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WP 1, 2 & 3: indicators on researchers' stock, career and mobility

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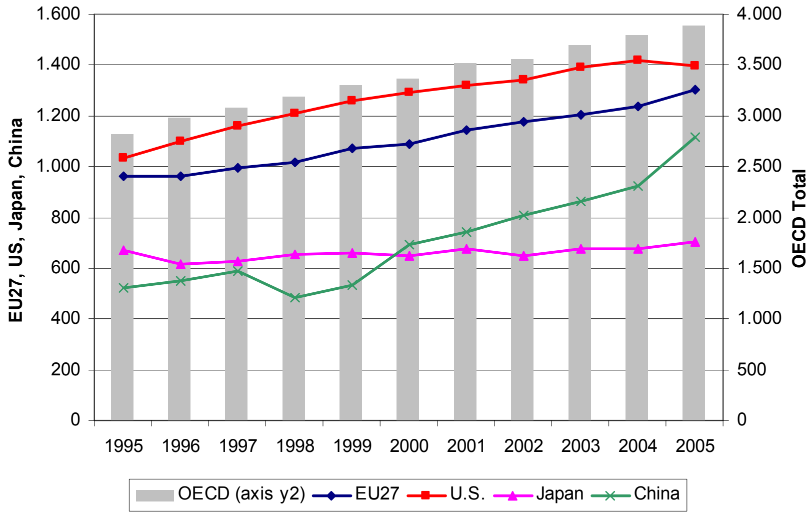
Main Findings

In this fiche, researchers are defined according to the Frascati Manual's definition: "Researchers are professional engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned". This definition is applied in R&D surveys which are the source for Eurostat and OECD R&D statistics.

- In 2005, there were 1.3 million of researchers (in full-time equivalent) in the EU27, 1.4 million in the U.S., 704,000 in Japan and 1.1 million in China (3.9 million in total in the OECD region). Demand for researchers is lower in the EU27 (0.56% of labour force) than in the U.S. (0.93%) and Japan (1.06%). The corresponding share is 0.70% on average in the OECD region and 0.15% in China.
- The number of researchers (FTE) increased from 964,000 in 1995 to 1.3 million in 2005 in the EU27 (+3.0% per year). Over the same period, the increases were 3.0% per year in the U.S., 0.5% in Japan, 7.9% in China, and 3.3% on average in the OECD region.
- Business researchers accounted for 0.27% of labour force in the EU27 in 2005, 0.74% in the U.S., 0.72% in Japan and 0.09% in China (0.70% on average in the OECD). The number of business researchers increased from 436,000 to 629,000 over 1998-2005 in the EU27 (+3.7% per year on average). The corresponding growths were 3.4% per year in the U.S., 2.3% in Japan and 13.7% in China (OECD average: 3.7%).

Number of researchers (FTE), in EU27, U.S., Japan and China, 1995-2005 (in thousands)



Source: IPTS with Eurostat data.

The stock and forecasts of researchers

In this fiche we analyse the evolution of the number of researchers in the European Union[1] over the last decade. The first section deals with concepts and definition. The second section presents some elements of international comparisons. The third section studies the evolution of the number of researchers in the EU. The fourth section carries out a short and medium term forecasting exercise of the number of researchers.

Concepts and definitions

Defining and measuring "scientists" is not an obvious question. Many different terms are used to qualify "scientists" (in a broad sense), among others: qualified personnel, highly skilled workers, human resources in science and technology, brains, scientists, engineers, R&D personnel, researchers.

Identifying the skills is a traditional but complex solution to specify and classify jobs. The term skill refers to the general capacities, the abilities to apply knowledge to perform and complete a set of tasks, and to solve problems. They include physical abilities (e.g., dexterity, strength, speed), cognitive skills (e.g., reasoning, logical thinking, perception, numerical and verbal abilities) and interpersonal skills (e.g., social communication and interactions, leadership).

In empirical work, researchers frequently use proxies based on education and occupation. Education is usually measured by years of schooling or final degree obtained; but it is quite specific to each educational system. Occupations provide more information on the skills required of workers, but they vary across countries and may be ambiguous. One possible solution is therefore to use international standard classifications.

For education, the International Standard Classification of Education (ISCED) is a framework for the compilation and presentation of national and international education statistics and indicators, which is maintained by the UNESCO Institute for Statistics[2]. It has been designed to serve as an instrument suitable for assembling, compiling and presenting comparable indicators and statistics of education both within individual countries and internationally. It is a classification both of levels of education and of fields of study. The term "qualified" refers to formal qualification.

