and equipment with improved technological performance.

On average, intramural R&D represents about half of the expenditure (53 % for manufacturing and 46 % for services) on innovation activities. The remaining expenditure in the manufacturing sector consists of 22 % on acquisition of disembodied technology and 25 % on machinery and equipment. In the service sector, machinery and equipment was the second largest component (38 %) of expenditure, followed by 16 % on acquisition of disembodied technology (Figure 5.8.).

Examining the data by size class in the manufacturing sector, the proportion of expenditure on disembodied technology is about 25 % in each class. However, large enterprises tend to spend more on intramural R&D whereas small enterprises spend more on machinery and equipment. This is reflected in Figure 5.8. where the proportion of intramural R&D expenditure increases with size class from 21 % in the small enterprises to 58 % in large enterprises and the expenditure on machinery and equipment decreases from 56 % in the small enterprises to 16 % in the large ones.

In the service sector, the structure of expenditure on innovation activities is less strongly influenced by firm size. The proportion of expenditure on machinery and equipment is lowest in each class, and around 40 % is spent on disembodied technology.

Turnover of new products in the manufacturing sector

One important indicator on the impact of innovation activities is the relative share of the turnover due to new or improved products. CIS2 revealed that 32 % of turnover in the enterprises of the manufacturing sector was due to new or improved products. However, only 6 % of this turnover was due to products which were also new to the market (see Figure 5.9.). Examining the data by class, it can be seen that the turnover due to products new to the firm increases with size class, from 15 % for the small enterprises, to 21 % for the medium enterprises and 38 % for the large enterprises.

Referring to Table 5.7., the percentage of total turnover due to new and improved products in the manufacturing sector stands the highest for Germany at 45 % followed by Ireland (32 %). For Belgium and Portugal, only 14 % of their total turnover is due to new or improved products.

In terms of economic categories, the proportions of turnover due to new or improved products in the manufacturing sector are highest for Transport equipment (51 %) and Machinery and equipment n.e.c., and Electrical and optical equipment (45 %).

Tab. 5.6. Innovation expenditure as a % of total turnover in manufacturing and service sectors by country, size class and NACE — 1996

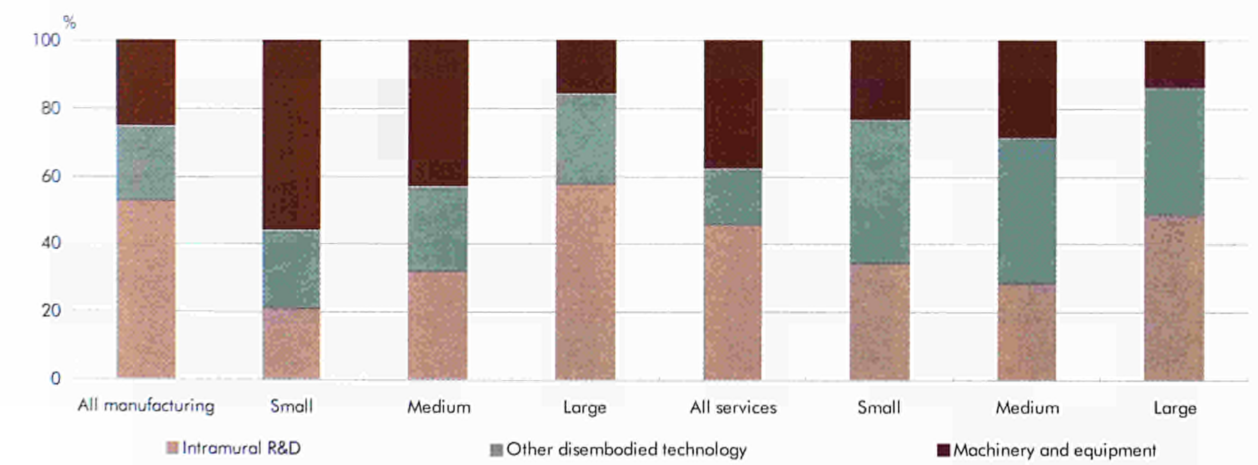
Code	Breakdown	B	DK	D	E	F	IRL	I	NL (2)	A	P	FIN	S	UK	NO	Total
	Manufacturing															
	Total	2.1	4.8	4.1	1.8	3.9	3.3	2.6	3.8	3.5	1.7	4.3	7.0	3.2	2.7	3.7
	Size class															
20-49	Small	2.1	10.5	3.3	1	1.4	2.8	2.4	3.0	4.4	1.8	1.6	2.6	3.3	2.2	2.5
50-249	Medium	1.4	3.5	2.4	1.6	2.2	3.2	2.2	1.8	3.1	1.9	1.6	2.7	2.9	2.8	2.3
250+	Large	2.3	4.5	4.7	2.2	4.8	3.7	3.1	4.6	3.5	1.6	5.1	8.2	3.2	2.8	4.2
	NACE															
23-26	Coke and chemicals, rubber and other non-metallic	2.5	8.6	4.9	1.7	3.2	4.2	2.5	4.4	4.9	1.1	2.7	6.3	2.9	4.5	3.6
29-33	Machinery and equipment, electrical and optical equipment	4.6	9.2	6.1	3.1	8.9	4.9	3.8	..	5.7	..	7.4	10.4	6.1	4.2	6.3
34-37	Transport equipment, n.e.c. and recycling	1.1	6.5	3.9	2.7	6.2	5.3	4.0	..	3.3	3.0	..	10.2	1.7	2.5	4.1
40-41	Electricity, gas and water distribution	..	0.1	0.4	0.8	..	:	..	..	0.4	0.1	1.5	0.9	0.4	0.3	0.8
	Services (1)															
	Total	1.2	4.7	3.0	:	1.2	2.1	:	1.6	3.0	1.1	2.4	3.8	4.0	3.5	2.8
	Size class															
20-49	Small	0.9	2.6	3.1	:	0.8	5.9	:	2.4	2.8	2.1	3.6	1.1	6.9	2.2	2.9
50-249	Medium	2.7	1.5	2.5	:	1.0	1.2	:	2.4	3.9	1.5	3.0	6.1	2.7	1.2	2.3
250+	Large	1.1	6.3	3.0	:	1.5	2.9	:	1.3	2.7	0.7	1.8	5.0	3.7	3.3	2.9
	NACE															
60-62,64.2	Transport and telecommunications	0.7	5.5	1.7	:	0.9	2.7	:	1.2	2.1	1.0	1.7	..	..	2.8	1.8
72, 74.2	Computer and related activities; engineering services	2.2	3.9	5.1	:	2.0	1.7	:	1.9	4.9	2.1	4.4	..	..	5.9	4.4

(1) Excluding Wholesale Trade & Commission Trade (NACE 51) and Financial Intermediation (NACE 65-67).
(2) In the Netherlands, medium-sized is defined as 50 to 199 and large as more than 200 employees.

NB: Symbol '..' means confidential data.

Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.8. Relative distribution of innovation expenditure in manufacturing and service sectors by type and size class in the EU — 1996



Source: Eurostat — Community Innovation Survey 1997/98.

Tab. 5.7.

Total turnover due to new and improved products in manufacturing by country, size class and NACE in % — 1996

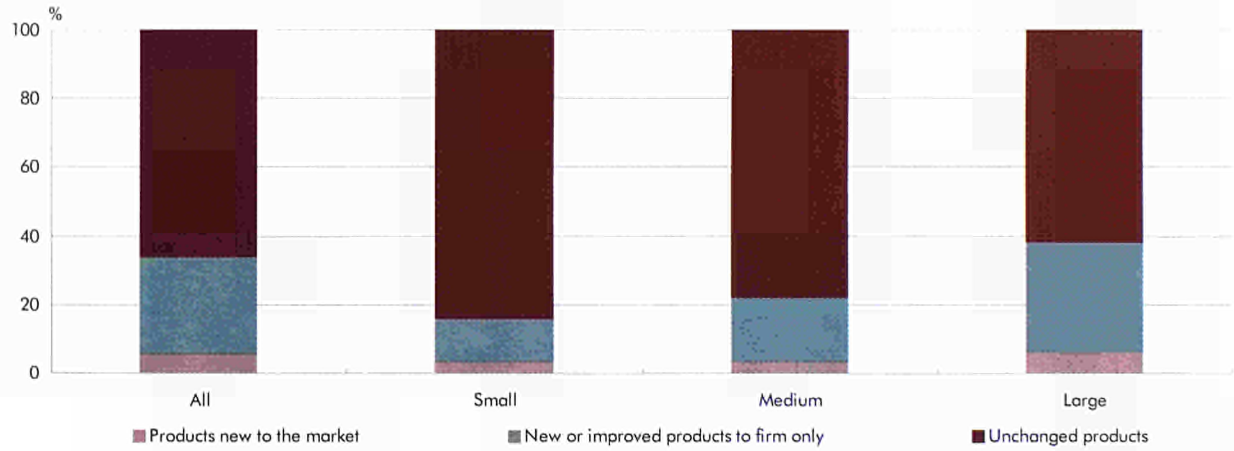
Code	Breakdown	B	DK	D	E	F	IRL	I	NL (1)	A	P	FIN	S	UK	NO	Total
	Total	14	21	45	27	21	32	27	25	31	14	25	31	23	20	32
	Size class															
20-49	Small	11	18	30	9	8	21	15	15	29	4	6	11	14	8	15
50-249	Medium	12	18	31	16	14	26	20	20	20	9	13	22	21	16	21
250+	Large	16	22	48	37	25	43	38	28	37	20	28	34	25	26	38
	Description															
15-19	Food, beverages and tobacco, textile and leather	13	7	27	15	8	12	17	20	23	6	11	16	16	14	17
20-22	Wood, pulp and printing	7	13	16	13	12	20	16	15	26	12	10	16	18	6	15
23-26	Coke and chemicals, rubber and other non-metallic	14	16	37	26	20	25	35	29	25	6	19	19	19	24	27
27-28	Basic and fabricated metals	10	18	15	17	13	26	15	14	28	6	19	19	22	23	16
29-33	Machinery and equipment, electrical and optical equipment	29	42	50	42	36	69	34	40	47	29	54	51	44	37	45
34-37	Transport equipment, n.e.c. and recycling	11	44	68	46	28	22	37	28	38	43	27	39	19	21	51

(1) In the Netherlands, medium-sized enterprise is defined as 50 to 199 employees and large as more than 200.

Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.9.

Relative distribution of new or improved products in manufacturing by size class in the EU — 1996



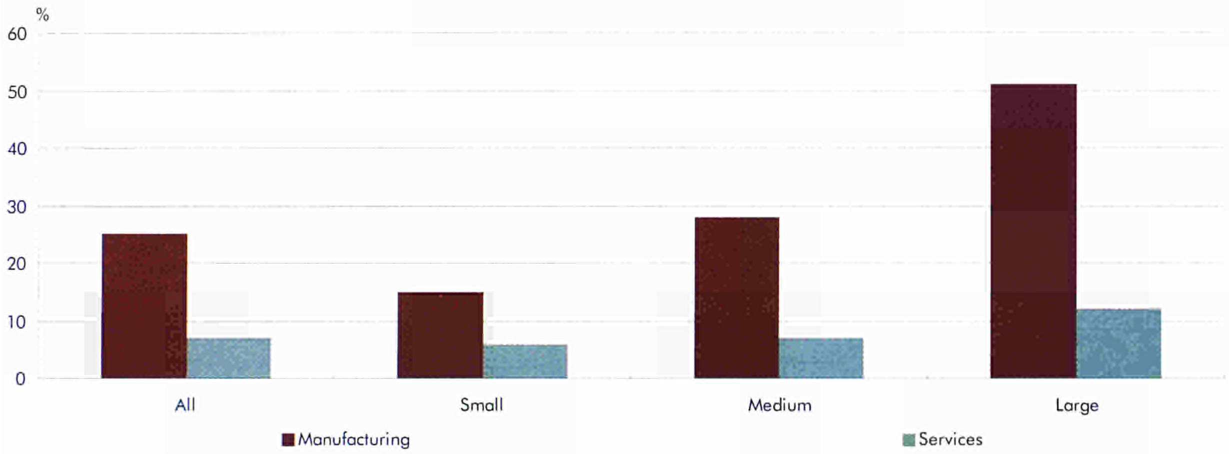
Source: Eurostat — Community Innovation Survey 1997/98.

Tab. 5.8. Innovating enterprises in manufacturing and service sectors by objectives considered as very important for innovation in the EU — 1996

Very important objective for innovation	Manufacturing in %	Services in %
Replace products/services being phased out	25	18
Improve product/service quality	60	68
Extend product/service range	46	49
Open up new markets or increase market share	54	48
Fulfil regulations and standards	22	17
Improve production/internal business process flexibility	33	40
Reduce labour costs	40	38
Reduce material consumption	31	18
Reduce energy consumption	23	16
Reduce environmental damage	25	18

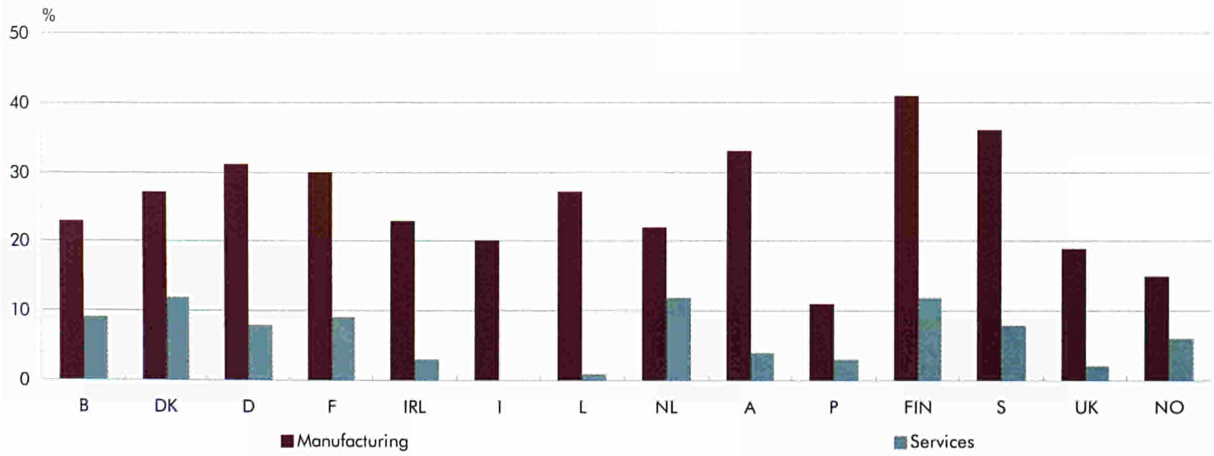
Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.10. Innovators having applied for a patent in manufacturing and service sectors by size class in the EU — 1994-96



Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.11. Innovators having applied for a patent in manufacturing and service sectors by country — 1994-96



Source: Eurostat — Community Innovation Survey 1997/98.

5.5. OBJECTIVES FOR INNOVATION, PATENTING ACTIVITY AND GOVERNMENT ASSISTANCE

Objectives for innovation

The *1997 Oslo Manual* recommends that a firm's reasons for engaging in innovative activity should be identified via its economic objectives in terms of products and markets, and how it rates a number of goals that process innovation can bring within reach.

Table 5.8. lists, with multiple responses possible, a number of objectives specified in the CIS2, which were considered as very important for innovation. In both the manufacturing and service sectors, improving the product/service quality was considered as the most important objective (by 60 % of manufacturing enterprises and 68 % for service enterprises). The other objectives which were considered as important by manufacturing firms were opening up new markets or increasing market share (54 %) and extending product/service range (46 %). In the service sector, almost 50 % of enterprises considered these same objectives as very important. In both sectors, minor importance was attached to objectives such as replacing products/services being phased out, fulfilling regulations and standards, lowering production costs by reducing material and energy consumption, and reducing environmental damage.

Patenting activity

Patent indicators reflect an important part of the overall innovation process, as there is the requirement of novelty in inventions for the granting of patents (4).

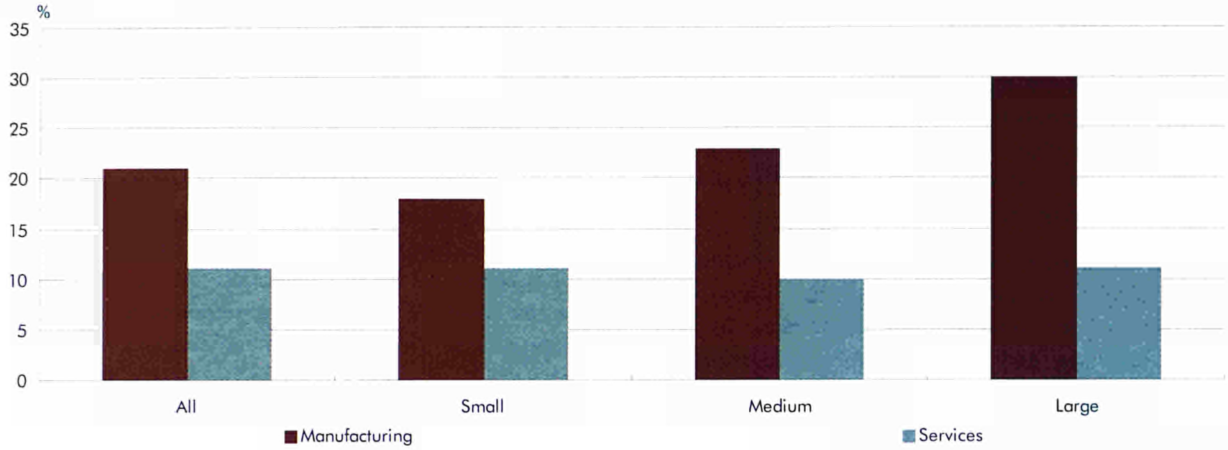
Referring to Figure 5.10., the proportion of innovators having applied for a patent between 1994 and 1996 is generally higher in the manufacturing sector (25 %) than in the service sector (7 %). Considering the breakdown of innovating enterprises by size class, the proportion of innovators having applied for a patent increases as the enterprises get larger, especially in the manufacturing sector (from 15 % in small enterprises to 51 % in large enterprises). This pattern is not marked in the service sector.

Examining the data by country in Figure 5.11., the pattern in the proportion of patent applications is similar in both sectors, with the proportion of service sector applications being lower than that of the manufacturing sector. In the manufacturing sector, Finland and Sweden have the highest proportion of applicants, being 41 and 36 % respectively, while Portugal has the lowest proportion with 11 %. In the service sector, Denmark, the Netherlands and Finland each have 12 % of applicants, representing the highest proportion for that sector.

(4) For a more in-depth analysis of patenting activity, refer to Chapter 4.

Fig. 5.12.

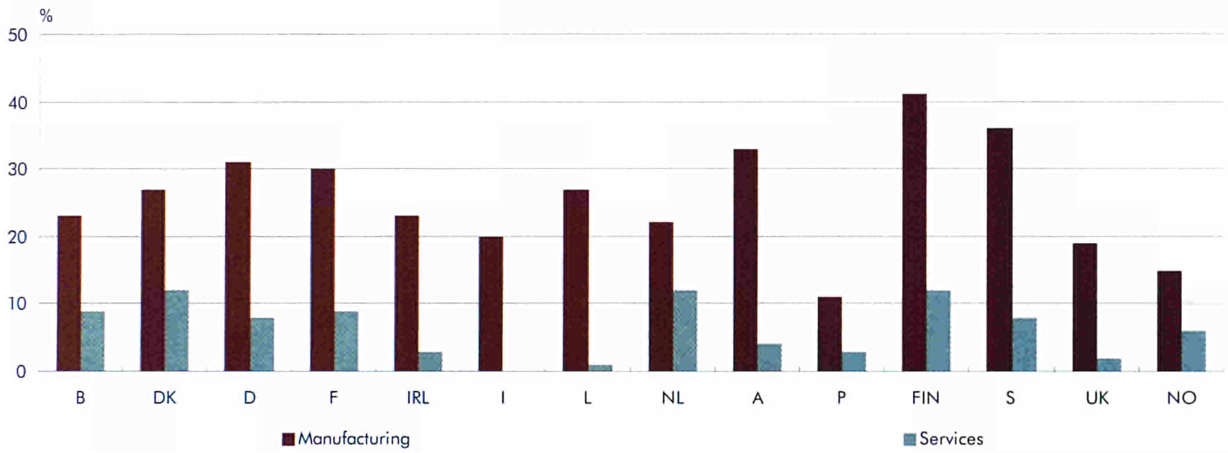
Innovators with government support in manufacturing and service sectors by size class in the EU — 1996



Source: Eurostat — Community Innovation Survey 1997/98.

Fig. 5.13.

Innovating enterprises receiving government assistance in manufacturing and service sectors by country — 1996



Source: Eurostat — Community Innovation Survey 1997/98.

Government assistance

On average, 21 % of the manufacturing innovators have been involved in government programmes to encourage innovation activities, compared to only 10 % in the service sector.

When considering firm size, a clear pattern emerges for the manufacturing enterprises — the larger the firm, the higher the percentage of innovators receiving government support. In the service sector, the proportion of innovating enterprises with government assistance remained between 10 to 11 %, irrespective of size class.

From Figure 5.13., the innovating enterprises with the highest share of government assistance in the manufacturing sector are from the Netherlands (49 %) and Finland (48 %). In the service sector, the highest proportions of innovators with government assistance are from Finland (25 %), the Netherlands (20 %) and Denmark (14 %).

CONCLUSIONS

The following are the main findings from CIS2:

- On average, one out of two manufacturing enterprises is a technological innovator and two out of five service enterprises have successfully implemented a technologically new or improved service on the market.
- Every fifth manufacturer has introduced a product new to their market.
- The propensity to innovate increases with the size of the enterprise.
- Roughly two thirds of manufacturing innovators are engaged in both product and process innovation.
- There are more innovators among exporters than among non-exporters.
- On average, one in four innovators has established an innovation co-operation with another enterprise or organisation.
- National partners are the dominant innovation collaborators, but every second partner in the manufacturing sector is based in another EU country; every third for the service sector.
- Enterprises within the same group represent the most common innovation partner; market-related partners (clients, suppliers, competitors), universities and government-based organisations also actively participate in innovation co-operation.
- Every second innovator engaged in joint projects has been implementing a product new to its market.
- Generally, large enterprises have been introducing relatively more innovative products than smaller ones.
- One in four manufacturing innovators have applied for a patent between 1994 and 1996; only one in fourteen for service innovators.
- On average, one in five manufacturing innovators and one in ten service innovators have been involved in government programmes to encourage innovation activities.