For occupations, the corresponding classification is the International Standard Classification of Occupations (ISCO), for which the International Labour Organisation is responsible[3]. It is a tool for organising jobs into a clearly defined set of groups according to the tasks and duties undertaken in the job. The current (and third) version of the International Standard Classification of Occupations, ISCO-88, was adopted by the 14th International Conference of Labour Statisticians in 1987. ISCO-88 is currently in the process of being updated to take into account the developments in the economies of countries all over the world. The updated version will be ready in 2008. ISCO 88 groups jobs together in occupations and more aggregate groups mainly on the basis of the similarity of skills required to fulfil the tasks and duties of the jobs. Two dimensions of the skill concept are used in the definition of ISCO 88 groups:

- Skill level, which is a function of the range and complexity of the tasks involved; and
- Skill-specialisation, which reflects type of knowledge applied, tools and equipment used, materials worked on, or with, and the nature of the goods and services produced.

Unfortunately, there is no agreement on a definition of highly skilled/qualified workers at the international level. However, an international framework, known as the Canberra Manual, has been jointly developed by Eurostat and OECD to measure the Human Resources devoted to Science and Technology (HRST). The Canberra Manual[4]

[1] Some data refer to the EU25 and other to the EU27. It has not been possible to fully harmonise the geographical coverage as some data were not available or incomplete when the calculations were done, and recent updates have introduced inconsistencies.

[2] http://www.uis.unesco.org/ev.php?ID=3813_201&ID2=DO_TOPIC

[3] http://www.ilo.org/public/english/bureau/stat/isco/index.htm

[4] OECD (1995), *Manual of the measurement of human resources devoted to science and technology*, OECD, Paris. OECD (2001), *International Mobility of the Highly Skilled*, OECD, Paris.

proposed guidelines for the measurement of human resources devoted to S&T. It has been prepared by the OECD Group of National Experts in Science and Technology Indicators.

There are as well some agreements to measure R&D personnel and researchers, which is known as the Frascati Manual. The Frascati Manual[5] proposed standard practice for surveys on research and experimental development. The Frascati Manual has become the internationally recognised methodology for collecting and using R&D statistics.[6]

HRST

The Canberra Manual proposes a definition of HRST as persons who either have higher education or persons who are employed in positions that normally require such education. HRST are people who fulfil one or other of the following conditions:

a) Successfully completed education at the third level in an S&T field of study (HRSTE);

b) Not formally qualified as above, but employed in a S&T occupation where the above qualifications are normally required (HRSTO).

Under this definition, people can be HRST on the basis of either a renewable event (occupation) or a non renewable one (education). Once people have successfully completed education at the third level they are HRST for life, whatever their occupation. The situation is different for people who are HRST on the basis of their current occupation, without being formally qualified. Their status as HRST ends as soon as they change to an occupation outside S&T, retire, become unemployed or inactive.

In this definition, S&T are defined in 7 broad fields of study: natural sciences; engineering and technology; medical sciences; agricultural sciences; social sciences; humanities; other fields. Education at the third level covers studies leading to a first or higher university degree and also other studies at post-secondary level leading to awards not fully equivalent to a first university degree. The International Standard Classification of Education (ISCED) is used.

Occupations are defined in terms of jobs. The current employment is only considered. Employment refers to any kind of work, even as little as one hour, for pay (paid employment) or profit (self-employment) during the reference period (usually one week). S&T occupations[7] are defined using the following ISCO-88 categories:

- 122 Production and operations department managers
- 123 Other department managers
- 131 General managers
- 21 Physical, mathematical and engineering science professionals
- 22 Life science and health professionals
- 23 Teaching professionals
- 24 Other professionals
- 31 Physical and engineering science associate professionals
- 32 Life science and health associate professionals
- 33 Teaching associate professionals
- 34 Other associate professionals

The advantage of using a double educational/occupational classification is that it allows for looking at both the supply side of HRST (in terms of qualification) and the demand side (in terms of occupation), but two drawbacks can be mentioned:

- It does not allow for homogeneous measurement because the two classifications are based on different premises;
- It is too broad to meet specific analytical needs. Notably, it may be criticised for being 'too wide' insofar as it includes many persons who are not involved in R&D in their professional activities.

Therefore, subsets within this broad population have been defined. For example:

- HRST core (HRSTC): HRST population with both tertiary-level education and an S&T occupation;

[5] OECD (2002), *Proposed Standard Practice for Surveys on Research and Experimental Development*, OECD, Paris.

[6] Other international manuals exist, such as the Oslo Manual (*Guidelines for collecting and interpreting innovation data*).

[7] Alternative definitions can be proposed. Cf. *Feasibility of indicators for researchers' geographical mobility and career paths*, Framework Service Contract Nr -150176-2005-F1SC-BE, Final Report WP1, submitted to the IPTS by the ERAWATCH Network ASBL, Prepared by NIFU-STEP Norway, 2 May 2006.

- Scientists and engineers: generally defined as ISCO categories 21 (Physical, mathematical and engineering science professionals) and 22 (Life science and health professionals);
- IT labour force: ISCO categories 213 (Computing professionals), 1236 (Computing services department managers) and 312 (computer associate professionals).