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Employment in high technology sectors

CHAPTER 6

In all major industrialised countries there is a link between the input of research and development (R&D) on one hand and expansion, productivity and exports on the other; competitiveness, sustainable economic growth and job security rely on the conversion of knowledge into innovation. Sectors with a high input of R&D, which employ manpower with above average skills, are contributing on an ever increasing scale to macroeconomic surplus value, and the international exchange of goods includes more and more commodities with a high knowledge content (1).

Technological progress originates and spreads particularly fast in those economies and regions where high-performance research-intensive industries are located, i.e. where R&D is performed on a large scale (2). The economic sectors with high levels of R&D include large sections of the capital goods industry (mechanical and automotive engineering, information technology, measurement and control techniques, and aerospace) and chemicals. In manufacturing industry, it is the companies that are research intensive (with a high ratio of their output reinvested into R&D) that form the core of innovative activities.

Interaction between industry and the service sector

More recently, in the industrialised countries around the world, it is the services sector that has seen higher growth, with both new employment fields and value added chains arising. This is especially true in those knowledge-intensive fields in which high-grade technologies expand existing, or even create new, markets (3). Industry and services are growing closer and closer together via their reciprocal market ties; and service providers mainly act as customers and suppliers to industry.

Growing high-grade services, in their capacity as lead users, are increasingly pointing the way forward for innovation, particularly in high-research technology sectors. Moreover, industry is orienting itself more and more to this demand. Examples of this are the close relations between medical technology/biotechnology/pharmaceuticals and health care, between telecommunications technology and telephone companies, or between the aviation industry and airline companies.

However, industry's demand for services is also growing. The development opportunities of company-oriented service providers (management and business consultancy, technical consultancy, finance) are strongly dependent upon impetus from innovative branches of industry. Only in those areas where R&D, marketing, finance or production are carried out is there a demand for the associated services.

Moreover, the spatial clustering of skills in research-intensive industries and high-grade services encourages technological innovation and thus, ultimately, the technological performance of the overall economy (4). For this reason, using data on employment, this chapter attempts to identify not only innovative industrial clusters, but also the corresponding service clusters in the EU.

(1) See, for example, OECD, 1992; Gehrke, B. et al., 1995; OECD, 1996.

(2) Measured as the ratio of R&D expenditure to output (R&D intensity).

(3) The further argumentation refers to *Innovationsstandort Deutschland: Chancen und Herausforderungen im internationalen Wettbewerb*, 2000.

(4) See Beise, M.; Gehrke, B. et al., 1998.

INTRODUCTION

6.1. METHODOLOGY

The analysis in the chapter is conducted using the regional data (NUTS 2 whenever statistically significant) from the Community Labour Force Survey (5) for NACE Rev. 1 (6) divisions (two-digit NACE information) in 1995-99 (7).

Demarcation of research-intensive industries

Research-intensive industries are usually defined on the basis of lists of high-tech products or product groups. This yields a distinction between highly and less highly research-intensive products — something which is only possible to a limited extent at the branch-of-industry level.

By analogy with the OECD classification of industries based on technology intensity (8) and the ISI-NIW list of research-intensive industries (9), the NACE two-digit level yields a group of eight R&D-intensive economic sectors:

- NACE 24: Manufacture of chemicals and chemical products;
- NACE 29: Manufacture of machinery and equipment (not elsewhere classified);
- NACE 30: Manufacture of office machinery and computers;
- NACE 31: Manufacture of electrical machinery and apparatus n.e.c.;
- NACE 32: Manufacture of radio, television and communication equipment and apparatus;
- NACE 33: Manufacture of medical, precision and optical instruments, watches and clocks;
- NACE 34: Manufacture of motor vehicles, trailers and semi-trailers;
- NACE 35: Manufacture of other transport equipment (10).

There are considerable intrasectoral differences in R&D intensity, particularly in the chemicals sector (pharmaceuticals and other chemical goods) and in the electrotechnology/information technology sectors (telecommunications versus office machinery/home electronics).

However, three rough clusters can be formed in the production context in order to illustrate the sectoral specialisation patterns in the regions:

- chemical industry — NACE 24;
- mechanical and automotive engineering — NACE 29, 34 and 35;
- electrotechnology/Information and Communication(I&C) /measurement, control and instrumentation/optics — NACE 30-33.

(5) On the survey and methods, see: *Labour Force Survey: Methods and Definitions*, Eurostat, 1998.

(6) NACE Rev. 1 is the *Statistical classification of economic activities in the European Community*, 1996.

(7) Prolonged time-series analyses are not possible. This is firstly because data for Austria, Finland and Sweden have only been available since 1995, their year of entry to the EU; and secondly, fundamental changes in the NUTS classification were made in 1995.

(8) The OECD classification is based on the International Standard Industrial Classification (ISIC), Rev. 2. Of the four groups identified according to technology content, two (medium-high, high) form the class of research-intensive industries See: *STI Working Papers*, Directorate for Science, Technology and Industry, OECD, Paris, 1997/2.

(9) The ISI-NIW list distinguishes on the NACE 4-digit level between leading-edge technology and advanced technology. For the definition see Grupp, H., Legler, H., 1991 and for adaptation to the NACE classification see Gehrke, B. et al., 1997.

(10) Only one part group of Division 35, i.e. aerospace engineering (35.30), conducts highly research-intensive production and also qualifies as leading-edge technology. The sector is nevertheless included, as this sector contributes at least half of the employees within group 35 in each of the major high-research countries — see OECD, 1999.

Demarcation of knowledge-intensive services

R&D intensity is the decisive parameter for research-intensive enterprises, although in services it does not serve as a suitable indicator. By contrast, the share of highly skilled employees should present a relatively accurate picture of the innovativeness in services. The human capital tied up in the labour force is a factor for successful innovative activities, and is also indispensable for the application of technical knowledge from manufacturing industry.

Thus far, Eurostat had identified three NACE service sectors as being 'high-tech', subdivided into Post and telecommunications (64), Computer and related activities (72) and Research and development (73) — denoted as Information and communication-oriented services (ICS).

However, in order to take into account the indirect interaction between industry and services, a broader definition of high-grade, knowledge-intensive services makes additional sense. Knowledge-intensive services (KIS) include:

- Water transport (61), Air and space transport (62), Post and telecommunications (64) (parts of Section I);
- Section J: Financial intermediation (11);
- Section K: Real estate, renting and business activities (12);
- Section M: Education (80);
- Section N: Health and social work (85) (13);
- Recreational, cultural and sporting activities (92), i.e. motion picture and video activities, radio and television activities; libraries, archives, museums, etc.

(11) Including: Financial intermediation, except insurance and pension funding (65), Insurance and pension funding, except compulsory social security (66) and Activities auxiliary to financial intermediation (67).

(12) Including: Real estate activities (70), Renting of machinery and equipment without operator and of personal and household goods (71), Computer and related activities (72), Research and development (73), Other business activities (74).

(13) Including: Human health and veterinary activities, social work activities.

6.2. THE NATIONAL LEVEL: R&D AND KNOWLEDGE-INTENSIVE SECTORS

In the course of the growth in the tertiary sector in all European industrialised countries, industrial employment has shown a downward trend (notwithstanding differences in the speed and positioning in structural change and the effects of the business cycle) and throughout Europe, it is currently well below the level at the beginning of the '80s. In the EU in 1999, more than 31.5 million employees were working in manufacturing industry i.e. only about a fifth of total employment, whilst almost two thirds were working in the service sector (Table 6.1). Knowledge-intensive services, especially, have made a significant contribution to the expansion of this sector.

Knowledge-intensive services

In 1999, over 100 million people were employed throughout the EU in the service sector, which is more than three times as many as in industry (see Table 6.1.). Of these, roughly half were in knowledge-intensive services in the broader sense (KIS), with one in ten of these (5 million) in Information and communication-oriented services (ICS). However, these shares vary considerably from country to country. It is worth noting that the larger Member States (Germany, France, Italy and the United Kingdom) account for around 77 % of total EU high tech manufacturing employment, whereas these four account for 70 % of total EU KIS employment.

The countries where KIS account for the biggest share of the total labour force are Denmark and Sweden (more than 40 %), followed by Belgium, France, the Netherlands, Finland and the United Kingdom, each with above average rates. Next, albeit at some distance and with values below the EU average, are Germany, Ireland and Austria. These are in turn followed by the southern European Member States.

The situation for the more narrowly defined ICS group is similar. The leading group retains the same countries, with slight variations in the order and the exception of Ireland, where ICS represents around 13 % of KIS, compared with an EU average of 10 %. In Sweden, ICS now stands out the most, with nearly 5 % of total employment. Denmark, Finland and the United Kingdom also have high rates of employment in ICS (just over 4 % of total employment), closely followed by Ireland, ahead of France and the Netherlands (3.8 and 3.6 % of total employment). The gap between these and the other countries is considerable. Belgium, Germany, Austria and Italy, who is in a slightly stronger position with ICS than for KIS overall, show rates between 2.7 and 3.2 %.

The still relatively low emphasis on knowledge-intensive, high-grade services in the countries of southern Europe can be seen looking at the employment in KIS in relation to employment in all service sectors. The rates vary from around 60 % for Denmark, Finland and Sweden to less than 40 % for Greece, Spain and Portugal.

Employment in KIS rose sharply in the course of 1995 to 1999. Europe-wide, about 5.3 million jobs (gains of 2.9 % on average per year) were created in this sector, and more than 700 000 of these in ICS. Nevertheless, a country-by-country analysis again reveals differences (see Table 6.2.).

Of the countries with an above average emphasis on KIS in 1995 (compared to the EU average), KIS employment grew strongly in Belgium, the Netherlands and Finland. On the other hand, below-average growth rates were recorded in Denmark, France and the United Kingdom, whilst in Sweden KIS employment in 1999 was only marginally above its 1995 level.

Within the group of countries with less specialisation in KIS, above average KIS employment growth was registered in Italy; Germany matched the EU-average, whereas Austria showed below-average growth rates. In contrast to this, KIS jobs increased in Ireland by almost 8 % on the annual average. Of smaller EU countries, Greece and Spain developed at an above average rate of growth: Greece with 4 % a year and Spain with almost 6 %.

In Information and communication-oriented services, the differences in growth vary more from country to country than for KIS. Although ICS employment grew in all Member States except Portugal, the mean annual expansion rates differ greatly, from over 20 % in Ireland, to rates of between 6 and 10 % in Spain, the Netherlands, Finland, and the United Kingdom, 2 to 3 % in France and Austria and around 0.5 % in Germany.

Tab. 6.1.

Employment in selected sectors by country
1999

	Manufacturing: Total manufacturing	Manufacturing: High-tech industries: Total	Chemical industry	Mechanical & automotive	Electrotechnology, I&C, etc.	Services: Total services	Knowledge-intensive services: Total	ICS	Other KIS
	Thousands	Thousands	%	%	%	Thousands	Thousands	%	%
EU-15	31 551	11 916	18	53	29	102 513	49 689	10	90
B	739	287	33	44	22	2 864	1 464	9	91
DK	512	173	17	51	32	1 882	1 125	11	89
D	8 574	3 924	17	56	27	22 845	10 797	9	91
EL (1)	578	95	31	52	17	2 349	863	7	93
E	2 621	752	19	58	23	8 538	3 309	9	91
F	4 291	1 647	18	51	31	15 789	7 887	11	89
IRL	291	116	23	26	51	996	497	13	87
I	4 869	1 570	16	57	26	12 825	5 404	10	90
L (2)	21	3	(21)	48	(31)	133	67	9	91
NL	1 099	355	26	43	32	5 368	2 970	9	91
A	753	244	19	45	36	2 354	1 024	10	90
P	1 121	173	21	51	28	2 516	910	6	94
FIN	470	169	10	49	40	1 532	873	11	89
S	754	335	10	60	30	2 917	1 840	10	90
UK	4 858	2 073	16	52	32	19 603	10 658	11	89

(1) Exception to the reference period — EL: 1998.
(2) Data in parentheses are uncertain due to sampling error.

Sources: Eurostat — CLFS, NIW calculations.

Tab. 6.2.

Annual average growth rates of employment in selected sectors by country
1995-99

	Manufacturing: Total manufacturing	Manufacturing: High-tech industries: Total	Chemical industry	Mechanical & automotive	Electrotechnology, I&C, etc.	Services: Total services	Knowledge-intensive services: Total	ICS	Other KIS
	%	%	%	%	%	%	%	%	%
EU-15	0.3	0.9	1.2	1.6	- 0.6	1.8	2.9	3.9	2.8
B	- 0.8	- 0.7	1.0	0.5	- 4.8	2.3	4.1	4.1	4.1
DK	- 0.4	- 2.5	1.6	- 5.3	0.4	1.4	2.7	5.8	2.3
D	- 1.0	- 0.1	1.1	0.6	- 2.0	1.2	2.9	0.4	3.2
EL (1)	0.0	3.8	5.7	2.6	4.3	2.9	4.0	5.9	3.8
E	2.9	4.3	3.2	4.1	6.0	4.1	5.8	7.3	5.6
F	0.8	0.9	- 0.7	1.7	0.6	1.3	1.7	1.8	1.7
IRL	5.4	8.7	10.2	8.0	8.4	7.1	7.7	20.9	6.3
I	1.6	1.4	1.8	3.5	- 2.8	1.6	3.1	3.4	3.0
L (2)	- 1.1	- 1.3	(4.1)	- 7.2	(7.5)	4.0	7.8	19.6	6.9
NL	0.4	1.1	- 0.1	1.9	1.0	2.9	4.6	9.6	4.1
A	- 1.8	- 0.2	3.7	- 1.0	- 1.2	1.4	2.1	2.6	2.1
P	2.8	- 0.9	- 3.2	2.9	- 5.0	0.3	- 1.3	- 6.1	- 0.9
FIN	3.3	5.8	- 2.4	5.6	8.8	4.2	3.8	6.6	3.5
S	- 1.1	0.8	3.7	- 0.3	2.3	- 0.1	0.1	4.2	- 0.4
UK	- 0.3	1.1	1.5	2.1	- 0.4	1.9	2.8	7.1	2.4

(1) Exception to the reference period — EL: 1995-98.
(2) Data in parentheses are uncertain due to sampling error.

Sources: Eurostat — CLFS, NIW calculations.

Research-intensive industries

In order to gain some point of comparison, a cursory inspection of the situation in manufacturing industry as a whole reveals that, in the years 1995-99, the shedding of jobs has stabilised somewhat. In some countries, new employment opportunities have been created. As a consequence, the level of employment in manufacturing industry has remained roughly unchanged throughout the EU (Table 6.2). The fastest growth has been experienced in Ireland, clearly ahead of Finland, which suffered the most serious job losses at the end of the '80s/beginning of the '90s. A high rate of growth was also seen in Spain and Portugal. In France and Italy, jobs have been created in industry on a limited scale since 1995, whilst job levels in the Netherlands (with a slightly positive trend) and Greece (referring to 1995-98) remained stable. By comparison, employment opportunities within manufacturing industry in the other EU-countries have declined in spite of an economic revival. The smallest losses are observed for Denmark and the United Kingdom, the most important for Austria, Sweden and also Germany, where industry is an important element of the economic structure.

Within a recently stable manufacturing industry, the high-tech sector in Europe has expanded appreciably. A total of nearly 12 million people in the EU were employed in research-intensive industries in 1999, with more than 50 % of these in mechanical/automotive engineering, nearly 30 % in electrotechnology/I&C/etc. and almost 20 % in chemicals (Table 6.1.). The big four EU Member States — Germany, France, Italy and the United Kingdom — accounted for over three quarters of total employment in this sector; almost a third of total employment in the research intensive sector is in Germany alone, where research-intensive industries hold the largest share of employment within the economy as a whole (11 % of total jobs are in this field). Second is Sweden, with a share of roughly 8 %. In Belgium, France, Ireland, Italy, Finland and the United Kingdom, between 7 and 8 % of the labour force are employed in research-intensive industries, whilst in the Netherlands it is less than 5 % ([14]).

In 1999, 38 % of employees in manufacturing in the EU were employed in research-intensive industries. Germany (with 46 %) and Sweden (44 %) are similarly highly specialised in research-intensive industries — each with a definite emphasis on mechanical/automotive engineering. In Ireland and the United Kingdom, too, research-intensive industries within manufacturing industry are of above average importance. In Ireland, this is mainly attributable to special strengths relative to the EU average in electrotechnology/I&C/etc. Belgium (emphasis on chemicals) and France (electrotechnology/I&C/etc.) still reach slightly above average shares. Finland (with emphasis on electrotechnology/I&C/etc.) lies slightly below the EU-average for research-intensive industries. In Austria, Denmark, Italy, and the Netherlands, roughly a third of industrial employment is engaged in high-tech sectors, comparing favourably with Spain (nearly 30 %).

In spite of the broad growth in the importance of industrial high-tech sectors, additional employment opportunities have only been generated to a limited extent in the larger, research-oriented countries. France, Italy, Sweden and the United Kingdom have each achieved positive growth rates between almost 1 and 1.5 % per year, respectively (Table 6.2.), whereas in Germany, employment has only just remained stable. The same is true for Austria. By comparison, industrial high-tech employment has developed much more significantly in many smaller countries. Out on its own is Ireland with an increase of nearly 9 %, followed at some distance by Finland (6 %), Greece and Spain (both around 4 %). In these countries there has been a major expansion of high-tech industries, though starting at a comparatively low level. Contrasting with this, the number of jobs in high-tech industries in Belgium, Portugal, and particularly Denmark, declined from 1995 to 1999. For Denmark this is on an even larger scale than in industrial employment overall. Within the observation period at the EU level, employment in research-intensive industries rose by around 410 000 (in absolute figures). This result is mainly due to the employment gains in the mechanical and automotive engineering sectors (around 395 000 thousand). In the chemical sector there was a smaller increase of 97 000 jobs, but in electrotechnology/I&C/etc, roughly 80 000 jobs were destroyed at the EU level.

([14]) In the Community Labour Force Survey basic data, 5 % of Dutch employees cannot be assigned to any economic sector. For the other countries, the equivalent rates vary from 0 to 0.4 %. A glance at the employment figures in the Dutch statistics suggests that this 'deficit' is probably at the expense of the service sector.
The importance of manufacturing industry from the Community Labour Force Survey (15 %) concurs with that given in the national statistics.

6.3. THE REGIONAL LEVEL: IDENTIFYING LEADING R&D AND KNOWLEDGE-INTENSIVE REGIONS IN EUROPE

Based on the respective rates of employment [15] and on the absolute number of jobs, the following regional analysis (NUTS 2) will identify:

- the leading knowledge-intensive and technically centred service regions in Europe;
- the leading industrial high-tech regions in Europe.

The leading group is therefore composed of all regions in which the employment rate in each observed sector is at least 20 % higher than the EU average, and in which the relevant threshold of employed persons (in absolute figures) is reached.

The analysis for 1999 is based on 210 regions. In the tables the identified areas are ranked according to their respective percentages of total employment. As an indication of differences in regional development patterns, the annual average growth rates in employment in the respective sectors [16] are also given.

Knowledge-intensive services

The highest number of employees in knowledge-intensive service sectors can be found in Greater Paris (Île de France, F) with almost 2.2 million and Greater London (UK) with 1.7 million (Table 6.3.). These are by far the most important European centres of knowledge-intensive services, well ahead of all other regions. Even from a relative point of view, London (UK), with an employment share of about 50 %, is shortly behind Stockholm (S) (around 53 %). Those two are followed by Surrey and East/West Sussex, Berkshire Bucks and Oxfordshire (both UK), Noord-Holland (NL), Greater Paris (Île de France, F) and Uusimaa, the Finnish metropolitan city, with rates between 44 and 47 % of total employment. The British regions show a dominance in the KIS field, much in the same way as Germany does in research-intensive industries (see Table 6.5.); they alone contribute 9 of the 18 regions within the leading group. These include not only South-East England, but also West Yorkshire and Eastern Scotland (UK). Germany is only represented twice in the lower and middle range of the leading regions, with Berlin and Hamburg (D), reflecting the high structural weight of industry. Furthermore, there are two highly specialised regions in both the Netherlands (Noord-Holland and Zuid-Holland) and Sweden (Stockholm and Västsverige — Greater Göteborgs). Denmark is the remaining area, in the mid-section of the table.

Compared to 1995, Noord-Holland (NL), Berlin (D) and Hampshire Isle of Wight (UK) improved their ranking, mainly at the expense of Bedfordshire Hertfordshire (UK), Denmark, Greater Paris and Provence-Alpes-Côte d'Azur in France, which has fallen out of the leading group. Newcomers are Uusimaa (Helsinki, FIN), Hamburg (D) and Kent (UK), where the number of people working in KIS did not yet reach the 'threshold value' in 1995 [17]. In 10 of the 18 regions, employment developed at below-average rates (EU-15: 2.9 %), and one Swedish region (Västsverige) even experienced negative growth. The biggest growth rates were recorded by the two Dutch regions, Uusimaa (Helsinki, FIN) and some British regions (Hampshire Isle of Wight on top position with an annual growth rate of more than 8 % and London, which showed an above average growth rate).

The group of leading regions in Information and communication-oriented services contains many of the Member States' capital cities (Table 6.4.). ICS shows a stronger spatial concentration (the 28 leading regions account for about 43 % of all people employed in ICS in Europe) than knowledge-intensive services or research-intensive industries. The greatest numbers of jobs in

(15) Prior ranking criterion is employment in research-intensive-industries, KIS or ICS as a share of total employment. As the measure of specialization patterns within industry, reference is also made to employment in manufacturing industry as a whole, and for KIS and ICS employment in the whole of the service sector.

(16) For the British regions only data for NUTS 1 regions were available for 1995. Annual average growth rates can therefore only be calculated at the NUTS 2 regional level for the period 1996-99.

(17) See conditions for Table 6.3.

Tab. 6.3.

Leading knowledge-intensive service regions (1) in the European Union 1999 (2)

Ranking 1999	Region	Country	Employment in KIS 1999: Thousands	% of total employment	Annual average growth rate 1995-99 (3)	% of total services
	EU-15		49 689	32.3	2.9	48.7
1	Stockholm	S	447	53.4	0.6	63.6
2	London	UK	1 708	52.0	3.2	62.2
3	Surrey, East-West Sussex	UK	572	46.8	2.6	58.1
4	Noord-Holland	NL	554	44.8	5.0	57.7
5	Berkshire Bucks, Oxfordshire	UK	500	44.8	4.3	60.6
6	Île de France	F	2 182	44.5	1.8	55.8
7	Uusimaa	FIN	314	44.1	4.8	57.9
8	Essex	UK	332	42.7	3.3	58.6
9	Zuid-Holland	NL	686	42.4	5.1	56.0
10	Västsverige (NUTS 95)	S	343	42.3	- 0.6	63.1
11	Berlin	D	615	42.1	0.7	55.5
12	Denmark	DK	1 125	41.6	2.7	59.8
13	Kent	UK	306	41.1	2.1	55.8
14	Hampshire Isle of Wight	UK	351	40.7	8.4	55.6
15	Bedfordshire Hertfordshire	UK	318	40.7	0.9	55.0
16	Hamburg	D	317	40.2	2.8	52.2
17	Eastern Scotland	UK	348	39.7	1.8	53.6
18	West Yorkshire	UK	370	38.7	3.0	53.9

(1) With a share of at least 38.7 % of total employment (equivalent to 120 % of the EU average) and at least 300 000 people working in KIS.