R&D personnel and researchers

The International standard classification of occupations (ISCO) does not have a code to define researcher. Consequently we do not have a clear-cut definition that enables us to select and distinguish them from other types of skilled labour. The Frascati Manual proposes the following definitions of R&D, R&D personnel and researchers:

- Research and experimental development: "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." (p. 31);
- R&D personnel: "All persons employed directly on R&D should be counted, as well as those providing direct services such as R&D managers, administrators, and clerical staff." (p. 92);
- Researchers: "Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned." (p.93);

Researchers are classified in ISCO-88 Major Group 2, "Professionals", and in "Research and Development Department Managers" (ISCO-88, 1237). The Frascati Manual recommend that, by convention, members of the armed forces with similar skills who perform R&D should also be included. Postgraduate students at the doctoral level engaged in R&D should be considered as researchers.

According to the Frascati Manual, R&D surveys are the most appropriate instrument for collecting R&D personnel data. "Population censuses, labour force surveys or population registers are useful complementary data sources but cannot be used systematically to obtain R&D personnel data." (p. 98).

Following the Frascati manual, R&D efforts, R&D personnel and researchers are classified in five main sectors (institutional classification): business enterprise (BES), government (GOV), private non-profit (PNP), higher education (HE) and abroad. The business enterprise sector includes "All firms, organisations and institutions whose primary activity is the market production of goods or services (other than higher education) for sale to the general public at an economically significant price […]" (p. 54).[8] The government sector covers: "All departments, offices and other bodies which furnish, but normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community." (p. 62). The private non-profit sector includes "Non-market, private non-profit institutions serving households (i.e. the general public) [and] Private individuals or households" (p. 64). The higher education sector is composed of "All universities, colleges of technology and other institutions of post-secondary education, whatever their source of finance or legal status [and] also […] all research institutes, experimental stations and clinics operating under the direct control of or administered by or associated with higher education institutions." (p. 68).

The measurement of personnel employed on R&D involves two exercises:

- Measuring their number in headcounts (HC);
- Measuring their R&D activities in full-time equivalence (FTE) = person-years.

HC data

Data on the total number of persons who are mainly or partially employed on R&D (HC data) allow links to be made with other data series, (for ex. education or employment data or the results of population censuses). This is particularly important when examining the role of R&D employment in total stocks and flows of scientific and technical personnel. HC data are also the most appropriate measure for collecting additional information about R&D personnel, such as age, gender or national origin. Such data are needed to conduct analytical studies and implement recruitment or other S&T policies.

Various options are available for reporting headcount numbers:

- Number of persons engaged in R&D at a given date (e.g. end of period).

[8] For more details see Frascati Manual, Chapter 3, p. 51-73.

- Average number of persons engaged in R&D during the (calendar) year.
- Total number of persons engaged in R&D during the (calendar) year.

FTE data

R&D may be the primary function of some persons or it may be a secondary function. It may also be a significant part-time activity (e.g. university teachers or postgraduate students). To count only persons whose primary function is R&D would result in an underestimate of the effort devoted to R&D; to do a headcount of everyone spending some time on R&D would lead to an overestimate. The number of persons engaged in R&D is, therefore, also expressed in full-time equivalents on R&D activities (FTE data). This is a “true” measure of the volume of R&D.

Diverse methods can be used for measuring FTE data. The most precise method involves carrying out time-use surveys for each individual researcher. However, more approximate methods are often used in practice. One method often used consists of counting the number of positions for each category of personnel, then multiplying by appropriate R&D coefficients. In some cases, the R&D coefficients used are founded on survey data of some sort, while in others they are simply based on assumptions made by those who compile the statistics.[9]

To obtain appropriate data on R&D personnel in the higher education sector, time-use surveys or studies should be carried out. The main problem is related to the definition of the working time, which varies according to number of teaching hours per week, examinations, supervision and administrative duties, nature of R&D activities etc.

HRST, R&D personnel and researchers in the EU

To illustrate statistically the importance of the various groups that have been defined, results on the numbers of HRST, sub-groups of HRST, R&D personnel and researchers are given for the EU25 in 2004, in the following table.

The active population was estimated to be about 214 millions in the EU25 in 2004. HRST accounted for 40.4% of this total. HRSTE (defined in terms of Education only) accounted for 28.7% and HRSTO (Occupations) for 26.6%. HRSTC (Core, i.e. defined both in terms of Education and Occupations) accounted for nearly 15%, and scientists and engineers for 4.4%. Total R&D personnel (HC) accounted for 2.9 million, 1.36% of the active population.

Researchers, the group to which the remaining of this fiche is going to be devoted, accounted for 0.84% of the active population if measured in HC, i.e. nearly 1.8 million, and 0.57% (1.2 million) if measured in FTE.