(2) Exception to reference period — EL: 1998. Growth rates for EL are therefore calculated for the period 1995-98.

(3) For UK only data for NUTS 1 regions were available.
Therefore annual growth rates have been calculated on the NUTS 98 level 2 for the period 1996-99.

Sources: Eurostat — CLFS, NIW calculations.

Tab. 6.4.

Leading information-communication service regions (1) in the European Union 1999 (2)

Ranking 1999	Region	Country	Employment in ICS 1999: Thousands	% of total employment	Annual average growth rate 1995-99 (3)	% of total services
	EU-15		4 958	3.2	3.9	4.8
1	Berkshire Bucks, Oxfordshire	UK	94	8.4	10.7	11.3
2	Stockholm	S	61	7.3	2.1	8.7
3	Uusimaa	FIN	52	7.3	8.1	9.5
4	Surrey, East-West sussex	UK	81	6.6	14.2	8.2
5	Île de France	F	316	6.4	2.0	8.1
6	Bedfordshire Hertfordshire	UK	48	6.2	0.9	8.3
7	Hampshire Isle of Wight	UK	53	6.1	14.6	8.4
8	London	UK	196	5.9	7.7	7.1
9	Midi-Pyrénées	F	55	5.7	11.5	8.3
10	East Anglia	UK	59	5.6	17.4	8.0
11	Utrecht	NL	31	5.5	14.0	7.1
12	Lazio	I	101	5.4	3.9	6.9
13	Avon Gloucestershire Wiltshire	UK	58	5.3	14.6	7.4
14	Comunidad de Madrid	E	96	4.9	9.4	6.8
15	Östra Mellansverige	S	32	4.6	7.1	6.7
16	Zuid-Holland	NL	74	4.5	8.9	6.0
17	Denmark	DK	122	4.5	5.8	6.5
18	Karlsruhe	D	52	4.4	8.4	7.2
19	Leicestershire Northamptonshire	UK	34	4.4	6.6	6.5
20	Darmstadt	D	73	4.3	2.3	6.2
21	Aquitaine	F	49	4.2	6.0	6.0
22	Berlin	D	61	4.2	- 2.2	5.5
23	Upper Bavaria	D	84	4.2	1.9	6.2
24	Rhône-Alpes	F	92	4.1	4.5	6.1
25	Central Franconia	D	31	4.1	5.9	7.1
26	Noord-Holland	NL	50	4.1	6.7	5.2
27	Västsverige	S	33	4.0	5.4	6.0
28	West Midlands	UK	43	3.9	11.1	5.8

(1) With a share of at least 3.8 % of total employment (equivalent to 120 % of the EU average) and at least 30 000 people working in ICS.

(2) Exception to reference period — EL: 1998. Growth rates for EL are therefore calculated for the period 1995-98.

(3) For UK only data for NUTS 1 regions were available.
Therefore annual growth rates have been calculated on the NUTS 98 level 2 for the period 1996-99.

Sources: Eurostat — CLFS, NIW calculations.

absolute terms in this area are located in Greater Paris (F, 316 000) and London (UK, 196 000). These are followed by Denmark (122 000), Lazio — with Rome as its centre — (I, 101 000), the Spanish metropolitan area, the British region Berkshire, Buckinghamshire and Oxfordshire and Rhône-Alpes in East France, with between 92 000 and 96 000 employees. Situated in London's urban field, Berkshire, Buckinghamshire and Oxfordshire (UK) also has the highest rate of specialisation at over 8 % of regional employment. With the exceptions of Leicestershire & Northamptonshire and the West Midlands, the other British regions in the leading group that have a high specialisation in ICS all are situated in England's South East. Also prominent are the Finnish and Swedish capitals, with almost 7.5 % of employed people in ICS.

Overall, the leading group contains 9 British regions, 5 German, 4 French, 3 each from the Netherlands and Sweden, the Finnish metropolitan centre (Uusimaa), Madrid in Spain, Lazio in Italy and also Denmark. Whilst Germany, France, Sweden and the United Kingdom have at least two spatially separate ICS focuses, the ICS sector in the other highly developed Member States is largely confined to the regions around the capital cities.

Of those regions in the leading group in 1995, improvements over their 1995 rankings were achieved by the southern French region Midi-Pyrénées and individual British regions in the South-East such as Surrey/East-West Sussex, East Anglia and Avon Gloucestershire and Wiltshire. Other regions, for which employment did not reach the threshold of 30 000 people in 1995 [18], have joined the leading group. These regions are Utrecht (NL), the surroundings of the capital area (Östra Mellansverige) and Västsverige (Greater Göteborg) in the South West of Sweden, Karlsruhe and Mittelfranken in Germany, Rhône-Alpes (F) as well as Leicestershire/Northamptonshire and West Midlands (UK).

Over the period 1995 to 1999 (Table 6.4.), the annual average growth rates in ICS employment vary from annual losses of more than 2 % in Berlin to 17 % gains in East Anglia (UK). The capital city regions saw disparate ICS job development. London (UK), Uusimaa (Helsinki, FIN) and Madrid (E) have grown at an above average rate of growth, whereas in Berlin (D), ICS-employment has shrunk. Greater Paris (F), Lazio (I) and Stockholm (S) show relatively small expansion rates. The same applies to the German metropolitan areas of Munich (Upper Bavaria), and Darmstadt, but to only one of the 9 British regions (Bedfordshire Hertfordshire).

By comparison, London (UK) and the urban fields around the capital made significant progress, as is the case for the development of KIS-employment. Apart from East Anglia, double-figure growth rates were achieved in four other British regions, in the Dutch Utrecht and in the French Midi-Pyrénées. In the United Kingdom, in addition to South-East England, a second small but dynamic ICS centre has formed in the West Midlands. But, the fastest growing region is, East Anglia, which includes the rapidly expanding high-tech oriented city of Cambridge.

In France, besides Greater Paris, ICS show a high concentration in the South-West (Midi-Pyrénées and Aquitaine) on one hand and in the East (Rhône-Alpes) on the other. But it is the regions in the South-West that have achieved stronger expansion rates during the observed period.

(18) See conditions to Table 6.4.

Research-intensive industries

At the EU level, 7.7 % of total employment were working in research-intensive industries in 1999, or, in other words, close to 4 out of 10 jobs in manufacturing industry belonged to research-intensive industries. Taking all the regions into consideration, the rates of employment in research-intensive industries range from close to 0 % to just over 20 % for Stuttgart (D) at the top of the table. The largest job contingent in research-intensive industries in absolute terms can be found in the Italian region of Lombardia with some 443 000 employed people, followed by Stuttgart (D, 379 000) and Greater Paris (Île de France, F, 335 000) — which represents close to 7 % of total employment and is therefore not incorporated into the table [19]. These regions are well ahead of Upper Bavaria, Darmstadt and Düsseldorf in Germany as well as Italy's Piemonte region and the Spanish Cataluna, with values between 210 000 and 270 000 employees.

The group of leading industrial high-tech areas comprises a total of 27 regions (Table 6.5.), accounting for about 39 % of total industrial high-tech employment.

German dominance in the field of research-intensive industries in Europe is underlined by a regional analysis. The leading group is formed by the following distribution of regions: 16 German, 4 Italian, 4 British, 1 Spanish, 1 French and 1 Swedish.

In 10 European regions, including 7 German, 2 British, and 1 Swedish region, research-intensive industries account for well over half of industrial employment. Right at the top of the table are Hampshire Isle of Wight (UK) and Darmstadt (D) with a share of more than 60 %.

Two of the four British high-tech regions (Berkshire Bucks/Oxfordshire and particularly Hampshire Isle of Wight) show a strong degree of specialisation [20] in the field of electrotechnology/I&C/etc. The latter additionally shows a slightly above average position in mechanical and automotive engineering. The West Midlands, with its long history of industrialisation, owes its strong position to mechanical and automotive engineering. Derbyshire Nottinghamshire is highly specialized in chemicals as well as in mechanical and automotive engineering. By comparison, the strengths of the German regions are overall widely scattered; there is usually specialisation in at least two of the three high technology sectors. The same also applies to the French Alsace, Veneto and Lombardia in Italy, whilst Emilia-Romagna, Piemonte and Västsverige (S), only show an outstanding strength in mechanical and automotive engineering.

If one considers trends in employment in research-intensive industries from 1995 to 1999, there is a broad scatter in the leading industrialised high-tech regions, ranging from negative growth of 4.9 % in Hannover (D) to average annual gains of 8.0 % in Derbyshire and Nottinghamshire (UK) or 5.4 % in Berkshire Bucks and Oxfordshire (UK). The French Alsace also experienced considerable growth (5 %). On the EU average, employment over the same period experienced a slight upward trend (0.9 %). The German regions show, at best, a slightly above average, in five cases even negative, employment trend in this area. Only in the 'newcomer region' of Detmold, as well as in Arnsberg and Rheinhessen-Pfalz (D), did the number of jobs clearly rise, with growth rates between 3.0 and 3.8 % a year — a similar improvement was evident in Veneto (I). In the other Italian regions — with the exception of Piemonte which suffered absolute losses — slightly above average employment opportunities in high-tech industries were created. Hampshire Isle of Wight, along with the West Midlands, shows by far the lowest growth rate within the British leading regions for high-tech industries combined with strong growth in KIS and ICS, thus indicating that the region is experiencing a marked structural change towards KIS. Also in the French Alsace region and in the Italian regions — with the exception of Piemonte — additional jobs were created in high-tech industries.

Compared with 1995 or 1996, respectively the composition of the leading 15 regions remained nearly unchanged. The German regions Karlsruhe and Hannover, as well as Piemonte (I), slipped down the table considerably and Freiburg (D), West Midlands (UK), Västsverige (S), the Italian Lombardia and Veneto gained a few places. In contrast, in the lower half of the leading group some British (Berkshire Buckinghamshire and Oxfordshire as well as Derbyshire Nottinghamshire) and German regions (Detmold, Arnsberg and Düsseldorf) can be found now, whose percentage of high-tech employment did not reach the threshold value of 20 % above the EU average in 1995. Thus, they all have raised their ranking significantly. On the other hand regions like Weser-Ems (D), the surroundings of Greater Paris (Haute-Normandie, F) and also South Western Scotland (UK) slipped out of the leading group.

(19) These regions comprise at least 80 000 persons in research-intensive industries, representing at least 9.3 % of total employment (equivalent to 120 % of the EU average).

(20) Positive (negative) specialization is indicated by a value greater (less) than 100, i.e. the share of employees in a sector is higher (lower) than the European average.

Tab. 6.5.

Leading industrial high-tech regions ([1]) in the European Union and specialisation index of their employment shares and HRSTO ([2])
1999

Ranking	Region	Country	Employment in High-tech industries: Thousands	% of total employment	Annual average growth rate 1995-99 ([4])	% of total manufacturing	Specialization index ([3]) (EU-15=100): Chemicals: Employment	Chemicals: HRSTO	Mechanical & automotive: Employment	Mechanical & automotive: HRSTO	Electrotechnology, I&C, etc.: Employment	Electrotechnology, I&C, etc.: HRSTO
		EU-15	11 916	7.7	0.9	37.8	100	100	100	100	100	100
1	Stuttgart	D	379	20.5	1.0	56.9	63	74	340	129	241	104
2	Braunschweig	D	124	17.7	1.5	58.5	136	104	319	99	111	97
3	Tübingen	D	143	17.5	2.5	50.0	76	99	283	113	206	115
4	Rheinhessen-Pfalz	D	152	17.0	3.0	59.3	545	100	157	106	129	125
5	Karlsruhe	D	194	16.4	- 1.8	53.0	138	105	234	110	209	118
6	Freiburg	D	142	14.8	1.7	46.0	145	141	179	100	235	103
7	Unterfranken	D	88	14.5	- 1.1	48.9	85	83	254	100	121	84
8	Schwaben	D	120	14.5	1.7	47.3	105	97	221	124	169	113
9	Central Franconia	D	111	14.4	- 1.2	48.8	74	130	154	114	308	130
10	Piemonte	I	242	14.1	- 1.8	43.1	81	73	251	63	108	102
11	Darmstadt	D	235	13.8	1.8	61.4	339	129	138	129	148	143
12	Alsace	F	102	13.6	5.0	48.7	164	102	187	107	157	93
13	Oberbayern	D	273	13.6	2.2	58.9	139	107	166	166	210	167
14	West Midlands	UK	142	12.8	1.6	48.5	60	66	239	63	89	60
15	Lombardia	I	443	11.6	2.2	36.0	189	71	139	77	140	84
16	Västsverige	S	92	11.3	1.5	51.1	36	178	206	134	100	117
17	Hampshire Isle of Wight	UK	94	11.0	0.6	63.5	87	96	110	96	229	96
18	Köln	D	197	10.8	- 1.0	49.2	309	95	107	149	92	124
19	Derbyshire Nottinghamshire	UK	96	10.4	8.0	40.6	154	54	145	102	101	88
20	Arnsberg	D	160	10.3	3.3	36.4	100	81	141	109	135	103
21	Veneto	I	189	10.0	3.1	28.2	70	74	129	72	164	63
22	Berkshire Bucks, Oxfordshire	UK	112	10.0	5.4	56.4	124	139	103	110	177	94
23	Emilia-Romagna	I	170	9.9	2.4	33.4	92	93	154	81	96	55
24	Düsseldorf	D	211	9.6	1.7	40.5	217	106	105	142	100	100
25	Hannover	D	86	9.4	- 4.9	42.0	119	145	139	103	86	100
26	Detmold	D	83	9.4	3.8	29.0	108	65	125	123	118	115
27	Cataluña	E	221	9.3	2.8	34.1	162	108	109	64	110	64

([1]) With a share of at least 9.2 % of total employment (equivalent to 120 % of the EU average) and at least 80 000 people working in high-tech industries.
([2]) Professionals and technicians (ISCO 2+3) as a share of total employment in high-tech industries.
([3]) Sector's share of employment in manufacturing weighted with the particular EU-15 average share.
([4]) For the UK only data for NUTS 1 regions were available. Therefore annual growth rates have been calculated on the NUTS 98 level 2 for the period 1996-99.

Sources: Eurostat — CLFS, NIW calculations.

Regional demand for skilled labour in Science and Technology (S&T) occupations

The presence of research-intensive industries represents a region's industrial innovative potential. The extent to which this is exploited can be measured by the share of highly skilled manpower, determined with the aid of the occupation classifications used for measuring human resources in science and technology ([21]). Europe-wide, the share of employees in research-intensive industries working in S&T professions (HRSTO) is about 27 %, with considerable variation between the large high-tech regions — both for research-intensive industries overall and within the three separately considered high-tech sectors (see Table 6.5.). This indicates the functional division of labour between the regions. Some of the locations reveal a bias towards standardised production and manufacturing functions, whilst in other regions there is a greater emphasis on R&D and other more advanced services.

By far the highest percentage of highly skilled employees is in Upper Bavaria (centred around Munich, D) with around 43 %, followed by Darmstadt (D) with virtually 40 % ([22]). Köln and Mittelfranken (D) are 25 % above the European average.

The other British regions, except the West Midlands, achieve at best slightly above average and in most cases slightly below-average percentages of highly skilled manpower. This suggests a comparatively high manufacturing depth and a low presence of professional (i.e. non-productive) functions. The West Midlands, however, with their long tradition of industrialisation, come particularly low on the scale. The same applies to the Italian regions. The French Alsace matches the EU-average.

The German strength in the field of research-intensive industries is manifested not only by the presence of such industries, but also by a high input of human resources in many regions, and above all in southern and South-West Germany, contrasting with France, where human resources are strongly concentrated in Paris and the surrounding area.

If sectors are analysed within the field of research-intensive industries, the percentage of highly skilled employees in the fields of chemicals and electro-technology/I&C/etc. — each with roughly a third — is much higher than in mechanical and automotive engineering, with around 20 %. Nevertheless, there are, in some cases, large differences between the various regions:

- Darmstadt (D) has specialisation advantages and very high HRSTO levels (at least 10 % above the EU average) in all three industrial sectors and is thus particularly well equipped in competition as a location for innovative companies. The same applies for two sectors (mechanical and automotive engineering and electrotechnology/I&C/etc.) in Upper Bavaria, Tübingen, Karlsruhe, Schwaben and Mittelfranken (D).
- In Västsverige (S), an above average percentage of highly skilled staff is employed, although there is one-sided specialisation in machinery and transport.
- The British regions employ in general, and particularly in their respective main sectors, less highly skilled staff than the other leading European regions do. This is particularly noticeable in the West Midlands.

CONCLUSIONS

This brief review of the regional distribution of research-intensive industries and knowledge-intensive services in European regions points to differences in interregional and intersectoral development patterns, which frequently spread beyond the national borders. However, the demarcation of the various sectors on the level of NACE divisions (two-digit level) is rather crude, and this applies particularly to the research-intensive industries. A demarcation on the three-digit level would be desirable for the benefit of future and more detailed studies — it would then be possible to differentiate aerospace manufacturing from manufacturing of transport equipment, in general. The same is true for pharmaceuticals within the chemicals, chemical products and man-made fibres classification.

Further analysis of the reservoir of skills in the labour force should bear interesting clues to two initial aspects. Firstly, to the functional division of labour (for example, between KIS, ICS and research-intensive industries). Secondly, to the competitiveness of regions in attracting innovative companies (via resource advantages such as the educational qualifications of employees). There is also a need for additional diversified research, partly to include additional subgroups (alongside ICS) within the sector of knowledge-intensive services as well as to illuminate the interplay between industry and the service sector.

([21]) The *Canberra Manual*, jointly compiled by OECD and Eurostat (1995), provides guidelines for recording and measuring human resources in science and technology (HRST).
For further information on the classification of HRST in this publication, see Chapter 7.

([22]) Even higher proportions are observed for Greater Paris, Stockholm, Uusimaa and Noord-Holland, regions that are not considered in Table 6.5 because of the low structural weight of the high-tech industries in total employment.

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PART 2

Human resources in science and technology

CHAPTER 7

INTRODUCTION

Data on Human Resources in Science and Technology (HRST) can improve our understanding of both the demand for, and supply of, science and technology personnel. As a result, this chapter focuses on two main aspects: stocks and flows. The former serves to show the needs of the labour force and the latter indicates to what degree this demand is likely to be met in the future. Within this assemblage, particular attention should be paid to the sub-set of scientists and engineers (S&E), quite often the innovators at the nucleus of the technology led development.

7.1. METHODOLOGY

Data on Human Resources in Science and Technology are collected in line with the recommendations laid down in the *Manual on the Measurement of Human Resources Devoted to S&T — Canberra Manual* ([1]).

HRST stock data are extracted from the Community Labour Force Survey (CLFS). The CLFS is based upon a sample of the population and, therefore, the results are subject to the usual types of errors associated with sampling techniques, as well as a number of other non-sampling errors, for example, non-response, miscoding, etc. All results conform to Eurostat guidelines on sample-size limitations and are therefore not published if the degree of sampling error is likely to be high ([2]).

HRST flows data are obtained from two sources. Data on flows coming from the education system use the joint UOE (Unesco, OECD, Eurostat) questionnaire on education, which began in 1985 ([3]). A revision in 1992 and a resulting break in some aspects of comparability have implied that if a consideration of field of study is to be made, then 1993/94 becomes the starting point. Data on mobility of highly qualified personnel come from the CLFS, using information both on when the current job began and the working status of the person in question one year before the survey.

Some definitions

HRST is defined according to the *Canberra Manual* as a person fulfilling one of the following conditions:

- Successfully completed education at the third level in a S&T field of study ([4]);
- Not formally qualified as above, but employed in a S&T occupation where the above qualifications are normally required.

HRST by education (HRSTE)

In order to minimise cultural differences in education systems and to increase cross-country comparability, HRST analysis uses the International Standard Classification of Education (ISCED) developed by Unesco ([5]). Due to an increasing demand for internationally comparable indicators on education and a mounting complexity in the educational programmes on offer in different countries, the original standard, developed in 1976, has been revised and updated in 1997.

As a result, HRST data in this chapter up to and including 1997 are built up utilising the original classification. From 1998, ISCED 1997 is employed.

Prior to 1998, therefore, HRST consists of those persons that belong in ISCED categories 5, 6 and 7. ISCED 5 is comprised of people that are involved in studies at the third/tertiary level, first stage that leads to an award not equivalent to a first university degree. ISCED 6 refers to education that leads to a first university degree or the equivalent, whereas ISCED 7 refers to education that leads to a postgraduate university degree or equivalent.

Under the new ISCED classification, HRST consists of those persons that belong in categories 5B, 5A and 6. ISCED 5B refers to programmes which are practical/technical/occupationally specific; 5A refers to programmes which are largely theoretically based/research preparatory or which provide access to professions with high skill requirement; 6 refers to programmes which lead directly to an advanced research qualification, such as a doctoral degree.

HRST by occupation (HRSTO)

Occupations relevant to S&T are classified according to the International Standard Classification of Occupation (ISCO), developed by the International Labour Organisation (ILO) ([6]). Recommendations in the *Canberra Manual* identify certain occupation groups as HRST, whether the person has a formal education qualification or not. The major group 'professionals' (ISCO major group 2) is defined as: occupations which mostly require skills at the fourth ISCO level, which is considered equivalent to ISCED '76 categories 6 or 7 i.e. university level HRST. Similarly, ISCO 3 ('technicians') is defined as requiring skills that correspond to ISCED '76 level 5.

(1) *Manual on the Measurement of Human Resources Devoted to Science and Technology — Canberra Manual*, OECD, Paris, 1994.
(2) Further details of the methodology and definitions of the CLFS in general and from a country specific point of view can be found in the publication: *The European Union Labour Force Survey — Methods and definitions*, Eurostat, Luxembourg, 1998.
(3) See *Education Across the European Union — Statistics and indicators*, Eurostat, Luxembourg, 2000.
(4) According to the *Canberra Manual*, the seven broad S&T fields of study are Natural Sciences, Engineering and Technology, Medical Sciences, Agricultural sciences, social sciences, humanities, other fields, *Canberra Manual*, Paragraph 71.
(5) Unesco, *International Standard Classification of Education*, Unesco, Paris, 1976, 1997.
(6) International Labour Organisation, *International Standard Classification of Occupation*, ILO, Geneva, 1988.

For this reason, both these groups are comprehensively included. Professionals are sub-divided into four sub-major groups — physical, mathematical and engineering science professionals; life science and health professionals; teaching professionals; and other professionals — the first two making up the sub-set of scientists and engineers (S&E). In contrast to the recommendations laid down in the *Canberra Manual*, legislators and managers (i.e. Production and Operations Department Managers, Other Department Managers, General Managers) that may work in the field of S&T (ISCO 122, 123 and 131) are only included if they have attained education at the third level (7). This is because a pilot survey conducted in 1995 tested the validity of the original definitions for HRST and the results indicated that, for the EU, including these certain managerial occupations distorted the results significantly, due to variations between countries in the treatment and classification of managers.

The breakdown of HRST

In addition to overall HRST, the following sub-set of HRST categories considered in this chapter is more easily understood by looking at Table 7.1.

- **HRSTO**: those people working in a S&T occupation;
- **S&E**: those people working in scientific and engineering related occupations (a sub-set of HRSTO);
- **HRSTE**: those people who have successfully completed third level education;
- **HRSTC**: the core HRST (those people who have a third level education and work in a S&T occupation);
- **HRSTU**: those people with third level education who are unemployed.

Some caveats

A number of caveats should be underlined. The first concerns the use of ISCED. While the use of this international classification provides data that is generally comparable, the system is not perfect. Since the analysis takes place at the international level, it encompasses manifold education systems and, thus, some differences are inevitable. However, a revised version of ISCED, introduced in 1997, has sought to more accurately categorise different education classifications. But this also means that data over the time series are collected according to different methodological definitions. As a result, Eurostat and Unesco have both conducted research into the comparability of these two versions. Both have recommended that comparison between new and old versions should take place by creating an ISCED 'High', grouping subsets within this category. For ISCED '76 this consists of levels 5, 6 & 7. And for the 1997 version, this is composed of 5B, 5A and 6. The starting point for data using ISCED '97 in the Community Labour Force Survey is 1998.

A second note of caution arises from the differences that exist in national education systems. The age bracket where people begin to work is one of the most fundamental areas for this research. But, because there are idiosyncrasies in the average age of graduation across countries and cultures, it is only natural that there will be no perfect solution to the question of comparability. The general consensus, however, is that using the age 25 as a starting point will reduce the shortcomings as far as possible.

(7) The *Canberra Manual* states that legislators and managers should be included as HRST regardless of their level of education.

Tab. 7.1.

Categories of HRST (1)

		HRSTE (Education)				
		Tertiary education			Lower than tertiary education	Total
		ISCED 6	ISCED 5A	ISCED 5B	ISCED < 5B	
HRSTO (Occupation)	Professionals	HRST core			HRST without tertiary education	
	Technicians					
	Managers	HRST non-core				
	All other occupations					
	Unemployed	HRST unemployed				
	Inactive	HRST inactive				
	Total					

(1) This table utilises the education classification ISCED '97.
With the former ISCED '76, tertiary education would be compiled of ISCED 5, 6 and 7.

Source: Eurostat.

Tab. 7.2.

HRST stocks by country 1999

	HRST in thousands		HRSTE in thousands		HRSTO in thousands		HRSTC in thousands		HRSTC as a % of labour force		
	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Total
EU-15	29 965	35 134	20 939	25 089	19 977	22 454	10 950	12 409	15	13	14
B	976	1 079	839	840	567	660	431	421	23	17	20
DK	565	620	421	429	425	440	280	249	21	16	19
D	7 878	10 093	4 362	7 525	5 855	5 943	2 339	3 375	14	15	14
EL (1)	561	692	471	582	352	414	263	303	15	11	13
E	2 796	3 121	2 540	2 629	1 240	1 575	984	1 084	15	11	13
F	4 962	5 282	4 000	3 752	2 924	3 454	1 962	1 924	17	14	15
IRL (2)	277	294	249	247	133	154	105	107	18	11	14
I	2 944	3 554	1 556	1 742	2 232	2 859	844	1 047	9	7	8
L	32	46	19	29	25	36	12	19	17	17	17
NL	1 666	1 963	1 000	1 291	1 255	1 407	589	735	17	16	17
A	481	560	192	241	409	453	120	134	7	6	7
P	412	404	299	219	331	333	217	148	9	5	7
FIN	697	566	519	431	441	347	263	212	21	15	18
S	997	1 051	791	724	708	742	501	416	24	18	21
UK	4 720	5 809	3 681	4 408	3 079	3 636	2 040	2 235	16	14	15

(1) Exception to the reference period: 1998.
(2) Exception to the reference period: 1997.

Source: Eurostat — CLFS.

7.2. STOCKS: LABOUR MARKET EVOLUTIONS

This section concentrates on presenting the recent trends in HRST in the labour markets of the EU Member States and highlights a number of interesting developments. The effective starting point for the analysis is 1994, however the comprehensiveness of the data is not uniform and thus some stock indicators can not be presented for all countries for all years.

General HRST

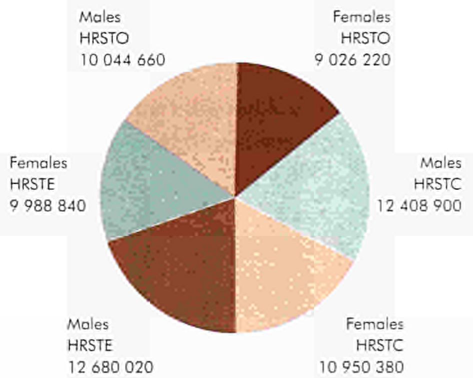
According to the latest available data from the CLFS for 1999, there were approximately 65 million people classified as HRST in the EU, of which just more than 35 million were male (see Figure 7.1.). Nearly 23.5 million people in the EU have a third level education and work in a S&T occupation (HRSTC), but women are slightly more likely to work in a S&T related occupation following third level education than men are (36.5 % of women enter this category as compared with 35.3 % of men). Men, on the other hand, seem more likely to enter a non-S&T profession following studies than women do (36.1 and 33.3 %, respectively).

Disaggregating the data by country reveals some national differences, both in the overall levels of HRST and in the presence of women in science (see Table 7.2.). In absolute terms, the four large EU countries (Germany, France, Italy and the United Kingdom) have the highest levels of HRST. However, when a consideration of HRSTC is made, both Spain (slightly more) and Italy (slightly less) follow Germany, France and the United Kingdom with around 2 million people in this category.

A more informative indicator is HRSTC as a proportion of the respective labour force (where the labour force equals employed plus unemployed persons, but excludes inactives) allowing an insight into the degree to which countries have a highly qualified workforce employed in S&T occupations. The Nordic countries are particularly strong as compared to the EU average. Furthermore, the ratio is higher in the case of women than of men. This is especially true in Sweden, where almost one in four women in the labour force are part of the HRSTC stock.

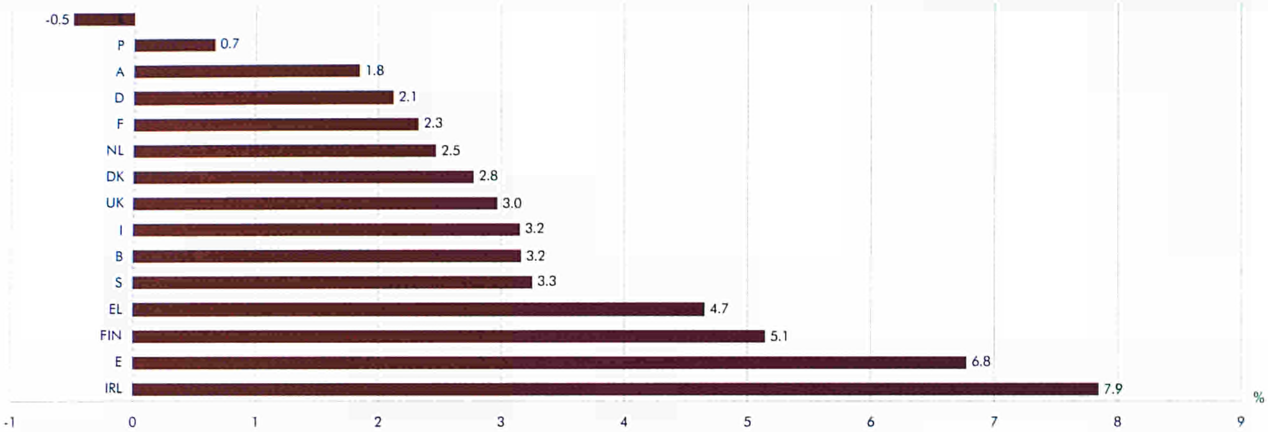
Ireland, Austria and the southern Member States fall below the EU average in the case of men; in Italy, Austria and Portugal, less than one in ten men in the labour force are HRSTC. In Germany, female HRSTC as a proportion of the labour force falls below the average. This is also the case for Italy, Austria, and Portugal.

Fig. 7.1. Stock of HRST in the European Union 1999



Source: Eurostat — CLFS.

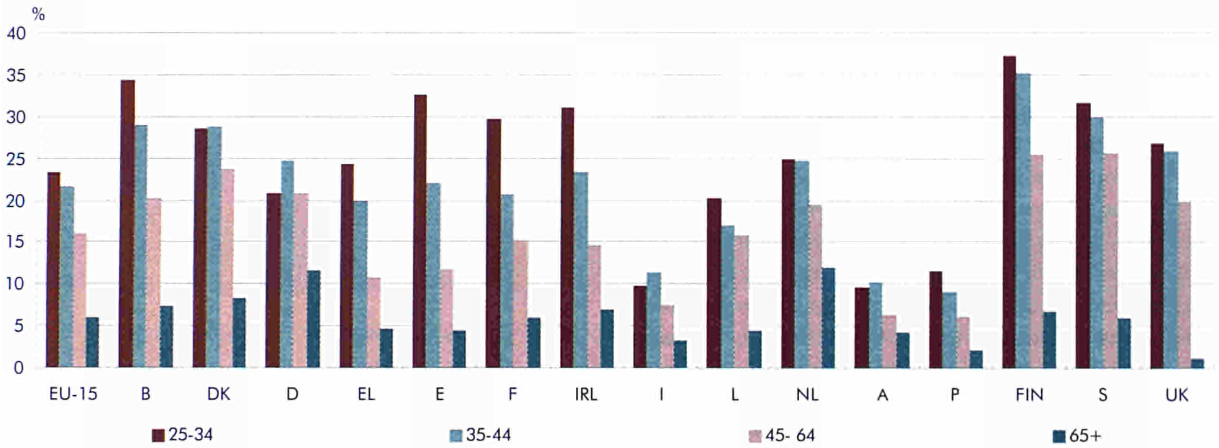
Fig. 7.2. Annual average growth rate in HRST by country 1994-99 (1)



(1) Exceptions to the reference period — EL: 1994-98, IRL: 1994-97, A: 1995-99, P 1998-99, FIN: 1998-99, S: 1997-99.

Source: Eurostat — CLFS.

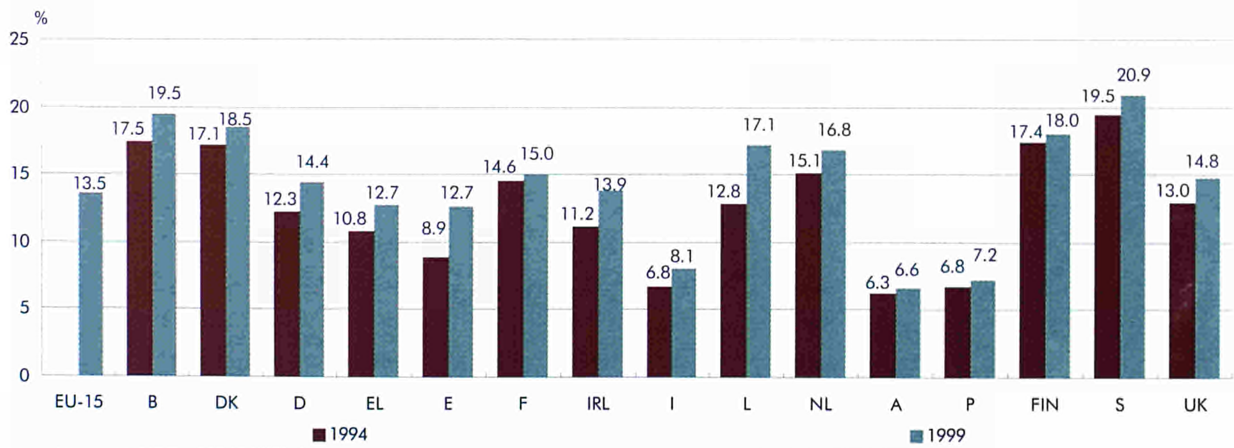
Fig. 7.3. HRSTE as a % of the respective population by age and country 1999 (1)



(1) Exceptions to the reference period — EL: 1998, IRL: 1997.

Source: Eurostat — CLFS.

Fig. 7.4. HRSTC as a % of the labour force by country 1994 and 1999 (1)



(1) Exceptions to the reference period — EL: 1994-98, IRL: 1994-97, A: 1995-99, P: 1998-99, FIN: 1998-99, S: 1997-99.

Source: Eurostat — CLFS.

HRST has nevertheless been increasing over time in all countries but Luxembourg (see Figure 7.2.). Over the period 1994-99, the highest growth can be seen in the relatively smaller EU Member State, Ireland, at close to 8 % per annum; followed by Spain at nearly 7 % annual average growth. The next two, growing at almost 5 % per annum, are Greece and Finland (although the time series is not long). The remaining EU countries are all growing at around 2 to 3.5 % per year, apart from Portugal, where growth of nearly 1 % was experienced.

Education — HRSTE

The growth in the number of highly educated people is apparent from the disaggregation of HRSTE by age (Figure 7.3.). Measured as a proportion of their respective populations in 1999, the differences between the age groups 25-34, 35-44, 45-64 and 65 and over gives an indication of the degree to which the importance of higher education has grown in the EU. Only in Denmark, Germany, Italy and Austria is the ratio HRSTE/population lower for 25-34 year olds than it is for 35-44 year olds.

Finland has by far the highest HRSTE/population ratios with around 37 % for 25-34 year olds and 35 % for the age bracket above. Although, Belgium, Spain, Ireland and Sweden all have rates for the lowest age bracket of between 30 and 35 %. Over a quarter of people aged 25-34 have a third level education in Denmark, France and the United Kingdom — just above the EU average of 23 %. In Italy, Austria and Portugal between around 8 and 10 % of people in the same age group have a third level education.

Core — HRSTC

A cursory inspection of Figure 7.4. reveals that the number of people with a third level education and working in a S&T profession has increased in all EU Member States in the period 1994 to 1999. In 1999, Sweden had the highest overall level, with around 21 %, followed by Belgium (19.5 %), Denmark (18.5 %) and Finland (18 %).

Nevertheless, some of the other countries, notably Spain, Ireland and Luxembourg, are growing more quickly. In Italy, Austria and Portugal, HRSTC as a proportion of the labour force grew more moderately.

In the three other large EU countries — Germany, France and the United Kingdom — 1999 levels all stood at around 15 %, with Germany and the UK making larger gains since 1994 to put them on a more even level with France.

Scientists and engineers

A current sub-set of HRSTO (ISCO 2 and 3) of particular interest is that of those working in scientific and engineering professions.

There is a high degree of variation between the Member States in terms of the distribution of scientists and engineers, both with respect to the age categories that are the most in demand and to the differences between men and women (see Table 7.3.).

Portugal and Finland are the leading countries in terms of growth, although the measurement period is far shorter than for most of the other countries observed. Denmark, Spain, Ireland, Luxembourg and the Netherlands all saw growth of between 5.5 % and 7 % during their respective observation periods.

The country variations between levels of male and female scientists and engineers are also significant. These range from a heavy male dominance in countries such as Germany and Luxembourg to Ireland and Finland where the percentage of female S&E is slightly higher than their male counterparts. More than four out of ten scientists and engineers are female in Belgium, Spain, Ireland, Portugal and Finland.

Looking at the various age groups, differences in the relative demand for scientists and engineers become more apparent. You are most likely to be a scientist or engineer aged 25-34 in Denmark, Spain, Ireland, the Netherlands, Portugal or the United Kingdom. The same is true for S&E aged 35-44 in Belgium, Greece, Italy, Luxembourg and Austria. Scientists and engineers in Germany, France, Finland and Sweden are more likely to fall in the 45-64 age bracket. Ireland has the highest level of scientists and engineers aged below 25 — a sub-set of the 'other' age group.

Unemployment — HRSTU

A brief examination of Figure 7.5., which shows the share of unemployed people in the HRST stock as compared with the overall unemployment rates, reveals that most countries in 1999 had a share of unemployed HRST of under 5 %. The exceptions are Greece, Spain, Italy and France (for 1998). It is in these countries that total unemployment rates are higher also.

Most of the Member States have seen a diminution in both rates in 1999 compared to 1994, but the lowest rates for active HRSTE are evident in Luxembourg, the Netherlands and Austria.

Unsurprisingly, there is a strong disparity between the unemployment rate of those that have a third level education and the overall unemployment rate. This difference would be accentuated should unemployed HRSTE be excluded from the overall unemployment rate.

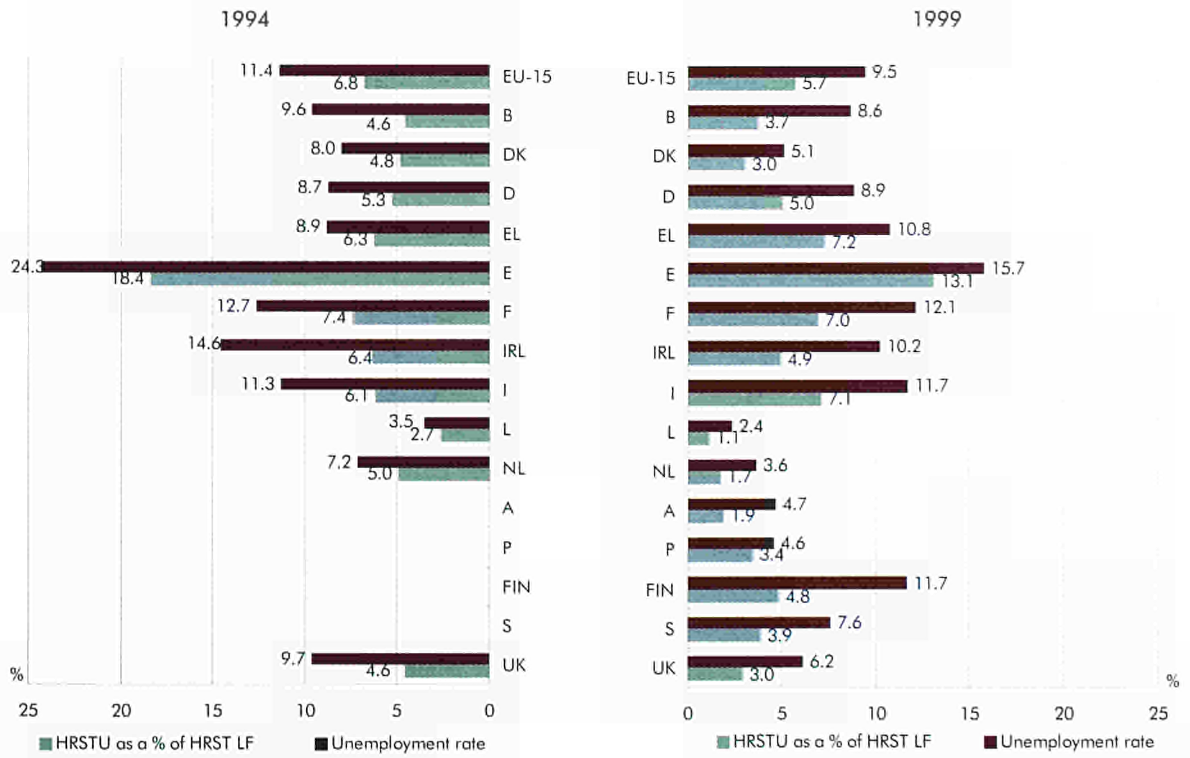
Tab. 7.3. Distribution of people employed as scientists and engineers by gender and age in 1999 (1) and annual average growth rate for 1994-99 (2)

	Total	Gender in %		Age groups				Annual average
		Female	Male	25-34	35-44	45-64	Other	growth rate
EU-15	7 930 430	31.2	68.8	2 406 010	2 559 610	2 556 680	408 130	:
B	314 460	47.8	52.2	101 880	110 360	80 910	21 310	2.4
DK	142 780	24.8	75.2	51 770	47 210	39 860	3 940	6.4
D	1 919 540	21.0	79.0	543 670	621 600	710 210	44 060	3.5
EL	142 660	29.0	71.0	37 760	53 440	48 120	3 340	2.9
E	573 410	37.3	62.7	187 020	183 930	161 630	40 830	5.9
F	1 045 550	23.8	76.2	296 590	345 030	373 830	30 100	2.2
IRL	111 870	51.0	49.0	38 910	30 880	25 190	16 890	6.7
I	585 070	29.3	70.7	122 280	247 160	194 010	21 620	4.7
L	9 660	20.1	79.9	2 810	3 450	3 150	250	6.4
NL	450 450	31.2	68.8	149 820	141 390	130 730	28 510	5.7
A	82 610	29.0	71.0	28 000	29 960	21 860	2 790	4.5
P	104 750	43.8	56.2	41 070	29 800	26 130	7 750	17.6
FIN	200 820	50.9	49.1	62 940	60 010	66 740	11 130	14.7
S	218 330	40.5	59.5	60 840	64 870	83 640	8 980	1.9
UK	2 028 470	37.1	62.9	680 650	590 520	590 670	166 630	2.9

(1) Exceptions to the reference period — EL: 1998, IRL: 1997.
(2) Exceptions to the reference period — EL: 1994-98, IRL: 1994-97, A: 1995-99, P: 1998-99, FIN: 1998-99, S: 1997-99.
EU-15 is not calculated due to the variable data series of Member States.

Source: Eurostat — CLFS.

Fig. 7.5. HRST unemployment and total unemployment by country 1994 and 1999 (1)



(1) Exceptions to the reference period — EL: 1998, IRL: 1997.

Source: Eurostat — CLFS.