Table 1. HRST, sub-groups of HRST, scientists and engineers, R&D personnel and researchers in the EU-25 in 2004

	In thousands	In % of active population
Active Population	213 834	100.0
HRST	86 338	40.4
HRSTE	61 322	28.7
HRSTO	56 843	26.6
HRSTC	31 827	14.9
Scientists and engineers	9 411	4.4
Total R&D personnel (HC)	2 905	1.36
Researchers (HC)	1 787	0.84
Researchers (FTE)	1 217	0.57

Source: IPTS based on Eurostat data.

Researchers: elements of international comparison (EU-U.S.-Japan-China-OECD)

Table 2 considers the “smaller” group (Researchers, FTE) and gives results for EU25, U.S., Japan and the total for OECD countries.

[9] e.g., teacher-researchers in France are, by convention, supposed to devote 50% of their time to teaching and 50% of their time to research.

In 2005, there were 1.4 million researchers in the U.S., 1.3 million in the EU27, 1.1 million in China and 704,000 in Japan. The total for the OECD region is 3.9 million. Demand for researchers is greater in Japan (1.06% of labour force) and the U.S. (0.93%) than in the EU27 (0.56%) and China (0.15%). It is 0.70% on average in the OECD.

The share of business researchers in the total number of researchers differs widely between the EU27 (48%) and the U.S. (79%), Japan and China being in-between with respectively 68% and 62%. Business researchers account for 0.27% of labour force in the EU27, 0.09% in China, 0.72% in Japan and 0.74% in the U.S.

Table 2. Researchers (FTE) and researchers in the business sector (FTE), number and percentage of active population, in the EU27, U.S., Japan, China and OECD (2005)

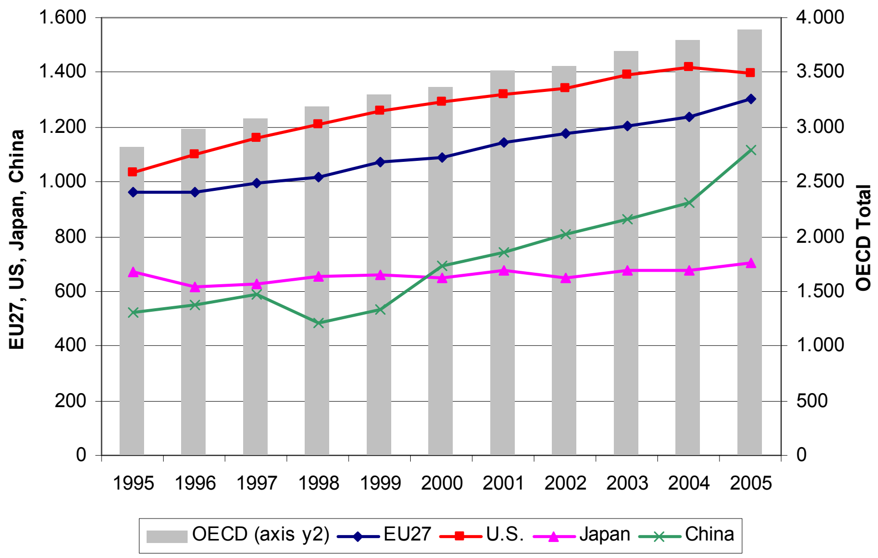
	Researchers, Total		Business researchers		Share of business researchers in total
	In thousands	% of labour force	In thousands	% of labour force	%
EU27	1 301	0.56	629	0.27	48.3
EU25	1 268	0.58	617	0.28	48.7
U.S.	1 395	0.93	1 105	0.74	79.2
Japan	705	1.06	481	0.72	68.3
China	1 119	0.15	696	0.09	62.3
OECD	3 891	0.70	2 496	0.45	64.2

Source: IPTS based on OECD data.

The number of researchers (FTE) increased from 964,000 in 1995 to 1.3 million in 2005 in the EU27 (+3.0% per year; cf. Figure 1). Over the same period, the increases were 3.0% per year in the U.S. (from 1.04 million to 1.39 million), 0.5% in Japan (from 673,000 to 705,000), 7.9% in China (from 522,000 to 1.12 million), and 3.3% in the total OECD (from 2.8 millions to 3.9 millions).

Over 2000-2005, the growth in the number of researchers (FTE) was faster in the EU27 (+3.6% p.a.) than in the U.S. (+1.6%), Japan (+1.7%) and the OECD average (+2.9%), while China experienced a growth of 10% per year.

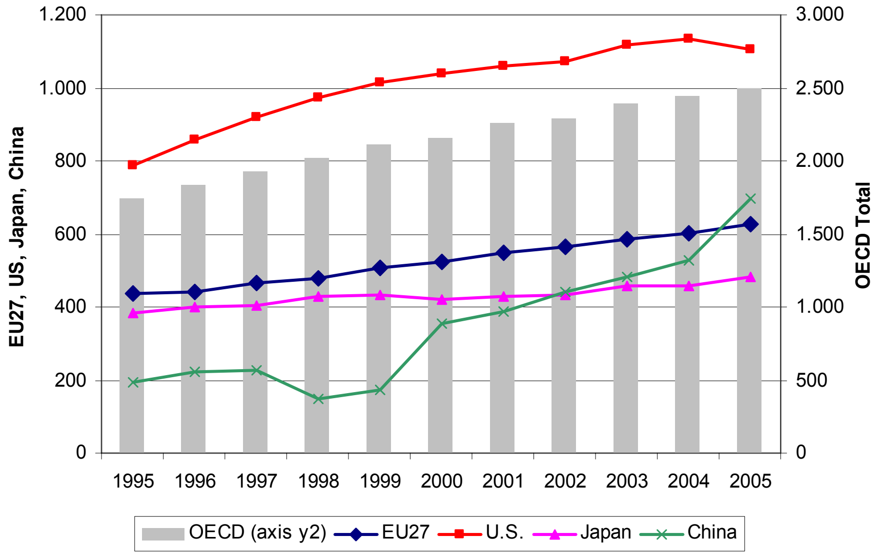
Figure 1. Number of researchers (FTE), in EU27, U.S., Japan and China, 1995-2005 (in thousands)



Source: IPTS based on OECD data.

The number of researchers (FTE) in the business sector increased from 436,000 to 629,000 in the EU27 (Figure 2), which corresponds to an annual growth of 3.7%. In the U.S., it increased from 789,000 to 1,105,000 (+3.4% p.a.), and in Japan from 384,000 to 481,000 (the growth was less strong, with 2.3% per year on average). In China, the growth was strong, from 193,000 to 696,000 (+13.7% p.a.). In the total OECD region, the number increased from 1.74 million to 2.5 million (+3.7% p.a.).

Figure 2. Number of business researchers (FTE), in EU27, U.S., Japan and China, 1995-2005 (in thousands)

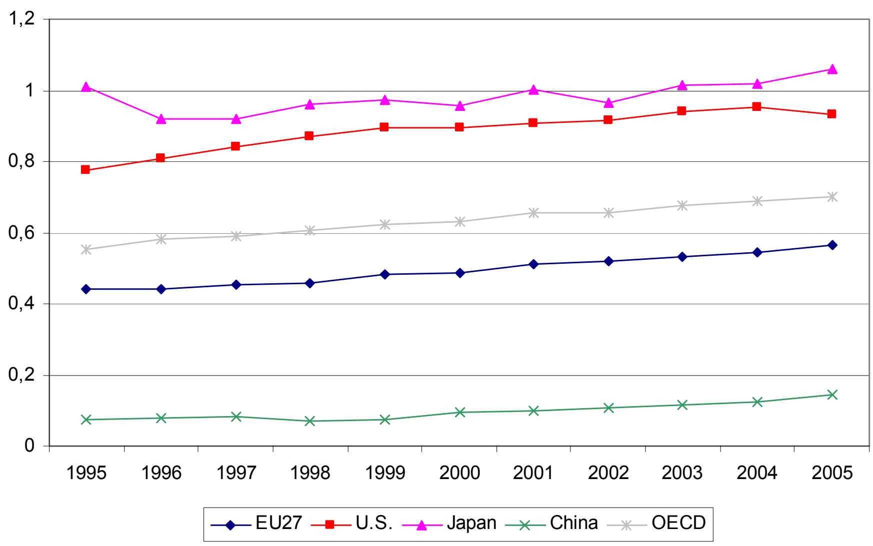


Source: IPTS based on OECD data.

The total number of researchers as share of the active population increased from 0.44% in 1995 to 0.56% in 2005 in the EU27 (+0.12 percentage points; Cf. Figure 3). Over the same period, the increase was slightly more pronounced in the U.S. (from 0.77% to 0.93%; but the highest share was observed in 2004 with 0.95%). In all OECD countries, the share increased from 0.55% to 0.70%, and in China it increased from 0.08% to 0.15%.