7.3. FLOWS: EDUCATION AND MOBILITY

The measurement of HRST stocks gives an indication of the various degrees of demand for S&T workers. It does not however provide any suggestion of what the future situation will be. Measuring the flows entering as well as leaving the national stock of HRST provides an important and interrelated proxy for expectations of the future environment.

There are many different flows entering and leaving the national stock of HRST (see Figure 7.6.), some of which are easier to compare at the international level than others. The number of graduates from a country's higher education system represents the main inflow into the national stock of HRST. A second type is intersectoral flows — or domestic mobility — of HRST, both of those that have a third level education and of those that do not, but enter/leave an S&T occupation nevertheless. Within these intersectoral flows, the former provides an indication of the level of knowledge diffusion, technology transfer and also flexibility of the labour market for the relevant sectors. The latter is interesting in that it provides an indication of the excess demand for S&T occupations.

Education

Inflows of HRST from the higher education system are probably the most significant factor when it comes to explaining changes in the stock levels of HRST. The financial commitment of Governments towards tertiary education was 1.1 % of GDP in the EU in 1996, again with country by country differences [8]. Although more is spent in absolute terms at the primary and secondary level, spending per head on higher education is generally much higher.

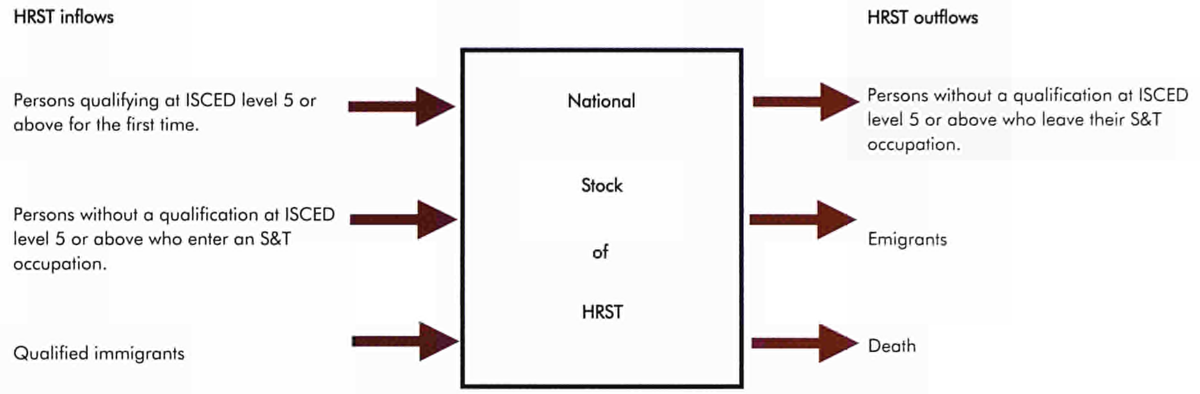
However, there are limitations in the degree to which comparisons of tertiary education within the EU can be made, since degree structures vary. A degree may be a long programme such as in Germany or a short programme as is the case in Ireland and the United Kingdom. Moreover, there are differences in the types of programmes available. Consequently, some degree of caution should be applied when considering these results, as some problems remain with comparing international education statistics.

Growth in tertiary education

There has been considerable growth in the higher education systems of the EU. Figure 7.7. displays the annual average growth in the number of students enrolled in higher education over the past 15 years for which data are available. The graph clearly shows the extent to which the higher education system has expanded in the 1980s and 1990s. According to these data, growth for the majority of countries seems to be at its strongest in the late 1980s, after which the pace has diminished somewhat. Only the Netherlands has experienced a reduction in the number of students participating in tertiary level education during the 1990s. The largest growth is evident in those countries where numbers were relatively low, as in the cases of Greece and Portugal, along with those countries where the first degree at university level requires a short amount of time (Ireland, the United Kingdom). The lack of comparable data for Germany prior to the third time period — 1992/93 to 1996/97 — reflects reunification.

(8) See *Education Across the European Union — Statistics and indicators*, Eurostat, Luxembourg, 2000.

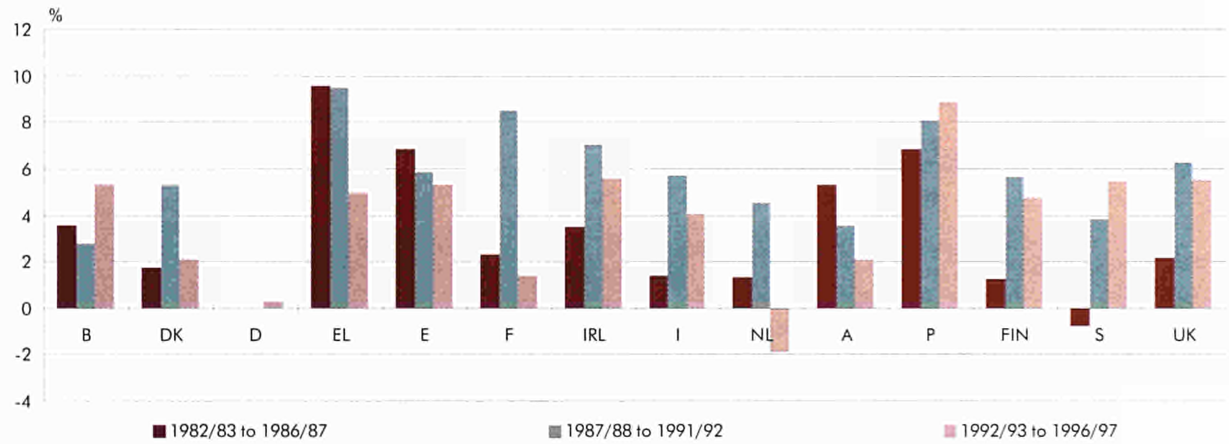
Fig. 7.6. The main flows into and out of the national stock of HRST ([1])



([1]) Figure 4.1. of the *Canberra Manual.*

Sources: European Commission, OECD.

Fig. 7.7. Annual average growth rate in the number of students in tertiary education by country ([1]) 1982/83-1996/97

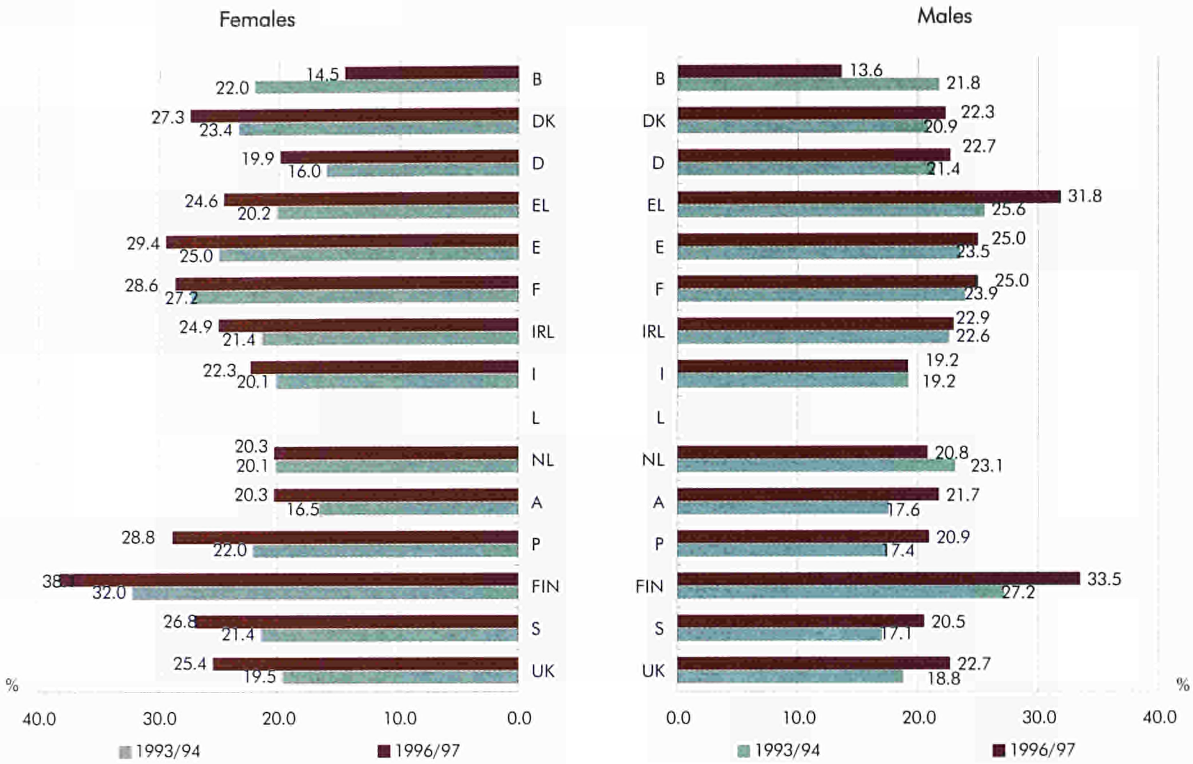


([1]) Germany (D) is not considered before time period 1992/93 to 1996/97 due to reunification.

Sources: Eurostat, Unesco.

Fig. 7.8.

Students in tertiary education as a % of people aged 20-29 by gender and country 1993/94 and 1996/97 (1)



(1) Exception to 1996/97: Belgian data refer to the Flemish Community only.

Source: Eurostat — Education across the EU, CLFS.

Tab. 7.4.

Graduation from tertiary education as a % of people aged 25-29 by gender and country 1993/94-1996/97 (1)

	Females in %				Males in %				Total in %			
	1993/94	1994/95	1995/96	1996/97	1993/94	1994/95	1995/96	1996/97	1993/94	1994/95	1995/96	1996/97
B	8.1	:	:	5.8	7.4	:	:	5.7	7.7	:	:	5.4
DK	6.2	8.1	8.4	9.1	5.3	7.2	7.3	7.4	5.7	7.7	7.8	8.2
D	4.3	4.9	5.1	:	5.1	5.7	5.7	:	4.7	5.3	5.4	:
EL	4.1	4.8	4.4	3.9	3.4	4.1	3.9	4.3	3.8	4.5	4.2	4.1
E	5.8	7.2	8.1	9.6	4.6	5.3	6.0	6.4	5.2	6.2	7.0	7.9
F	:	:	15.9	14.6	:	:	11.8	11.5	:	:	13.9	13.1
IRL (2)	12.2	13.7	12.4	13.7	11.6	13.1	12.6	12.9	11.9	13.4	12.5	13.3
I	4.8	4.3	4.1	:	3.7	3.4	3.2	:	4.2	3.9	3.7	:
L	:	:	:	:	:	:	:	:	:	:	:	:
NL	5.5	6.0	7.1	:	5.9	6.1	6.7	:	5.7	6.1	6.9	:
A	2.7	2.9	2.9	3.4	2.6	2.6	2.7	3.1	2.6	2.7	2.8	3.3
P	6.5	7.4	8.1	9.2	4.2	4.7	4.6	5.0	5.4	6.1	6.4	7.1
FIN	10.2	9.4	9.5	10.2	7.2	6.9	6.9	7.1	8.7	8.1	8.2	8.7
S	6.8	6.4	6.1	6.9	4.1	4.6	4.5	4.8	5.4	5.5	5.3	5.8
UK	10.5	11.2	10.4	11.1	9.7	9.4	9.5	9.7	10.1	10.3	9.9	10.4

(1) Exception to 1996/97: Belgian data refer to the Flemish Community only.

(2) Includes students who graduated a second time at the same ISCED level (approx. 4.0). Excludes a number of students at ISCED 5 who received professional qualifications from various professional bodies (accountancy, marketing and secretarial).

Source: Eurostat — Education across the EU, CLFS.

Participation in tertiary education

Since the lead times to train and develop S&T skills are long and the costs are high, whilst demand can change more rapidly, the education system can take several years to respond. For this reason it is necessary to have an indication of the number of S&T graduates that may potentially alleviate labour market shortages. In other words, student participation can provide the basis for projections of future supply of HRST. It is also necessary to put these figures into some kind of perspective that takes into account the size of the domestic population and, thus, the proportion of young people (aged between 20 and 29) who participate in tertiary education is considered.

A brief examination of participation rates in tertiary education as a percentage of persons aged 20-29 (Figure 7.8.) reveals the general overall rise in participation levels in tertiary education. For women, participation has increased in all of the analysed countries — something that does not hold true for men.

Also noteworthy is that a comparison of men and women shows that, in many of the Member States, participation is higher amongst the female population under consideration than it is for males. In the 1996/97 academic year, the exceptions are Germany — which has the lowest female participation rate — Greece, the Netherlands and Austria.

The highest participation rates for both men and women can be noted in Finland. In Denmark, Spain, France, Portugal, Finland, Sweden and the UK, a quarter or more of all females aged 20 to 29 undertake a tertiary level diploma. For males, this is the case in Greece, Spain, France and Finland.

Graduation from tertiary education

While a useful measure for future expectations, participation rates do not, on their own, give a comprehensive picture of flows into HRST. Rather they serve to illustrate potential HRST inflows. These figures should therefore be complemented by graduation rates. Tertiary graduation rates indicate the production rate of HRST by each country's education system.

A brief inspection of Table 7.4. highlights the non-axiomatic relationship between participation rates and the rate of graduation. However, certain factors must be taken into consideration.

Firstly, lower graduation rates in certain EU countries such as Italy and Austria can partly be explained by the longer duration of tertiary studies. Looking back at Figure 7.8. the disparity between these two countries and the rest of the EU is far lower than that exhibited in Table 7.4. Therefore, to a certain extent, comparison should be made with slight caution, owing to national specificities in education systems.

Furthermore, for comparison of participation rates and graduation rates, one should also highlight the differing populations. While for participation rates, in order to ensure the lowest possible level of exclusion, it is necessary to employ a population that covers 20-29 year olds, for graduation rates, in countries with longer duration tertiary education, including 20-25 year olds would distort the picture excessively. Thus, graduation rates are expressed as a proportion of the 25-29 year old population.

These caveats apart, closer scrutiny of Table 7.4. reveals rising overall graduation rates as a proportion of the 25-29 year old population, confirming the increasingly skilled (educated) nature of the labour force. However, this trend is not uniform across all Member States analysed. Excluding Belgium, for which 1996/97 data refer to the Flemish Community only, over the time period analysed, graduation rates have fallen only in Greece, France and Italy for women and in France, Italy and Finland for men. The highest overall graduation rates in 1997 are evident in Ireland.

Another noticeable feature is that graduation rates are, except for Germany and Greece, higher on the whole for females than they are for males over the observation period.

Table 7.4. and Figure 7.8. imply a negative correlation between the duration of the degree and the graduation rate, with those countries operating shorter degree programmes (i.e. in Ireland and the United Kingdom) achieving higher graduation rates compared to countries where a long programme predominates — as in Germany, Italy and Austria.

Tab. 7.5. People graduating in science and engineering by gender and country 1993/94-1996/97 (1)

	Females					Males					Total
	Thousands				% of grads	Thousands				% of grads	% of grads
	1993/94	1994/95	1995/96	1996/97	1997	1993/94	1994/95	1995/96	1996/97	1997	1997
B (1)	8.3	:	:	5.0	23.7	13.4	:	:	5.4	29.0	26.2
DK	4.2	6.1	5.2	5.0	29.8	5.2	6.5	6.2	5.0	36.0	32.6
D (2)	58.1	56.8	53.4	53.4	34.8	109.3	111.6	107.0	107.0	58.5	47.7
EL	4.4	:	:	:	:	5.8	:	:	:	:	:
E	19.5	26.1	28.0	32.4	25.2	26.1	32.2	35.4	40.4	42.8	32.6
F	:	:	84.0	65.6	21.1	:	:	126.2	110.5	46.2	32.0
IRL	5.1	5.7	4.1	5.1	28.1	7.6	8.4	8.4	8.4	49.3	38.3
I (2)	22.6	22.6	24.2	24.2	24.7	31.2	30.6	32.9	32.9	42.4	32.5
L	:	:	:	:	:	:	:	:	:	:	:
NL (2)	9.1	9.0	9.9	9.9	22.6	15.4	15.2	16.8	16.8	38.8	30.6
A	2.1	2.5	2.4	2.8	25.4	4.0	3.8	4.0	4.5	44.2	34.4
P	4.5	4.7	5.2	6.4	23.6	4.5	4.9	5.1	5.6	36.4	28.2
FIN	10.5	8.8	8.5	8.5	51.0	8.7	8.3	8.3	8.0	66.6	57.5
S	8.7	6.9	7.2	8.1	39.5	7.7	8.3	8.2	8.5	57.7	47.1
UK	89.5	90.3	62.5	70.0	29.2	106.8	100.1	98.7	97.6	45.1	36.7

(1) Exception to 1996/97: Belgian data refer to the Flemish Community only.
(2) Exceptions to 1996/97: Germany (D), Italy (I) and the Netherlands (NL) refer to 1995/96.

Source: Eurostat — Education across the EU.

Tab. 7.6. Graduates by country, gender and field of study 1996/97

Females in thousands	B (1, 2)	DK	D (2)	EL	E	F	IRL (3)	I (2, 4)	L	NL (2)	A	P	FIN	S	UK
Total	21.1	16.8	153.7	13.9	128.8	310.9	18.3	98.0	:	44.0	11.1	27.3	16.6	20.5	239.9
Humanities, Applied arts, Religion	1.9	2.2	19.3	:	12.4	52.5	3.8	19.6	:	4.5	1.7	3.4	1.7	1.4	47.6
Social sciences (5)	5.0	3.1	33.6	:	34.7	129.4	6.1	18.4	:	16.8	2.4	9.4	2.7	4.0	71.9
Education science and teacher training	4.1	4.4	9.1	:	20.1	20.1	1.5	3.5	:	8.5	2.8	5.1	2.3	6.2	36.9
Law	0.8	0.7	5.6	:	19.1	28.1	0.6	10.8	:	2.4	0.8	1.5	0.2	0.6	10.5
Natural sciences	0.3	0.3	6.3	:	5.5	23.4	2.9	5.4	:	1.0	0.5	0.7	0.4	0.8	16.8
Mathematics, Computer science	0.2	0.2	3.4	:	3.2	4.8	0.7	2.5	:	0.3	0.2	0.7	0.3	0.3	7.1
Medical sciences	3.5	3.6	34.6	:	16.4	21.9	0.9	10.9	:	7.3	1.6	3.3	6.8	5.6	36.4
Engineering, Architecture (6)	1.0	0.9	9.2	:	7.4	15.5	0.7	5.5	:	1.3	0.6	1.8	1.0	1.4	9.7
Others (7)	4.3	1.4	32.7	:	10.2	15.4	1.2	2.6	:	2.0	0.7	1.4	1.3	0.3	3.1
Field of study unknown	-	-	-	:	-	-	-	18.9	:	-	-	-	-	-	-

Males in thousands	B (1, 2)	DK	D (2)	EL	E	F	IRL (3)	I (2, 4)	L	NL (2)	A	P	FIN	S	UK
Total	18.6	14.0	182.8	14.0	94.3	239.4	17.1	77.5	:	43.2	10.3	15.5	12.0	14.7	216.3
Humanities, Applied arts, Religion	1.1	0.7	9.9	:	6.3	18.4	2.2	4.2	:	2.4	1.0	1.3	0.7	0.9	30.3
Social sciences (5)	4.3	5.0	39.6	:	23.6	76.1	4.8	17.2	:	15.6	2.2	5.7	1.5	3.0	61.6
Education science and teacher training	1.7	1.3	3.1	:	6.5	9.1	0.5	0.4	:	3.8	0.8	1.1	0.7	1.6	15.5
Law	0.7	0.5	7.6	:	11.6	15.6	0.4	8.8	:	2.0	1.1	0.8	0.2	0.5	7.9
Natural sciences	0.4	0.4	13.7	:	5.2	22.5	2.0	4.5	:	2.1	0.7	0.3	0.4	0.8	18.5
Mathematics, Computer science	0.8	0.3	8.8	:	6.5	9.2	1.2	2.6	:	2.3	0.7	0.6	1.2	1.1	19.7
Medical sciences	1.4	0.5	19.3	:	6.0	8.4	0.5	9.3	:	3.3	0.7	1.0	1.1	1.6	11.3
Engineering, Architecture (6)	2.8	3.8	65.2	:	22.7	70.4	4.7	16.5	:	9.1	2.5	3.7	5.3	5.0	48.1
Others (7)	5.2	1.5	15.5	:	5.8	9.7	0.8	3.3	:	2.6	0.6	1.0	0.9	0.3	3.5
Field of study unknown	-	-	-	:	0.1	-	-	10.6	:	-	-	-	-	-	-

(1) Exception to 1996/97: Belgian data refer to the Flemish Community only.
(2) Exceptions to 1996/97: Belgium (B), Germany (D), Italy (I) and the Netherlands (NL) refer to 1995/96.
(3) Includes students who graduated a second time at the same ISCED level (approx. 4.0).
Excludes a number of students at ISCED 5 who received professional qualifications from various professionnal bodies (accountacy, marketing and secretarial).
(4) All data in 'Field of study unknown' refer to ISCED 5.
(5) Includes Business admin., Mass communication, documentation.
(6) Includes Transport, Trade, craft and industrial programmes.
(7) Includes Agriculture, Home economics and Service trades.

Source: Eurostat — Education across the EU.

Science and engineering

Science and engineering include the following disciplines: Natural science, Mathematics and Computer science, Medical science, Engineering and Architecture (includes Transport, Trade, craft and industrial programmes).

As is evident from Table 7.5., the proportion of graduates that have studied science and engineering is relatively low across the EU. The gender differences are striking: in seven of the Member States analysed, a quarter or less of females students graduate in a science or engineering discipline. Only in Finland do more than half of all female graduates possess a S&E degree. Looking at the absolute figures, the data suggest that science and engineering remains, on the whole, a male dominated discipline. This is especially true in Germany, France and the Netherlands, where, for 1997, the disparity is at its greatest. In Portugal and Finland in 1997, and as a proportion of their respective populations, there are more female scientists and engineers than males. In Denmark the distribution is even. In Portugal, medical science is the most popular of these fields among females, a feature that holds true in all of the Member States with the exception of France and Ireland, where natural science is the most popular (Table 7.6). For males, on the other hand, Engineering and Architecture is by far the most dominant subject area in all of the EU Member States.

Figure 7.9. illustrates the growth rates of the Member States for which data were available. Growth rates appear strongest in the southern European Union countries of Spain and Portugal. Spain over the last four academic years has average annual growth of 16 % and 18 % for males and females, respectively. For women, over this same time period, average growth of over 5 % per year other than in Spain has also occurred in Denmark, Austria and Portugal.