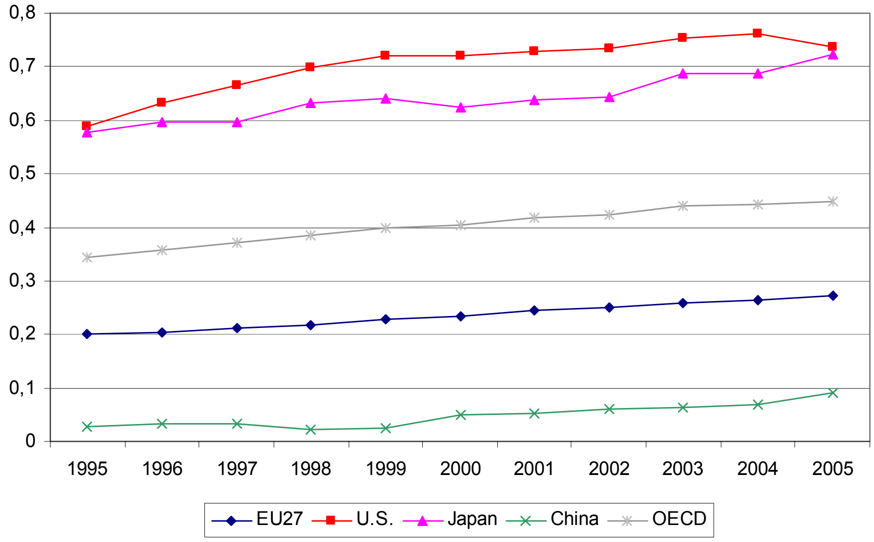
The share of business researchers in the active population (Figure 4) increased from 0.20% in 1995 to 0.27% in 2005. In the u.S. the increase has been stronger, from 0.59% to 0.74% (but the highest point was attained in 2004 with 0.76%). In Japan, we observed a similar increase in percentage points, from 0.58% to 0.72%. In China, the increase was less regular, but it varied from 0.028% in 1995 to 0.091% in 2005. In all the OECD countries, the share of business researchers grew from 0.34% to 0.45%.

Figure 3. Number of researchers (FTE) as % of the active population in the EU27, U.S., Japan and China (1995-2005)



Source: IPTS based on OECD data.

Figure 4. Number of business researchers (FTE) as % of the active population in the EU27, U.S., Japan and China (1995-2005)



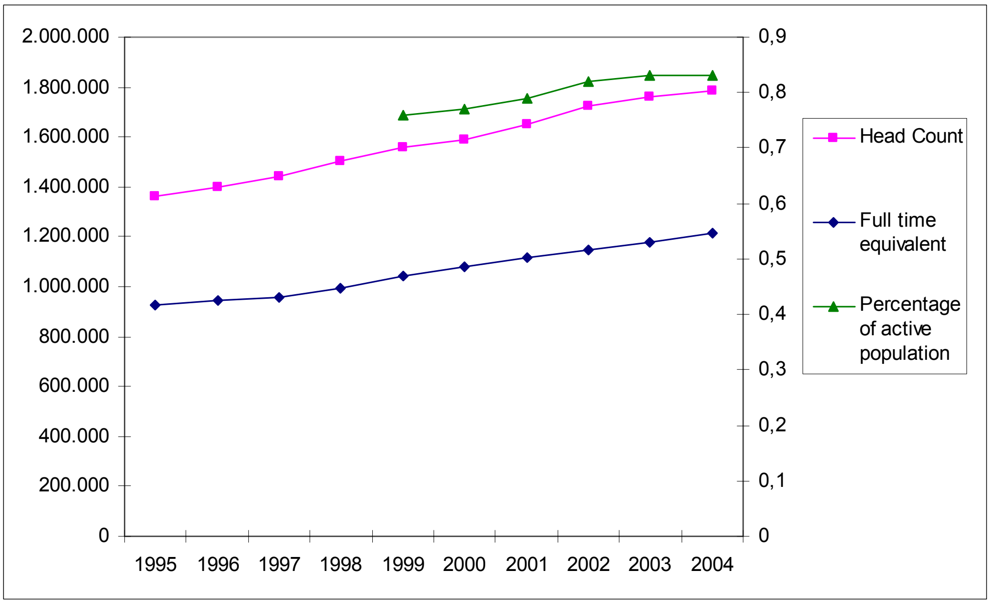
Source: IPTS based on OECD data.

Evolution of the number of researchers in the EU over the last decade

The total number of researchers in the EU: an increase of 3% per year over the last decade

The number of researchers in the European Union has increased from 1.36 million (in headcount, which amounts to 927 000 in full time equivalent) in 1995 to 1.79 million (1.22 million in FTE) in 2004. This represents an annual growth rate of 3%. This corresponds to an increase of about 50,000 researchers (HC) per year. The percentage of researchers (HC) in the active population also shows an upward trend, having risen from 0.76% in 1999 to 0.83% in 2004.

Figure 5. Number of researchers (HC, FTE) and number of researchers (HC) as percentage of active population in the EU25 (1995-04)