The largest contraction, on the other hand, for both men and women has taken place in the United Kingdom, where graduation in S&E is falling at an average annual rate of 3 % for males and 8 % for females. Finland is in a similar situation with a diminution in the level of S&E graduation of 2.8 % for men and 7 % for women.

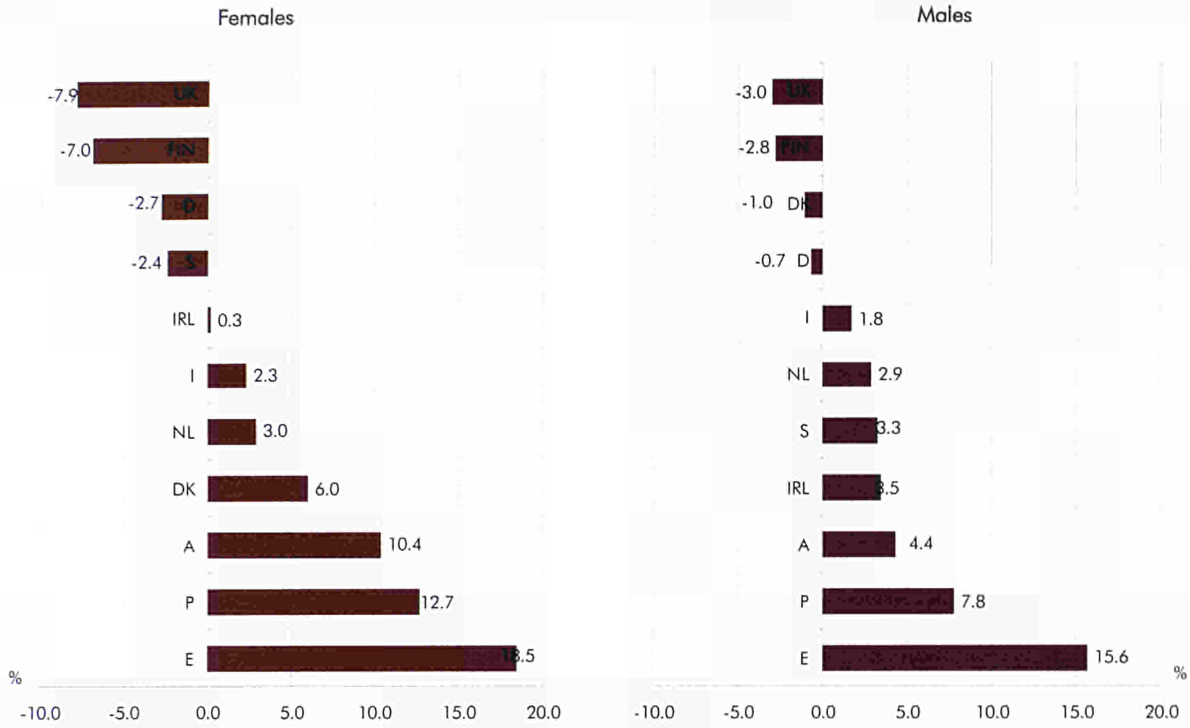
Mobility

In addition to education (the main inflow into HRST stocks), a further integral aspect of flows should be taken into account: mobility. For, as science and technology become less constrained by international boundaries, so too will migratory flows and international experience amongst Europe's HRST population. The migration of highly skilled workers has been well documented as to its potentially beneficial or detrimental effects for the sending and recipient countries, more familiarly known as the brain drain/brain gain/brain circulation argument. And this represents the other inflow (or outflow) into/from the national stock of HRST.

The degree to which this can be measured in an internationally comparable and harmonised fashion is in a process of development. Nevertheless, recent progress has been made in measuring internal job to job mobility. In its narrowest definition this can be taken to mean the mobility of individuals between one job and another over a two-year period. At the aggregate level this allows an insight into the labour market flexibility of highly qualified individuals (and its evolution) in a national economy as well as how this differs for women and for men.

This is the type of mobility that is considered below. Because, however, the data rely on the provision of information on supplementary questions in the Community Labour Force Survey, the coverage is not always as complete as is the case for the measurement of basic HRST stocks.

Fig. 7.9. Annual average growth rate in the number of science and engineering graduates by gender and country ([1]) — 1993/94-1996/97



([1]) Belgium (B) has been omitted from the analysis since 1996/97 data refer to the Flemish Community only; data for Luxembourg (L) are not available; data for France (F) are not available for 1993/94 and 1994/95; no breakdown by field of study is available for Greece (EL).

Source: Eurostat — Education across the EU.

Tab. 7.7. HRST mobility rates by gender and country 1994-99

	Females in %						Males in %					
	1994	1995	1996	1997	1998	1999	1994	1995	1996	1997	1998	1999
B	6.1	6.8	7.1	7.0	9.3	7.8	5.5	5.8	6.3	6.4	8.1	7.4
DK	13.0	11.4	11.3	9.9	11.8	12.6	9.4	11.2	11.2	8.9	10.9	11.8
D	6.9	6.5	6.9	6.0	:	7.8	6.5	5.5	6.0	6.1	:	7.2
EL	4.4	4.6	4.1	4.4	5.6	:	4.3	3.6	3.9	3.2	4.9	:
E	16.6	16.2	16.1	17.2	17.2	:	11.6	12.6	12.0	12.0	12.0	:
F	7.0	6.5	6.5	6.7	7.8	9.1	5.9	6.5	6.5	7.0	7.3	8.0
IRL	8.9	11.0	11.7	11.8	:	:	7.9	8.1	9.5	9.8	:	:
I	3.5	3.4	3.5	3.6	5.3	5.4	2.5	2.4	2.7	2.8	4.1	4.4
L	5.4	6.3	4.9	5.1	:	6.5	4.8	3.7	4.7	3.8	:	5.9
NL	7.4	7.8	6.8	7.0	11.0	9.6	6.6	6.5	5.8	7.1	9.9	8.8
A	:	5.9	6.3	:	:	:	:	5.6	5.9	:	:	:
P	:	:	:	:	8.8	7.6	:	:	:	:	7.3	7.9
FIN	:	:	:	:	12.3	12.3	:	:	:	:	10.4	11.9
S	:	:	:	7.2	7.8	8.0	:	:	:	7.0	8.9	10.2
UK	10.0	10.6	11.2	11.8	:	12.2	8.9	9.5	10.3	11.7	:	11.9

Source: Eurostat — CLFS.

Mobility rates

Due to the changeover from the old education standard (ISCED '76) to the new ISCED '97, some difficulties were experienced in various Member States. Data have been excluded where the distortion is too great. Nevertheless, data pertaining to 1998 for the remaining countries should be treated with some caution.

Taking an example to aid interpretation of the results, in the United Kingdom in 1999 HRST female mobility rates stood at 12.2 %. This means that of all the female HRST in the United Kingdom employed in both 1999 and 1998, 12.2 % changed employment during that year. Others may have left the labour force or indeed entered from a position of unemployment or inactivity (such as a former student). However, no consideration is made of these cases in the indicators compiled in Table 7.7.

For men, mobility of HRST is, in all cases, higher at the end of the observation period than at the beginning. For women, this is true for all countries but Denmark. Moreover, in the majority of Member States, mobility is higher for women than it is for men.

For women, the highest HRST mobility rate is manifest in Spain (between around 16 % and 17 % over the time period analysed). Denmark, Ireland, Finland and the United Kingdom all have double figure mobility levels, also. Lower levels of mobility — between 3 and 7 % — are evident in Greece, Italy, Luxembourg and Austria.

Mobilty of HRST amongst men is again highest in Spain, followed closely by Denmark, Finland and the United Kingdom (all with around 12 %). Sweden also has a double figure HRST mobility at just above 10 %. For men it is again in Greece, Italy, Luxembourg and Austria where the lower levels of mobility are manifest at the end of the observation period. Germany and France have more average mobility rates, with the French HRST labour market seeming slightly more dynamic.

CONCLUSIONS

This chapter has given an overview of the situation regarding HRST in the European Union over the time period 1994 to 1999, where data are available. Both the stocks of HRST and the flows (education and mobility) have been considered, showing that there has been a general increase in the level of highly qualified personnel at the EU level. There are some inter-country variations in the growth or diminution of HRST — and its sub-sets — not only by gender, but also by age.

In the year 2000, a 'field of study' variable was introduced to the CLFS, which, once the data have been evaluated, will allow the possibility to analyse further the transition from school to work at the international level. What, for example, are the subjects that appear most in demand, and can similar trends be found across the EU? If there is a shortage of computer programmers and other IT workers in the labour force and, concomitantly, fewer scientists, engineers, mathematicians and computer scientists are graduating at the third level of education, then who seem to be the substitutes? Are they other graduates at the third level (HRSTE), or do firms increasingly employ non-graduates to perform these functions?

References

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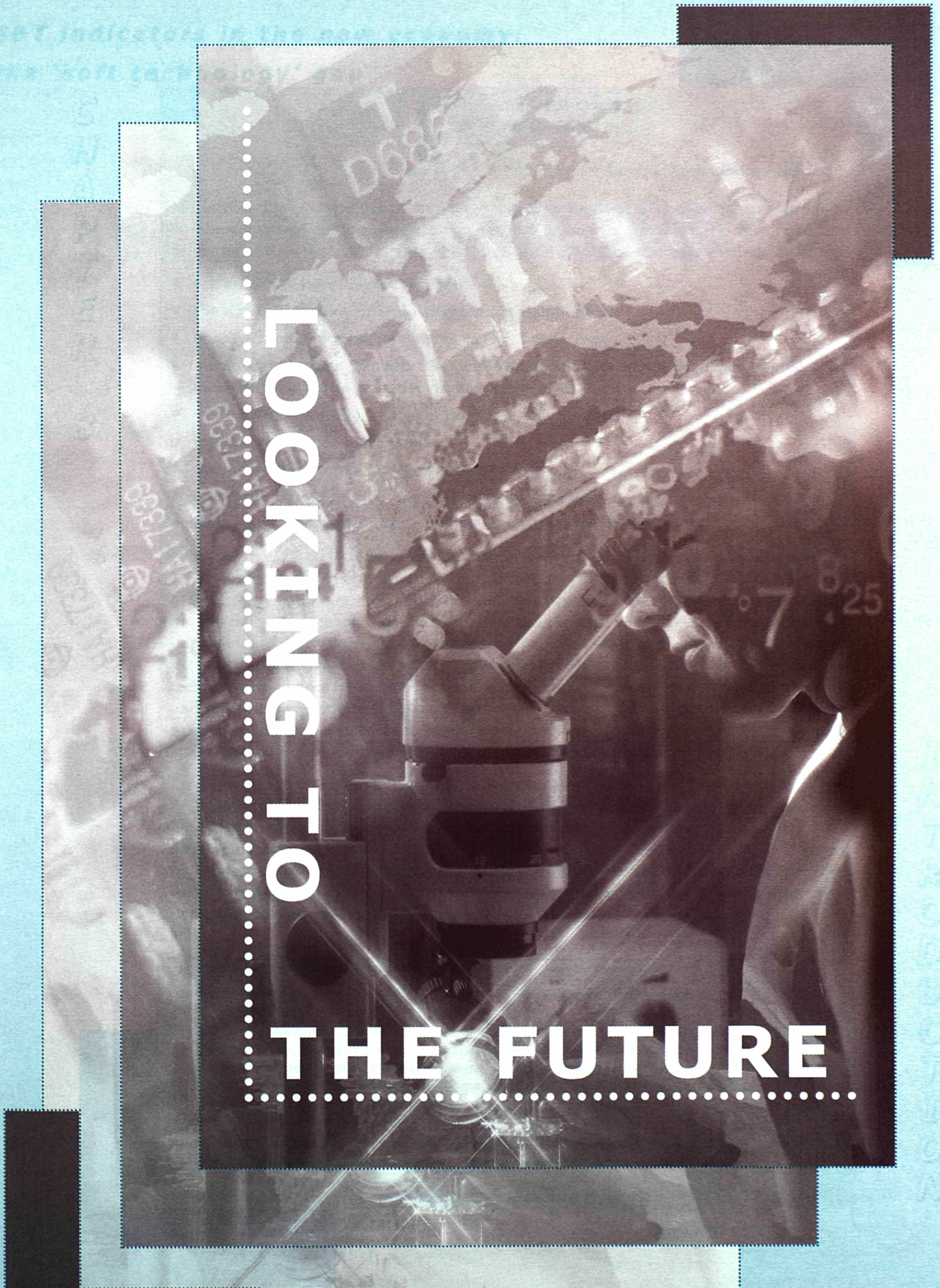
- *The European Union Labour Force Survey — Methods and definitions*, Office for Official Publications of the European Communities, Luxembourg, 1996 and 1998.
- *International Standard Classification of Education*, Unesco, Paris, 1976 and 1997.
- *Education at a glance*, OECD, Paris, 1996.
- *Manual on the Measurement of Human Resources devoted to S&T — Canberra Manual*, OECD, Paris, 1994.
- *International Standard Classification of Occupation*, ILO, Geneva, 1988.

PART 3

Statistics on Science and Technology in Europe

LOOKING TO THE FUTURE



PART 3

S&T indicators in the new economy: the 'soft technology' gap

CHAPTER 8

By James P. Gavigan, Eamonn Cahill and Jaime Rojo, Institute for Prospective Technological Studies.

INTRODUCTION

Measuring the economy in a period of rapid technological change is an extremely cumbersome and difficult task. Technological change is probably the most relevant driver behind the need to improve the established system of statistics in many areas (1):

- the growth of hard-to-measure services;
- the timely introduction and valuation of new products;
- quality change in goods and services (e.g. health care);
- technology, human capital, R&D, innovation and ideas whose measurements are incomplete, at times primitive, at best piecemeal;
- workers and households' use of time and health status;
- international trade and finance;
- the formation, growth and failure of new firms;
- financial innovation and changing payment methods;
- changes in the organisation of production and distribution.

It is said that 25-50 % of economic growth derives from research and technology (2), or 70-80 % from new and improved knowledge (3). In the so-called new economy, the role of technology and knowledge continues to increase even further (4). Thus intangible and immaterial resources and assets have overtaken physical and tangible assets in order of importance. From a science and technology perspective, this means that measures of S&T output and capacities need to capture the heretofore neglected soft and intangible technological factors in order to be in tune with current reality. However, hard 'artefact' and tangible elements have been the principal, if not exclusive, focus of S&T indicators to date. While this continues to be the case, the knowledge and information bases on which related policy analysis and decisions rest, will be seriously incomplete.

Direct experience of gaps between the existing measurement framework and the S&T phenomena under analysis permits a number of observations to be made on how these gaps might be filled, while not necessarily providing statisticians with direct prescriptions for the compilation of new indicators. Thus, this chapter aims to be thought-provoking in raising new issues for consideration by those who are more directly engaged in designing new indicators, as well as pointing to some promising developments detected in the literature.

(1) Boskin, M., 'Some Thoughts on Improving Economic Statistics', *Hoover Essay in Public Policy*, 1998.

(2) European Commision, *Towards a European research area*, 18 January 2000, COM (2000) 6. http://europa.eu.int/comm/research/area.html.

(3) Edquist, C., 'Building a Cross-border Learning Region', *The Case of the Oresund Region, Denmark/Sweden*, Sweden at The Learning Region and sustainable Development organised by The Danish Ministry of Education, the Swedish Ministry of Education and Science, The Centre for Educational Research and Innovation (CERI) and theTerritorial Development Service (TDS), Linkoping University, OECD 17-18 June 1999. http://www.uvm.dk/konferencer/oecd/speeches.htm#charles.

(4) Jarboe, K.P. and Atkinson, R.D., 'The Case for Technology in the Knowledge Economy — R&D, Economic Growth and the Role of Government', *The Progressive Policy Institute Policy Briefings*, June 1998. http://www.ppionline.org/ppi_ci.cfm?knlgAreaID=107&subsecID=124&contentID=1502.

8.1. THE INDICATORS CONCEPT (5) TECHNOLOGY AND INNOVATION IN A CHANGING ECONOMIC SYSTEM

Indicators are constructed from statistical information on the phenomena under study and, as such, are indirect and imperfect measurements. However, by examining several indicators together and their time dependence, trends in the underlying phenomena can be discerned. Science and technology indicators quantify aspects of the creation, dissemination and application of science and technology. They should help describe the S&T system, enabling a better understanding of its structure, of the impact of policies and programmes on it, and of its impact on society and the economy.

The elaboration of a system of indicators requires an understanding of the structure of science and technology — how much it costs, who performs the activities, how it is distributed among the players, and so on. However, the understanding on which the current system of S&T indicators is based, as reflected in the manuals for standard practice, has remained unchanged for nearly 40 years (6). The continuous revision of the *Frascati Manual*, for example, has been more in response to a need for international comparison than anything else. It is therefore not surprising that the nature and full extent of technological activity is not sufficiently captured by the standard indicators used.

The problem has two salient dimensions:

- first is the definitional question of what science and technology actually encompass,
- second is the question of who are the relevant actors and how scientific and technological activities are carried out.

But before exploring these any further, it is instructive to briefly recall how the workings of the economic system have changed over the years as far as S&T is concerned, and how this has dictated changes in the type of analytical model that can be usefully applied.

When the *Frascati Manual* was first produced, the so-called linear model of innovation (7) — Research → Invention → Innovation → Diffusion — was a sufficient and useful approximation to reality for analysts, policy makers and other commentators or stakeholders. As far as the relevant S&T indicators are concerned, over time the accepted output metrics of patent filings, publications, technology transfer and licensing, were joined by a host of others — employment figures, industrial production, GDP growth, etc. all within the perspective of the linear model. However, for over a decade now, studies and analyses by scholars have been forcefully arguing the obsolescence of the linear model (8), though it still today continues to dominate scientific and technological research and practical policy making.

The currently prevailing wisdom amongst policy researchers and commentators is that technology and innovation occur via much more complex processes for which there are a variety of model types proposed in the literature — chain-linked, organic chaos, neural nets, etc. (9). Discussions of such complex technology and innovation processes originally developed to describe the evolution and changes taking place within established sectors of the economy. However, the rise of services and more recently of the Internet economy should bring to a definitive end the reign of the linear model and policy derivatives. Meanwhile few 'formal' models for this non-linear approach exist on which new policies and indicators can be based.

In spite of this difficult situation, a careful sifting through the literature and reported experimental attempts to measure parts of this new economic reality, can in turn lead to further insights which make continuous, albeit slow, progress possible.

(5) See Shodjai, F., *Science and Technology Indicators and a Catalog of Major S&T Indicators of Canada*, 1996, http://www.shodjai.org/foad/st_ind.fm.html.

(6) The OECD is also performing work on new science and technology indicators for the knowledge based economy, covering mainly six priority areas: mobility of human resources, patents, innovative capability of firms, internationalisation of R&D, government support to industrial R&D, and IT and the services.

(7) See Shodjai, F., *Systems of Innovation*, 1995, and references therein: http://www.shodjai.org/foad/innov.fm.html.

(8) Kline, S.J., 'Innovation is Not a Linear Process,' *Research Management*, July/August 1985, 36-45.
Nelson, R.R., 'What is Public and What is Private About Technology?', *Consortium on Competition and Cooperation*, working paper 90-9, Center for Research in Management, University of California, Berkeley, 1990.
European Commission, *Green Paper on Innovation*, December 1995.
OECD-STI, *National Innovation Systems*, 1997.

(9) See Jackson, C., *Technology, Innovation, Transfer and Commercialisation: Need for a nonlinear approach*, 3rd Annual International Conference on Technology Policy & Innovation, Austin, Texas, 1999, http://www.ki-soft.com/nonlinear.html.

Focus on Science and Technology indicators

The remainder of the chapter focuses on the challenge of measuring stocks and flows of different facets of S&T capabilities and potentials residing within the economy — both in the productive sector and the knowledge infrastructure ([10]) — but not necessarily tied to the market-performance aspects required to measure the broader notion of innovation (dealt with in Chapter 2.1.). The examples drawn upon include recent developments which address the task of measuring or providing indicators for the so-called New Economy and the innovation which is driving it ([11]).

8.2. WHAT IS TECHNOLOGY?

Broadening the definition

We take a broad definition of technology to be any systematic knowledge applied to practical ends such as problem-solving or extending human capabilities. As such, technology encompasses procedures and routines, social/organisational processes as well as tools, hardware and useful artefacts. The need for such a broad definition of technology for indicator and ultimately for policy purposes, is borne out by recent developments. These include the semantic shift or switch in emphasis in business, policy and socio-economic research circles away from 'technology' per se to 'knowledge', together with the reality underlying this, e.g.:

- most economic growth is due to new and better knowledge;
- the stock market value of most firms exceeding net fixed assets is largely ascribed to the value of knowledge capital;
- services dominate industry and account for two-thirds of GDP and employment.

Such 'technology' (i.e. systematic, applicable knowledge) encompasses the results of many different types of innovative endeavours undertaken by individuals or organisations — continuous improvement, serendipity, formal or informal learning and training, or changes in organisation and procedures to improve quality and efficiency — and not just the outputs of structured R&D.

Arising problems

In a situation where the measurement of the relative importance of different types of technology to the modern economy is incomplete or partial, public technology policies suffer as a result. Either they will be unduly skewed in favour of the 'hard' technological themes where traditional indicators provide some basis for measuring slack or deficiencies, or they will attempt to address areas of technology where the basis for policy action is, at best, tentative. This is clearly seen in the persistent 'hard-technology' — or artefact-based rationale that underlies most practical technology-orientated public R&D programmes.

To quote the *1997 Panorama of EU Industry*:

> *A virtually exclusive focus on the 'hard' technological components and limited indicators such as R&D investments, therefore results in a highly incomplete and partial approach of industrial and technological policy design.*

In the case of the Intelligent Manufacturing Systems (IMS) R&D initiative, where the technical scope is actually predominantly in soft technology areas ([12]), attempts to establish positions of relative strengths and weaknesses among the IMS participating regions (European Union, Australia, Japan, the United States, etc.) proved to be very difficult precisely because of the lack of relevant indicator data ([13]).

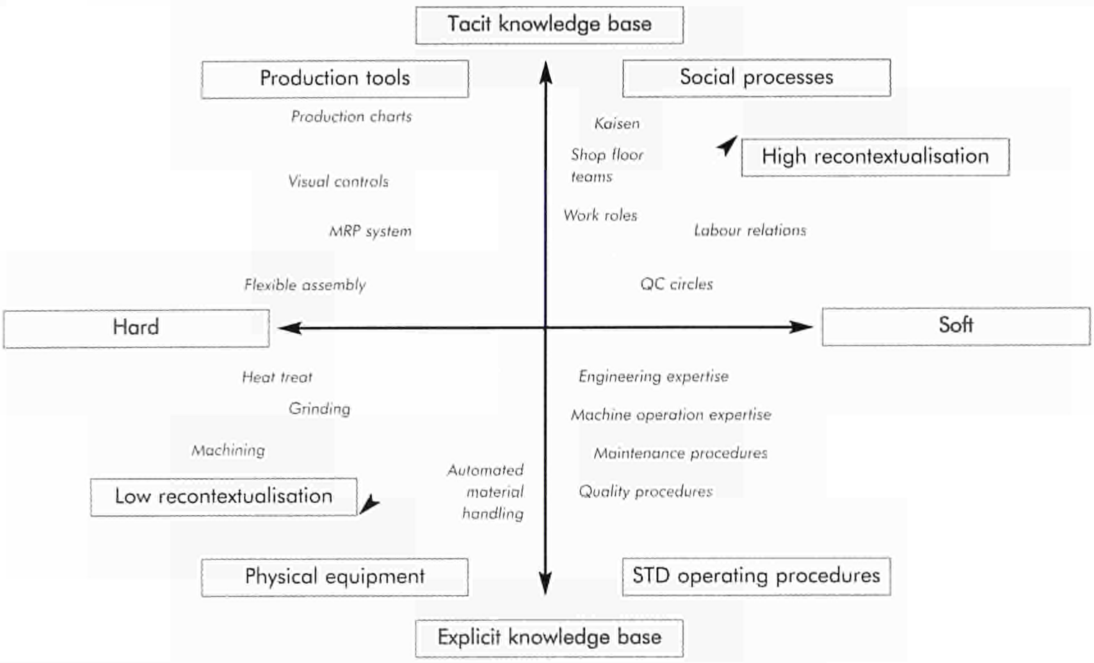
([10]) This includes the ensemble of universities, technical research centres, private knowledge brokers and technical consultants etc.

([11]) The Progressive Policy Institute, *The New Economy Index*, 1998, http://www.ppionline.org/ppi_ci.cfm?knlgAreaID=107&subsecID=123&contentID=1270. French *Ministère de l'Économie, des Finances et de l'Industrie, Innovation Indicators*, http://www.industrie.gouv.fr/observat/innov/f3o_bord.htm.

([12]) Total product life cycles, process issues, strategy/planning/design tools, human/organisational/social issues, virtual/extended enterprise issues. See the *IMS Technical Themes* at http://www.ims.org/index2.htm.

([13]) Institute for Prospective Technological Studies, SWOT, *Overview of Manufacturing Industry in Europe: Background to a European Strategy for IMS*, EUR-18103-EN-1998.

Fig. 8.1. Technology characteristics and the need for recontextualisation (1)



(1) Brannen, M. Y. et al., 'Recontextualization and Factory-to-Factory Knowledge Transfer from Japan to the US: The Case of NSK' in *Remade in America: Transplanting and Transforming Japanese Production Systems*, edited by Jeffrey Liker et al., Oxford University Press, New-York, 1998.

Source: see reference to this figure.

Tab. 8.1. Categories of firm-level intellectual capital (1)

Intellectual capital

Structural capital			Human capital
Organisational capital		Customer capital	
Innovation capital	Process capital		
Patents, concepts, models	Computer & administrative systems, informal organisation, internal networks & culture	Brand names, trademarks, reputation/image	Individuals' skill, education, experience, values & social skills

(1) Sveiby, K.E., *Measuring Intangibles and Intellectual Capital — An emerging First Standard*, 1998. http://www.sveiby.com.au/EmergingStandard.html.

Source: see reference to this table.

Technology classification schemes

The following sub-sections describe segmentation approaches developed in relation to quite different contexts and reference levels, which illustrate the relevance and practicality of this broader concept of technology.

First scheme

The first scheme was developed in relation to a specific case study of production-system technology-transfer from Japan to the United States. The need to sort 'technology' into different categories arose in distinguishing between production-system technologies that were readily transferable, and others that met significant barriers.

First, the scheme makes a distinction between tacit and explicit knowledge or technology. Regarding transferability, explicit knowledge is easy to document and convert into procedures, while tacit knowledge is deeply embedded into people's consciousness, and is therefore difficult to access. The second distinction between hard and soft technology is based on the extent to which the technologies in question rely on accompanying organisational systems, hard being much less reliant than soft.

This scheme allows a further differentiation: the extent to which transfer of the knowledge requires recontextualisation in the sense of conversion to adapt to the receiving environment. Hard, explicit technology/knowledge generally requires little recontextualisation, whereas soft, tacit technology/knowledge does. This is illustrated in Figure 8.1. with examples of several different, specific technologies.

Second scheme

The second scheme presented goes beyond the definition of technology given above to a conceptual framework for all types of knowledge, distinguishing between three levels of aggregation: the individual, the organisation and the community or system. The scheme is inspired by the firm-level debate around intellectual capital which over the past ten years or so has given rise to measurement systems for all categories of technology and knowledge residing in individual firms. Firms at the forefront of this debate (14) distinguish between three main types of intellectual capital (see Table 8.1.) which, for measurement purposes, are proxied by sets of non-monetised indicators. These are normally customised at the level of each business unit rather than standardised over the whole corporation, and provide the basis for annual intangible asset accounts which some firms have already been reporting for ten years.

Such means of measuring knowledge capital are guiding the type of investment patterns and strategies of firms, in both managing and adapting to, the knowledge and learning economy in which they operate. It demonstrates again how knowledge has swung to centre-stage as far as asset and revenue-generating value of private firms is concerned. Its importance is reflected by the fact that the stock-market value of firms is on average three to four times the value of their physical assets including technological hardware.

Following on from the above scheme, it has been proposed that an equally sophisticated understanding of knowledge-types and their importance could be developed in relation to individuals and systems or communities, and likewise be used to guide relevant public policies (15). Analogies are identified for the three main categories of firm-level intellectual capital, tracing downwards to the level of the individual and upwards to the higher system/community level. Based on this, the following Table 8.3. illustrates the three different types of knowledge at each different level.

Considering this table in conjunction with the previous firm-level scheme is a further illustration that the types of technology and knowledge captured in traditional indicators (hardware or artefacts, laboratories, universities and colleges, head counts of researchers, qualification counts in the labour force, etc.) is only partial, and largely leaves out the softer/intangible factors which in many ways have become the most important.

(14) Sveiby, K., *Measuring Intangibles and Intellectual Capital — An emerging First Standard*, 1998. http://www.sveiby.com.au/EmergingStandard.html.

(15) Gavigan, J., Mahroum, S. and Ottisch, M., *Knowledge and Learning — Towards a Learning Europe*, Futures Project Series, Institute for Prospective Technological Studies, 1999.

Tab. 8.2. Correspondences at individual and system level to categories of firm-level intellectual capital (¹)

Individual	<= Firm level =>	System/community
Instrumental competencies and general knowledge	<= Human capital => (Stock)	Technological know-how knowledge infrastructure
Personal competencies	<= Organisational capital => (Internal)	Soft' technologies and social capital
Social competencies	<= Customer capital => (External)	Ability to leverage benefits of system openness/internationalisation

(¹) Gavigan, J., Mahroum, S. and Ottisch, M., *Knowledge and Learning — Towards a Learning Europe*, Futures Project Series, Institute for Prospective Technological Studies, 1999.

Source: see reference to this table.

Tab. 8.3. Categories of knowledge for three different reference levels (¹)

		Knowledge resources		
		Accumulated intellectual stock	Internal organisation and processes	External environment interactions
Individual level	Individuals	Instrumental competencies (languages, science, literacy, numeracy, IT) general knowledge (economics, civics, literature)	Personal competencies (self-confidence, creativity, critical argumentation and analysis, psychological capital, intelligence)	Social competencies (language expression, teamwork, solidarity)
Collective levels	Organisations	Human capital (skills, experience, values)	Innovation (patents, concepts) and process capital (informal organisation, systems, internal networks and culture)	Customer capital (brand names, reputation, marketing prowess), networking ability
	Communities/systems	Knowledge infrastructure, technological know-how and proficiency, industrialists and entrepreneurs	Institutional capital (efficient and effective public administration governance system), social capital (trust, norms, networks), cultural diversity	Ability to leverage benefits from system openness, foreign trade, FDI in-flows and circulation of human capital

(¹) Gavigan, J., Mahroum, S. and Ottisch, M., *Knowledge and Learning — Towards a Learning Europe*, Futures Project Series, Institute for Prospective Technological Studies, 1999.

Source: see reference to this table.

8.3. HOW ARE SCIENCE AND TECHNOLOGY ACTIVITIES CARRIED OUT?

Radical change in the way in which formal scientific and technological knowledge is produced is clearly consistent with the rise of non-linear innovation processes and fall of the linear model. The advocated new 'mode 2' of S&T knowledge production, for example (16), is less self-contained than heretofore, reflecting the fact that in many leading edge areas of research and technological advances, many different skills are needed to solve problems. This mode of knowledge production is socially distributed and has five main characteristics (17):

- a rapidly increasing number of places where credible research is carried out;
- the stock of knowledge is derived from the flows of knowledge between these various sites where the interaction is extensive;
- the dynamics of this knowledge production lie in flows of knowledge and in the shifting patterns of connectivity related to problem contexts;
- the number of interconnections is accelerating. They are functional and survive only for the duration of problem interest;
- the density of communication between new sites of knowledge production outside of traditional institutions is increasing rapidly.

These are also the characteristics which should form the basis for indicators of the involvement of all actors, firms and sectors in knowledge production. The prevalence of these characteristics will vary from sector to sector and even among firms in the same sector.

'Soft-technology' indicators

This, in our opinion, is where the heart of the indicators problem lies. If we take again as an illustration the technical themes of the Intelligent Manufacturing Systems (IMS) Programme:

- total product life cycle issues: manufacturing systems architectures, communication networks, environmental protection, minimum use of energy and material, recyclability and refurbishment, economic justification methods,
- process issues: clean manufacturing, energy efficiency, technology innovation, flexibility and autonomy of processing modules, inter-functional co-ordination,
- strategy/planning/design tools: business process reengineering, manufacturing systems modelling and simulation, manufacturing process design tools,
- human/organisational/social issues: education, training, corporate memory, new organisational paradigms,
- virtual/extended enterprise issues: information processes, logistics, architecture, risk assessment, multi-organisation teams.

and ask the question which indicators can reasonably describe the scientific and technological capabilities residing in European industry and knowledge infrastructure in relation to these themes? — there is little or nothing available. The deficiency of S&T indicators is even more important in relation to the 'technological' capabilities underpinning the services sector, where again we recall that technology refers to any systematic knowledge applied to practical ends such as problem-solving, or extending human capabilities.

However, if we turn to the definition of technology used in the Community Innovation Survey:

> *A technology can be interpreted broadly as the whole complex of knowledge, skills, routines, competence, equipment and engineering practice which are necessary to produce a product (or service).*

It clearly covers all the soft issues referred to above. This suggests that surveys such as the CIS, perhaps combined with the more standard available statistical information and other survey data sets such as the Labour Force Survey, contain the basic data from which new indicators could be built up. Attempts to improve the relevance of S&T indicators could also learn from on-going efforts to measure innovation specifically in the services sector, and research projects such as the TSER's Indicators and Data for European Analysis (IDEA) project (18).

(16) Gibbons, M., Nowotry, H., Swchwartzman, S., Scott, P. and Throw, M., *New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies*, Sage Publications, London, 1994.

(17) Mansell, R. and Wehn, U., *Information Technology for Sustainable Development*, Knowledge Societies, Oxford University Press, New-York, 1998.

(18) See http://www.step.no/Projectarea/IDEA/default.htm.

8.4. TOWARDS NEW INDICATORS OR NEW MEASURES

Most effort to measure the new economy is going into the identification of important parameters on the input and output sides, with little effort aimed at parametrising and understanding the strengths and weaknesses of the underlying stock of S&T knowledge and capability. In this new, knowledge-based economy, human capital has become one of the primary factors in describing this stock of capability. Fortunately, in this area it is possible to point to the development in recent years of serious attempts to measure in internationally comparable ways the stocks and flows of human resources in science and technology (see Chapter 7.). Hopefully it will be possible to have a relatively sophisticated description of the levels of human capital in the economy and its importance as a determinant of technological capability.

As suggested in Table 8.3., it should be noted that the value of individual human capital is determined by much more than formal levels of education and qualification. Beyond the individual level, knowledge and technological capability are equally properties of collective groups of people in firms and organisations and, at higher levels still, of the innovation system and economy. In principle, if a reasonably complete description of S&T capability exists, it should cover the content of all the cells in Table 8.3.

Perhaps this is neither possible, nor reasonable to expect within the conservative and rigorous requirements of the national statistical offices, but then it becomes necessary to describe what escapes the statistical route by other means. In many ways, the rise in recent years of technology foresight as a highly collective and participative means of prospective policy analysis has, perhaps unwittingly, provided a route to obtaining substantial information on S&T capability from very large groups of stakeholders, when the appropriate tools and methods are used. This was the case, for example, in the first generation — in the recent wave — of technology foresight studies, which relied on major Delphi surveys, i.e. a group methodology using quantitative and qualitative opportunities to explore the future and aimed to help the experts reach a consensus. In these surveys, experts were asked to score different types of S&T capability (basic, applied, industrial) on topics, which, depending on their formulation, often referred to soft technology issues.

We said earlier that our primary concern relates to describing the stocks and flows of all types of S&T capacities residing within society. The few interesting new indicator-related developments and new ideas that can be identified, however, mostly relate to market-performance aspects (applied S&T, innovation).

Community Innovation Survey

The Community Innovation Survey (CIS) is an effort at EU level to provide a deeper understanding of the innovation process and the factors contributing to innovation by providing harmonised and comparable innovation statistics. It focuses on the overall dimensions of innovation, characteristics of innovating firms, internal and systemic factors that influence innovation processes. The survey permits allows the study of collaboration links, information flows and sources of spillovers from innovative activities. Given their growing importance in the economy, a particular section of the CIS questionnaire is devoted to the understanding of innovation in the services sector and how services contribute to the innovation process. The survey is structured in a way that allows the development of new indicators to study the innovation process [19] and to analyse the cross linkages existing between innovation, productivity growth and employment.

(19) *Innovation Outputs in European Industry: Analysis from the CIS*, EIMS No 34, 1996. provides an example on the exploitation of the CIS to study firms' innovative output.

Technology and innovation in services

The services sector is heterogeneous and services themselves are usually intangible and fast changing. This makes them very hard to monitor, although they are regarded as an essential component of modern economies, both in terms of their contribution to GDP and employment.

Several categories of the services sector — such as business services, communication services and knowledge intensive services — are key sectors in relation to the overall industrial dynamics. They act as nodes in the innovation system, compiling and codifying knowledge, connecting users and producers and distributing knowledge world-wide. Services are often major users of new technology, and this is liable to become more common with new generations of IT. Equally relevant, some services are dominant technology users (e.g. finance and banking, telecommunications, information services), having the capacity to influence the technologies they adopt and playing an active role in the development of a knowledge-intensive economy. Services may enhance the technology transfer process across sectors, or directly contribute to the development of new technologies.

These roles remain largely unexamined. Only now, are official R&D statistics beginning to encompass the contribution of services to the innovation process. Nevertheless, innovation in services comprises a wider range of activities than traditional R&D indicators are able to capture. Since much of the analysis of innovation in services still relies heavily on case studies, there is a perceived need of the necessity to improve the compilation of systematic data of innovation in services where much of the innovation is taking place. The CIS initiative in its conceptualisation extends its aims to track innovation in services. As statistical methods are refined, evidence implies that the level of innovation in the services sectors does not fall behind the level in other economic activities. In this respect, new taxonomies and analytical frameworks are being developed to improve the understanding of the processes of innovation and technology in the services sector (20) as well as new indicators which allow the identification of new patterns (see Chapter 6.) (21).

Since official statistics on services normally take their starting point from the supply side, there is an increasing need to complement this knowledge by surveying the demand for services, i.e. firms purchasing services for other firms or purchasing them in-house for internal use (22).

Knowledge-based economy

Based on our proposed expanded meaning for technology in Section 3, the S&T indicators problem becomes subsumed into the broader knowledge indicators problem. Here, traditional indicators on knowledge inputs (i.e. R&D expenditures, human resources) are complemented by the development of other indicators to measure and characterise the trends and shifts taking place in the knowledge based economy (23).

The adoption of an overall concept which relates S&T activity to knowledge production in the first instance, and then to innovation, as the process by which new or improved goods and services are provided, allows the appropriate stages of the process to be analysed. From this analysis both inputs and outputs can be screened to provide the variables for indicator selection and design.

Many existing analyses on innovation are based on the manufacturing sector. But, in order to understand the innovation process, it is crucial to understand how the service sector creates, acquires and distributes knowledge.

(20) Hauknes, J. and Miles, I., *Services in the European Innovation Systems — A review of Issues*, STEP Report 6, 1996.
Hill, P., *Tangibles, Intangibles and Services: A New Taxonomy for the Classification of Output*, paper presented at the CSLS Conference on Service Sector Productivity and the Productivity Paradox, Ottawa, April 1997.
Hauknes, J., *Innovation in the Service Economy*, STEP Report, 7, 1996.

(21) In this respect, refer to the work of the Voorburg Group on Service Statistics: http://www.un.org/Depts/unsd/citygrp/voorburg.htm.

(22) IPTS, *Industry Value Added Services*, Technical Report Series, 1999.

(23) OECD, *The Knowledge based Economy*, OECD Working paper, 50, 1996.

However, our understanding of what is happening in the knowledge-based economy (KBE) is constrained by the extent and quality of current indicators. New indicators are needed that capture the innovation process and the distribution of knowledge among key actors and institutions in society. This implies measuring 'national systems of innovation'. The 1996 OECD study entitled *The Knowledge-Based Economy* proposed the development of indicators:

- on knowledge stocks and flow, particularly relating to the diffusion of information technologies;
- on social and private rates of return to knowledge investment;
- on the functioning of knowledge networks and national innovation systems;
- on the development and skills of human capital.

These, of course, are difficult areas where qualitative assessments will be a major element. Also firm level data may be difficult to aggregate up to sector level etc.

The following briefly recalls the main lines of development relating to knowledge measurement, and introduces the concept of knowledge vectors.

Knowledge stocks and flows

Stocks of knowledge capital can be measured using basic S&T indicators and depreciation rates. The flow of knowledge is measured using proxy indicators for capital embodied knowledge (i.e. in machinery, equipment) and capital disembodied knowledge (i.e. in the form of patents, blue prints, and licenses). Embodied technology flows can be measured using input output technology matrices which distinguish between sectors producing a particular knowledge and sectors using a particular knowledge ([24]).

Knowledge outputs

A first approximation of the capacity to transform knowledge inputs into knowledge outputs is the classification of manufacturing sectors in an economy by their R&D intensity into high-tech, medium tech and low tech. Traditional S&T output indicators such as the technology balance of payments and the number of patent applications give an indication of the technological capacity of an economy ([25]). Recent efforts in indicators development have focused in providing benchmarking comparisons of the S&T and innovative capacities and performance across countries ([26]).

Knowledge networks

The dynamics of knowledge distribution and capacity building is measured through the use of surveys such as the previously mentioned Community Innovation Survey, Strength Weakness Opportunity & Threat (SWOT) analyses and foresight studies. These provide a means for mapping knowledge innovation systems, knowledge infrastructures and institutional capabilities. In this respect, the concept of national innovation systems has motivated research in order to develop new indicators to capture the notion of cluster of innovative firms ([27]).

Knowledge and learning

Traditional human capital indicators use measures of formal education and experience; they should be complemented with indicators that adjust for the quality and also account for informal education such as on the job training ([28]). Measurement of the private and social rates of return to investment in education provide a metric for the learning capacity of individuals and firms ([29]).

([24]) Verspagen, B., *Measuring Intersectoral Technology Spillovers: Estimates from the European and U.S. Patent Office Databases*, Economic Systems, No 9, 47-65, 1997.

([25]) OECD, *Basic Science and Technology Statistics*, 1999 Edition, Paris, 2000.

([26]) OECD, *Science, Technology and Industry Scoreboard 1999: Benchmarking Knowledge Based Economies*, Paris, 1999.

([27]) OECD, *Boosting Innovation: the Cluster Approach*, Proceedings, Paris, 1999.

([28]) Rojo, J., *Linking Human Capital and Economic Growth*, IPTS Report, No 37, 1999.

([29]) OECD, *Human Capital Investment: An International Comparison*, Paris, 1998.

Knowledge vectors

As a general consideration, it is impossible to extend measurement 'recipes' designed for an economy of goods and services to the knowledge-based economy. Knowledge, unlike conventional capital goods, has no fixed capacity; a given idea can spark enormous change, modest change or no change at all.

However, as a specific device for moving a bright idea towards market entry, S&T activity may initially be subjected to only 'soft' evaluative scrutiny — when management will use judgement, intuition and supportive interaction with researchers. Eventually the accountants will be unleashed as the firm grapples with the basic question 'Will this product add value?'

We consider that all S&T activities should possess four factors, two looking outwards from the company and two focused inwards:

- Market Need — a strong customer focus.
- Knowledge vectors — maintaining and developing networks of codified and tacit knowledge.
- Makeability — to deftly turn a good idea into a useful product/service.
- Better impact on the company — on both organisation and personnel.

Obtaining information in support of these 'soft' factors under current systems of data collection is cumbersome. For example, research collaboration between firms in different sector classifications will most likely only appear as expenditure in the respective sectors. A census of operations based on revisions to census of production, which could include creation, production and distribution of goods and services would be an improved basis for collecting data on modern activities. Knowledge acquisition would form part of the creative phase of the process and cross-sector (and international) collaboration could be captured. The basis for this might be built up from the concepts developed in the Technology Policy and Assessment Centre at Georgia Institute of Technology in Atlanta (30).

The idea of knowledge vectors describes the space between the present core knowledge residing in firms' internal and/or external networks, and their current search/research activities. Knowledge vectors encompass the idea that the knowledge needs and capabilities of firms are not solely cumulative (i.e. just related to amounts of knowledge) but they have a directional or strategic component. Where there is full complementarity between the knowledge capabilities of collaborators or partners there will be great combined strength. Lesser degrees of complementarity lead to lesser degrees of strength. From the point of view of European policy, what is important is the identification of whether the sources of complementarity are European based or not.