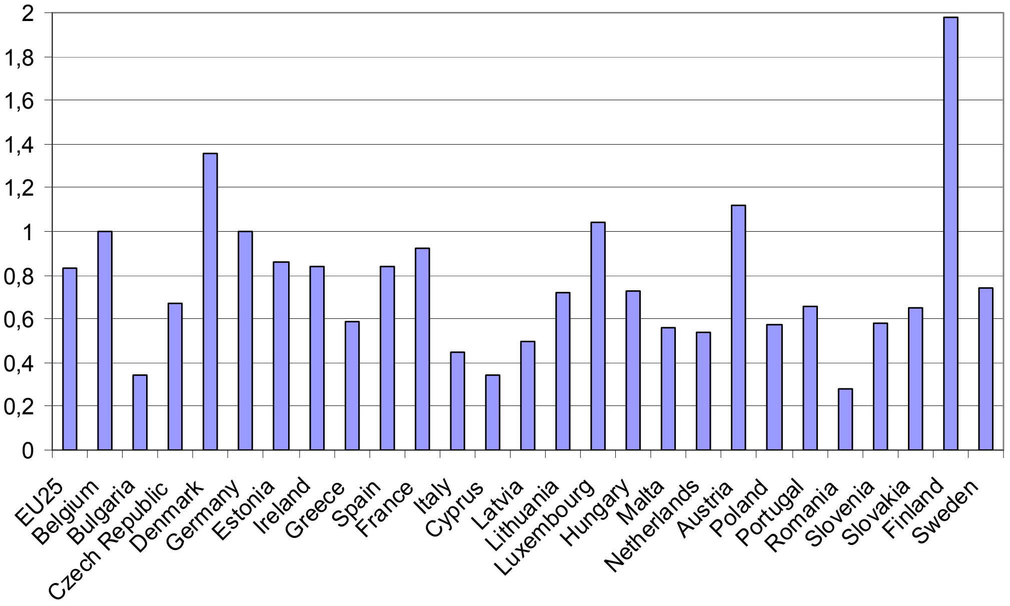


Source: IPTS with Eurostat data.

This growth in the number of researchers is matched by a slightly lower growth in expenditures (2% a year, in constant prices). This can be interpreted both as a sign of the expansion of the European R&D system, or as the increased effectiveness of R&D statistics. The slight mismatch between the increase in researchers and in expenditures can be explained by a more rapid growth in scientific disciplines (e.g. social sciences) and industrial sectors (e.g. services) that are more labour intensive and less demanding in terms of equipment.

However, these figures for Europe are based on very diverse national settings. Regarding the percentage of researchers in the active population, some countries in 2004 were still bellow the 0.5% level (Bulgaria, Italy, Cyprus, Latvia and Romania). The only countries above 1% are Denmark, Luxembourg, Austria and Finland.

Figure 6. Number of researchers (HC) as percentage of the active population by country in 2004

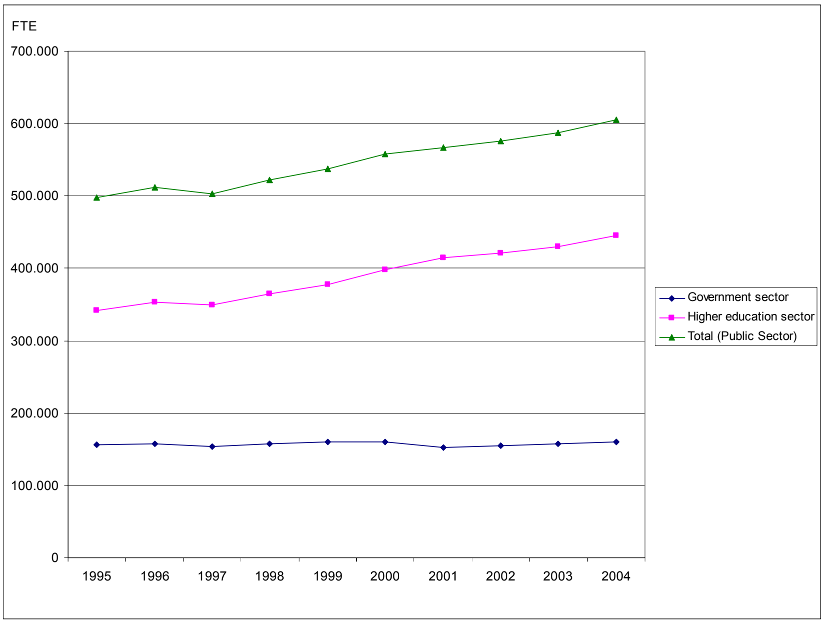


Source: IPTS with Eurostat data. Note: data from 2003 for Belgium, Germany, Greece, Luxembourg, Netherlands, Portugal and Sweden.

The number of researchers in the public sector: the growth has been driven by the higher education sector over the last decade

For the past ten years, the stock of researchers (in Full Time Equivalent) in the EU25 in the public sector has been growing quite steadily, at an average rate of 2% a year. This growth is mainly due to the higher education sector, which has shown an average annual growth rate of 3%, whereas the government sector has remained fairly stable. The number of researchers (FTE) in the public sector has reached 605 000 in 2004.