Council on competitiveness innovation index (31)

This work produced an index to serve as a quantitative benchmark of national innovative capacity — not scientific progress nor competitiveness per se, but the ability of a country to produce a stream of commercially relevant innovations. This is directly relevant to the main S&T indicator challenge — i.e. how to get as complete a measure as possible of the technological capability residing within a defined innovation system. The index framework used divided sources of national innovative capacity between a common pool of institutions, resource

(30) Roessner, D., Porter, A.L. and Newman, N., *Indicators of Technology based Competitiveness of Nations*, 1997.

(31) Council on Competitiveness, *The New Challenge to America's Prosperity: Findings from the Innovation Index*, 1999.

commitments and policies (called the common innovation infrastructure), and the particular capacities of groups of interconnected industries (cluster-specific innovation environment), and the linkages between the two.

The most interesting feature of the index construction is the attempt to explicitly factor-in, in an internationally comparable way, some of the systemic features on which technology and innovation depend — cluster characteristics, the quality and intensity of inter-linkages between actors and different parts of the innovation system, strength of institutions, etc. Regarding the difficulty involved in so-doing the report states that:

> *more subtle and multi-faceted concepts, such as the cluster-specific innovation environment cannot be quantified directly from available and internationally comparable data. We address this challenge by employing an intermediate measure which does not capture the underlying drivers ... but measures an outcome associated with the strength of those specific drivers.*

Other elements are directly measurable such as the strength of intellectual property protection, and public investment in higher education.

The specific variables used for the Quality of the Common Innovation Infrastructure in the calculation of the index were aggregate personnel employed in research and development; aggregate expenditures on research and development; openness to international trade and investment (average survey response by executives on a 1-10 scale regarding relative openness of the economy), strength of protection for intellectual property (average survey response by executives on a 1-10 scale regarding relative strength of intellectual property), share of gross domestic product spent on secondary and tertiary education and gross domestic product per capita.

For the Cluster-Specific Innovation Environment, the variable chosen was the percentage of R&D expenditure funded by private industry, and for the Quality of the Linkages, the percentage of R&D performed by universities. Time-series/cross sectional regression analysis was employed to weight the influence of each element on innovation output (proxied by the number of international patents issued to a country). The per capita index was calculated by summing across all measures appropriately weighted.

This work was used to make a novel comparative analysis including future projections regarding the innovative performance of the countries considered. But it also served to show some of the problems policy analysts face in trying to compensate for serious shortcomings or absence of data sets for key parts of the knowledge and technology landscape. Regarding the intermediate measures used, the report states:

> *These measures are far from perfect and cannot capture the full range and subtlety of how national innovative capacity is nurtured and maintained (p. 25).*

Tab. 8.4. Soft evaluation framework: the firm and its networks

	Key questions
1. Market need	What is the present market need for this improved product/service? What might be the future market need for this new product/service?
2. Knowledge vectors	What do the collaborators/partners learn/gain from one another? What value might this have and how will you use it?
3. Makeability	In making the new/improved product/service, what processing advances, if any, will be involved? Is the new product/process within the present or latent core competence of the firm or network?
4. An improving impact on the company	How might this project change your company's organisation/work practices/strategic stance?

Source: IPTS.

On-going European research

Within the Fifth Framework Programme, research work is underway, and more planned under further calls for proposals, in relation to the improvement of statistical indicators.

Within the STRATA action (strategic analysis of specific political issues), one of the target priorities is to foster research work aimed at achieving a common basis of science, technology and innovation indicators (32). The aim of this initiative is to provide a more comprehensive assembly of existing indicators, and promote work on the development of new S&T indicators, in recognition of the many deficiencies.

The recently published EPROS Workprogramme 2000, SINE (Statistical Indicators for the New Economy) (33) document produced by Eurostat and the Information Society Technologies (IST) programme gives a clear statement of the problems in this area. This paper has taken a very broad view on some of the issues in an attempt to stimulate a wider range of approaches, and sets out research themes in relation to four domains (Technology, Industry, Economy and Society), covering theories, models and concepts and measurement and statistics.

CONCLUSIONS

In summary, the search for relevant indicators of S&T activities and knowledge acquisition, distribution and exploitation must move from the linear model of innovation to a more complex context for which definitions and models have yet to be fully established and verified. It is not clear whether the stability of the older bases for measurement can be replaced with new concepts of similar stability over time, although some of the initiatives described in this chapter promise and merit continuing investigation and development.

The interaction of knowledge creation and diffusion processes from individual to organisational and then system level is the emerging context for value creation in the new economy. Central to any useful scheme for tracking these activities will be standard definitions of concepts and parameters. Much of the difficulty that exists stems from attempts to encompass new ideas within the strictures of the language of traditional economics. While concepts like human and intellectual capital reflect the increasing importance of knowledge and human resources in economic activity, their characteristics are so different to traditional forms of capital that trying to treat them like traditional capital assets may compound the problems.

Data collection problems are also constrained by the lack of innovation in the field of management accounting, which remains largely enslaved to the rigid and unchanging principles of financial accounting. Adoption of internal recording by firms, for management information purposes, of many of the ideas and issues outlined here, would assist statistical offices in their task of collecting relevant information. Here again the question of standards arises.

The rapid path of technological change poses great challenges to statistical offices trying to measure the dimension and growth rate of an economy. Problems arise because technological progress changes not only the quantity but also the quality of the goods and services being produced. In the context of the so-called 'new economy', statisticians are implementing new approaches and measurement initiatives to tackle these problems and to improve the mechanisms to measure the impact of technological advance in the economy.

(32) Line, E., *Support for the Development of Science and Technology Policies in Europe of the Key Action: Improving the Human Research Potential and the Socio-economic Knowledge Base*, http://www.cordis.lu/improving/home.html.

(33) Eurostat and IST, *The European Plan for Research in Official Statistics Workprogramme 2000 — SINE Statistics for the New Economy*, 10 February 2000, http://europa.eu.int/comm/eurostat.

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Notes on the methodological manuals

WHAT IS S&T?

To understand the shifting and expanding emphasis of data collection, a few definitions are necessary. According to the definition developed by the OECD in its *Proposed Standard Practice for Surveys of Research and Experimental Development — Frascati Manual*, R&D is: (1)

- Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

Science and technology, however, is far broader than just R&D. According to the United Nations Educational, Scientific and Cultural Organisation (Unesco), scientific and technological activities consist of 'systematic activities which are closely concerned with the generation, advancement, dissemination and application of scientific and technological knowledge in all fields of science and technology' (2). However, the current pace and type of economic development would seem to support an even broader definition that is capable of increasing the utility of the associated S&T indicators. According to the Institute for Prospective Technological Studies (IPTS), technology can be defined as: 'any systematic knowledge applied to practical ends such as problem-solving or extending human capabilities' (3).

What are the main objectives of collecting S&T data?

It is instructive to consider the multifaceted objectives of collecting statistics in the field of S&T at the international level. One of these is to facilitate international comparability of data, encourage policy learning and the exchange of information. Data collected from national sources are often based on distinct methodological concepts and constructed and developed in line with various national, economic and cultural reasons in mind. This, of course, has led to certain problems of comparability. Another objective, is to meet the growing requirement to measure not just the economic but also the social consequences of S&T. A third objective is to contribute to the existing stock of knowledge and develop a system of indicators which is able to increase our understanding of the interactions between the inputs invested in the S&T field and the eventual outcome obtained, or of the likely impact of certain decision-making.

Statistics on science and technology have always been indirect indicators, providing the policy maker with additional information that, while important and useful, is not necessarily conclusive. For example, data on patent applications provide an indication of the amount of invention that has occurred, but give no clear idea of the quality of the invention, nor of the marketability of the product. In many ways, data on R&D expenditure are the same: they give an indication of the amount of money that has been invested in research and development, but not of the consequences of this investment, thus they are considered as input indicators.

Keeping with the times

The difficulty that is being faced now is that statistical indicators have not been able to keep abreast of the velocity of innovation, such has been the recent booming of S&T activities in its various manifestations. Growth that has, of course, been aided by the increasingly

(1) *Proposed Standard Practice for Surveys of Research and Experimental Development — Frascati Manual*, OECD, 1994, p. 29.

(2) *Recommendations concerning the International Standardisation of Statistics on Science and Technology*, Unesco, 1978.

(3) See Chapter 8 p. 147.

favourable market conditions as barriers to innovative activity have reduced and incentives (such as tax credits) have been put in place. Internationally harmonised nomenclature, on the other hand, is an intricate device to develop.

The need for further data is reflected in the present publication: we include data on patents, employment in high technology, human resources in science and technology (including the flows from education into the system) and innovation.

Furthermore, not just economic but also social impacts of science and technology need to be (and are) increasingly reflected in the indicators. Growing emphasis is being placed on measuring the social consequences, from the types of jobs that are produced to the distribution of these jobs across the regions, age groups and gender.

HOW ARE THE DATA COLLECTED?

The development of data collection methods along national lines has inevitably led to certain problems of comparability. Considerations of creating a system whereby data are internationally comparable have therefore demanded that data collection is based on harmonised definitions, meets agreed international classifications and conforms to accepted methodological procedures.

The progress that has so far been made in harmonising international statistical methodology is, in large part, thanks to the efforts of policy makers, national statistical organisations and international bodies. The latter include the European Union (EU), the Organisation for Economic Co-operation and Development (OECD), The United Nations Economic, Scientific and Cultural Organisation (Unesco), the International Labour Office (ILO) and the World Bank.

In particular, a number of methodological manuals have been devised and developed to facilitate the collection of internationally comparable data. These are considered in turn.

The *Frascati Manual*

In 1963, the OECD produced the first edition of the *Proposed Standard Practice for Surveys of Research and Experimental Development*, or what is commonly known as the *Frascati Manual*. The manual was created in a first attempt to harmonise collection and compilation methods on R&D activities and place R&D in a wider context. Indeed, '... by providing internationally accepted definitions of R&D and classifications of its component activities, this manual contributes to intergovernmental discussions of both international co-operation and 'rules of the game' for science and technology policies' (4).

The manual provides methodological guidelines for the collection and measurement of statistics on R&D, sub-categorised into three main activities: basic research, applied research and experimental development.

The two main inputs, R&D expenditure and R&D personnel, are measured according to institutional sector, allowing the user to distinguish the relative importance of each sector of activity over time. Although five sectors are identified in the *Frascati Manual*, the lion's share of both expenditure and personnel fall into the three main sectors: Business Enterprise Sector, Government Sector and Higher Education Sector.

Providing indicators using implicit GDP price indices or in terms of the purchasing power standard (PPS), in order to

(4) *Proposed Standard Practice for Surveys of Research and Experimental Development — Frascati Manual*, OECD, 1994, p. 3.

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reflect the opportunity cost of performing R&D activities, allows important policy conclusions. For example, is there sufficient investment in business-led R&D or do there appear to be market failures in some areas?

Policy objectives, however, have changed over time — along with the rules of the game and the types of activity undertaken. Concomitantly, statistical standards have developed. In order to reflect these factors and the changing face of the economic and social environment, and relying on the experience gained from past editions of the manuals, frequent revisions have been conducted. In 1994, the fifth edition was published.

The success of the *Frascati Manual*, which should be qualified in terms of its limitations, and the need for international comparability, encouraged the OECD to develop a series of sister manuals (which in some cases jointly involved the European Commission). These are designed to assist in collecting internationally comparable data in the areas of patents, technology balance of payments, innovation and human resources in science and technology.

The *Oslo Manual*

The *Oslo Manual* provides guidelines for surveys on technological innovation and was an attempt to bring together the national experience from innovation surveys and define the main concepts. The manual has two main objectives: to provide a framework within which existing surveys can evolve towards comparability; and to assist newcomers to this important field (5).

The manual was subsequently used for the first harmonised pan-European innovation survey: the Community Innovation Survey (CIS), which has now become the largest effort to implement harmonised innovation surveys. Nevertheless, innovation surveys of the Oslo type have been undertaken in many other OECD countries, as well as in some non-OECD eastern European and Asian countries.

For a long time, technological innovation had been considered merely as an appendix to research — it was thought that simply funding research would be enough to ensure innovation. However, experience has shown that this simplistic vision should be abandoned. Now, innovation is recognised as a complex, interactive phenomenon that results from a mixture of knowledge and market requirements.

Thus, with the experienced gained from this exercise, a number of improvements were borne out. This led to the subsequent revision of the *Oslo Manual* and to the publication of the second edition in 1997.

The *Patent Manual*

This first edition of the *Oslo Manual* was followed, in 1994, by a manual providing guidelines for the collection of data on patents, taking into account a range of methodological questions and characteristics (6).

For a long time, patent statistics have been used as indicators of innovation output, being a gauge of the structure and evolution of innovative activities in countries, regions, or industries. Even if not all applications are granted, each application still represents technical effort by the inventor and is therefore considered to be an appropriate indicator of innovative potential. However, since the propensity, or tendency, to patent varies between enterprises and industries, the indicator has some limitations.

(5) *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data — Oslo Manual*, OECD, Paris, 1992.
Proposed Guidelines for Collecting and Interpreting Technological Innovation Data — Oslo Manual, Eurostat and OECD, revised version, Paris, 1997.

(6) *Patent Data as Science and Technology Indicators: Using and Interpreting Patent Data in Practice — Patent Manual*, OECD, 1994.

The *Canberra Manual*

At the end of 1994, under the joint aegis of the European Commission and the OECD, the *Manual on the Measurement of Human Resources Devoted to Science and Technology — Canberra Manual* was published. The development of indicators on human resources in science and technology (HRST) provides insights into current potential (how many 'highly qualified' workers there are in a country or region) and future potential (by how much is this stock of workers increasing or decreasing over time). Knowledge and ideas are the new vectors of growth: it is human capital that dictates the degree to which innovative potential is translated into technological and innovative practice.

However, excess demand in certain sectors and mismatching of skills in others have important implications for the design of education policy in Europe and beyond, which could consequently aid to close the skills gap. Data on such aspects are highly relevant for planning purposes: 'In rapidly changing societies individuals must update (or indeed significantly alter) their skill and competence profiles. Information about training and retraining could provide indicators of adaptability and potential response to future needs' (7).

The *Regional Manual*

Knowledge, therefore, is a principal dynamic in the network of regional economic growth. So, reflecting the increasing importance of the regional level in the world economy, in 1996 Eurostat published *The Regional Dimension of R&D and Innovation Statistics — Regional Manual.* Drawing on the above manuals, and especially the *Frascati and Oslo Manuals*, the *Regional Manual* provides definitions and recommendations for the compilation of data and endeavours to establish indicators capable of yielding harmonised and internationally comparable data on the measurement of input, process and output of regional R&D and innovation data (8).

After all, it is principally at the regional level that firms have the wherewithal to prosper and develop. Indeed, 'a growing number of scientists ... express the opinion that especially under the circumstances of rising globalisation, regional clusters of production and innovation are going to be increasingly important for the technological performance and international competitiveness of nations' (9).

A consequence of globalisation and the fragmentation of the R&D or innovation process is that procedures can take place in a number of different locations by a variety of different actors. For example, data on R&D expenditure may be available according to the administrative headquarters of a company when a degree of research is conducted in regional branches. To this end, and in order to reduce the margin of error, the *Regional Manual* provides recommendations for statistical units of measurement, which are employed by the EU Member States. These include the use of local unit (LU) for the business enterprise sector and local kind of activity unit (LKAU) for analyses according to sector of activity.

The local unit is an enterprise or part thereof (e.g. a workshop, factory, warehouse, office, mine or depot) situated in a geographically identified place. At or from this place economic activity is carried out for which — save for certain exceptions — one or more persons work (even if only part-time) for one and the same enterprise (10).

The local kind of activity unit, on the other hand, is the part of a KAU which corresponds to a local unit. The kind of activity unit groups all the parts of an enterprise contributing to the performance of an activity at class level (four digits) of NACE Rev. 1 and corresponds to one or more operational sub-divisions of the enterprise... (11).

(7) *Manual on the Measurement of Human Resources Devoted to Science and Technology — Canberra Manual*, OECD, Paris, 1994, Paragraph 41.

(8) *The Regional Dimension of R&D and Innovation Statistics — Regional Manual*, Office for Official Publications of the European Communities, 1996, p. 5.

(9) Gehrke and Legler, *Regional concentration of innovative potential in Western Germany*, 1998, p. 101.

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(11) Ibid., p. 29.

CONCLUSIONS

Despite the arguments in their support, the methodological manuals do have deficiencies, which have become apparent over time and through experience. For example, establishing the level of causality between the S&T system and the wider economy is one area that is not sufficiently covered by the manuals, and is likely to remain so in the near future.

Moreover, due to the very nature of the manuals — that they are produced at an international scale by a large number of countries, each with their own methodological and cultural concepts — there is, of course, a degree of compromise in certain areas. But this does not detract from their pertinence. Without such guidelines based on a common conceptual framework, comparability of data relating to R&D and its proximate domains would be, at best, extremely difficult, full of gaps and arbitrarily compiled.

Measures hitherto introduced need to be periodically improved and developed. Similarly, further, new measures are needed. In this way, the existing statistical environment can be improved and extended to more comprehensively depict the relevant socio-economic issues of today.

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Abbreviations and Symbols

A

Abbreviations

A

APR .... Association de prospective rhénane

B

BES .... business enterprise sector
BETA .... bureau d'études théoriques et appliquées

C

CD-ROM .... compact disc read-only memory
CERI .... Centre for Educational Research and Innovation
CERN .... European Centre for Nuclear Research
CIS .... Community Innovation Survey
CIS2 .... Second Community Innovation Survey
CLFS .... Community Labour Force Survey
CNRS .... Centre national de la recherche scientifique (F)

D

DG .... directorate-general

E

EAS .... Economic Analysis and Statistics Division (OECD)
EC .... European Community/Communities
EEA .... European Economic Area
EEC .... European Economic Community (now EC)
EI .... Environment Institute, Ispra (I)
EIMS .... European Innovation Monitoring System
EPO .... European Patents Office
EPROS .... European Plan for Research in Official Statistics
ESA .... European system of integrated accounts
EU/EU-15 .... European Union
EUR-11 .... Euro-zone (B, D, E, F, IRL, I, L, NL, A, P, FIN)
Euratom .... European Atomic Energy Community (EAEC)
Eurostat .... Statistical Office of the European Communities

F

FP .... Framework Programme
(e.g. FP2 ... FP5: Framework Programme No 2 ... Framework Programme No 5)
FTE .... full time equivalent

G

GBAORD .... Government budget appropriations or outlays for R&D
GDP .... gross domestic product
GERD .... gross domestic expenditure on R&D
GISCO .... geographic information system for the Commission (Eurostat)
GOV .... government sector
grads .... abbreviation for graduates
GUF .... General University Funds

A

H

HC .... head count
HES .... higher education sector
HRST .... human resources in science and technology
HRSTC .... human resources in science and technology core
HRSTE .... human resources in science and technology education
HRSTO .... human resources in science and technology occupation
HRSTU .... human resources in science and technology unemployed

I

IAM .... Institute for Advanced Materials, Petten (NL)
I&C .... information and communication
ICS .... information and communication-oriented services
IDEA .... indicators and data for European analysis
IHCP .... Institute for Health and Consumer Protection, Ispra (I)
ILO .... International Labour Organisation
IMS .... Intelligent Manufacturing Systems
IPC .... International Patent Classification
IPTS .... Institute for Prospective Technological Studies, Seville (E)
IRMM .... Institute for Reference Materials and Measurements, Geel (B)
ISBN .... international standard book number
ISCED .... international standard classification of education
ISCO .... international standard classification of occupation
ISI .... Fraunhofer-Institut fÿrSystemtechnik und Innovationsforschung
ISIS .... Institute for Systems Informatics and Safety, Ispra (I)
IST .... information society technologies
IT .... information technology
ITU .... Institute for Transuranium Elements, Karlsruhe (D)

J

JRC .... Joint Research Centre

K

KAU .... kind of activity unit
KIS .... knowledge-intensive services

L

LF .... labour force
LKAU .... local kind of activity unit
LU .... local unit

M

MECU .... millions of ECU
MEUR .... millions of euro
Mio .... million
MSTI .... Main Science and Technological Indicators

A

N

NABS ....nomenclature for the analysis and comparison of science budgets and programmes
NACE ....general industrial classification of economic activities within the European Communities
n.e.c. ....not elsewhere classified
NESTI ....National Experts on Science and Technology Indicators
New Cronos ....Eurostat's statistical reference database
NIW ....Niedersächsisches Institut für Wirtschaftsforschung
NUTS ....nomenclature of territorial units for statistics

O

OECD ....Organisation for Economic Cooperation and Development
OPOCE ....Office for Official Publications of the European Communities

P

Phare ....Poland-Hungary: aid for economic restructuring
(Community aid programme for central and east European countries)
PCT ....Patent Cooperation Treaty
PNP ....public non-profit sector
PPS ....purchasing power standard

Q

QC ....quality control

R

R&D ....research and development
RTD ....research and technological development

S

SAI ....Institute for Space Applications, Ispra (I)
S&E ....scientists and engineers
S&T ....science and technology
SESSI ....Ministère de l'industrie, service des statistiques indistrielles (F)
SINE ....Statistical Indicators for the New Economy
SME ....small and medium-sized enterprise
STEP ....Studies in Technology, Innovation and Economic Policy
STRATA ....Strategic Analysis of Specific Political Issues
SWOT ....Strength Weakness Opportunity and Threat

T

TACIS ....technical assistance to the Commonwealth of Independent States
TDS ....Territorial Development Service
TRCA ....Technology Revealed Comparative Advantage Index
TSER ....Targeted Socio-economic Research

U

Unesco ....United Nations Educational, Scientific and Cultural Organisation
UOE ....Unesco, OECD, Eurostat

A

Statistical symbols and abbreviations

fax	facsimile number
Fig.	figure
No.	number
p.	page
pp.	pages
R^2	R-squared value
tel	telephone number
Tab.	table
Vol.	Volume
%	pourcentage
:	data not available
..	confidential data
-	nil
0	less than fifty percent of the indicated unit
italics	estimates of Eurostat or OECD
1990-92	period of several calendar years (e.g. from 1.1.1990 to 31.12.92)
1991/92	period of 12 consecutive months

Countries

EU-15

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

Other countries

IS	Iceland
LI	Liechtenstein
JP	Japan
NO	Norway
US	United States

A

European currencies

ECU	ecu (European currency unit — up to 1998)
EUR	euro (European currency unit — from 1999)
ATS	Austrian shilling
BEF	Belgian franc
DEM	German mark
DKK	Danish crown (krone)
ESP	Spanish peseta
FIM	Finnish markka
FRF	French franc
GBP	pound sterling
GRD	Greek drachma
IEP	Irish pound (punt)
ITL	Italian lira
LUF	Luxembourg franc
NLG	Dutch guilder
PTE	Portuguese escudo
SEK	Swedish crown (krona)

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