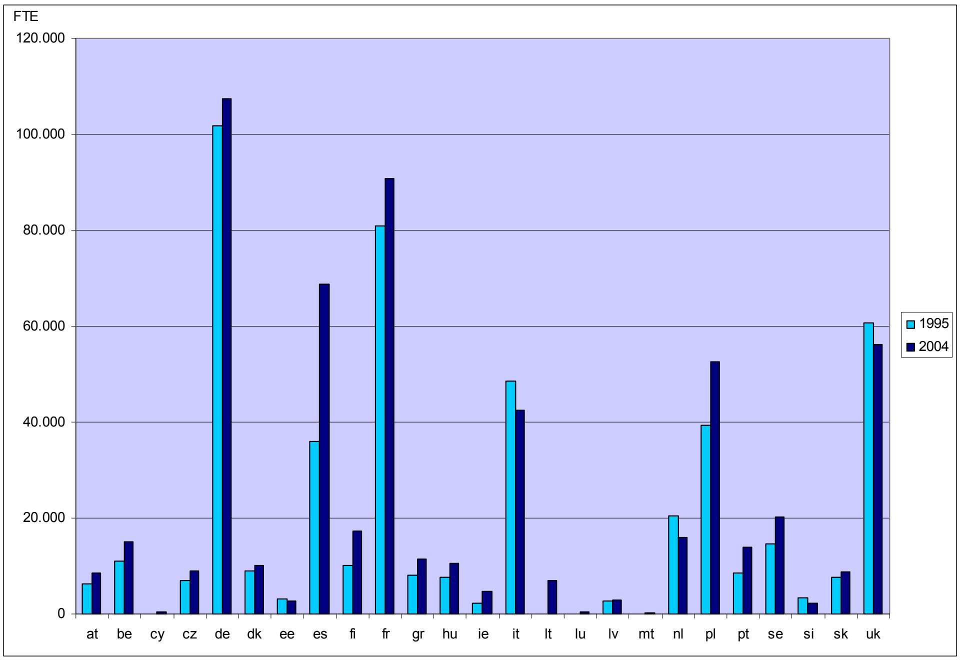
Figure 7. Researchers (FTE) in the Higher Education and Government sector in the EU25 (1995-04)



Source: IPTS with Eurostat data.

Regarding the differences by EU country, it is noticeable that almost all countries have contributed to the growth of researchers in the public sector, with the exception of Italy, Netherlands, Slovenia and the UK, where the number of researchers has decreased between 1995 and 2004. Spain shows the most significant increase in the number of researchers over the ten year period, almost doubling its public researchers stock.[10]

Figure 8. Researchers (FTE) in the Public Sector (higher education and government) by country (1995 and 2004)



Source: IPTS with Eurostat data.

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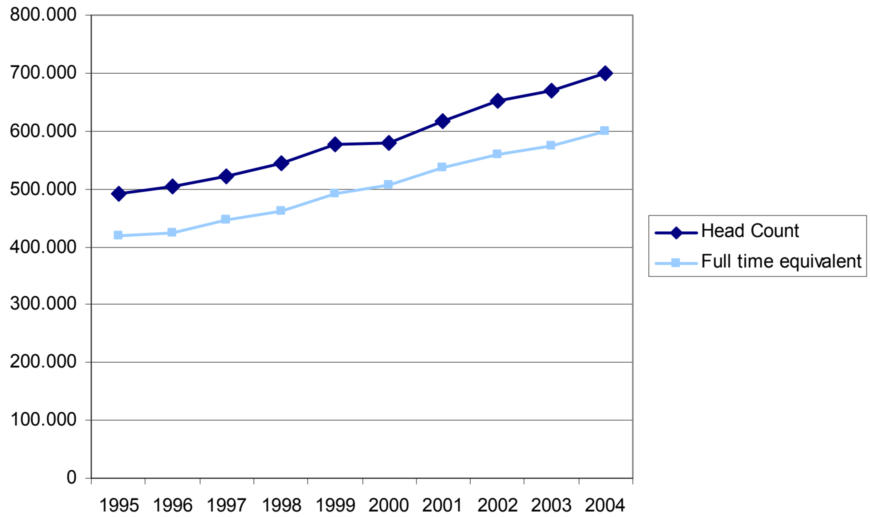
[10] However, this may be partly due to a change in definitions and methodology, according to a Spanish expert. In 2002, the methodology of the statistics on research and development changed. Until 2002, the definition of researchers according to the Frascatti Manual was ambiguous, so the number of researchers in Europe was not harmonized. For example, In Spain, until 2002, for someone to be considered a researcher, he/she had to work full-time and exhibit that he/she was constantly exerting his best efforts to complete his investigations. Until 2002, the occasional researchers were not taken into consideration in the R&D statistics. In addition, many non profit institutions were clasificated in the private sector.

The number of researchers in the business sector: a growth differentiated by areas of activity

The business sector in Europe shows an even clearer tendency for growth regarding the number of researchers, since the average annual growth rate between 1995 and 2004 is double the one observed for the public sector (4% for HC, 4.1% for FTE).

Figure 9. Researchers (HC, FTE) in the business sector in the EU25 (1995-04)



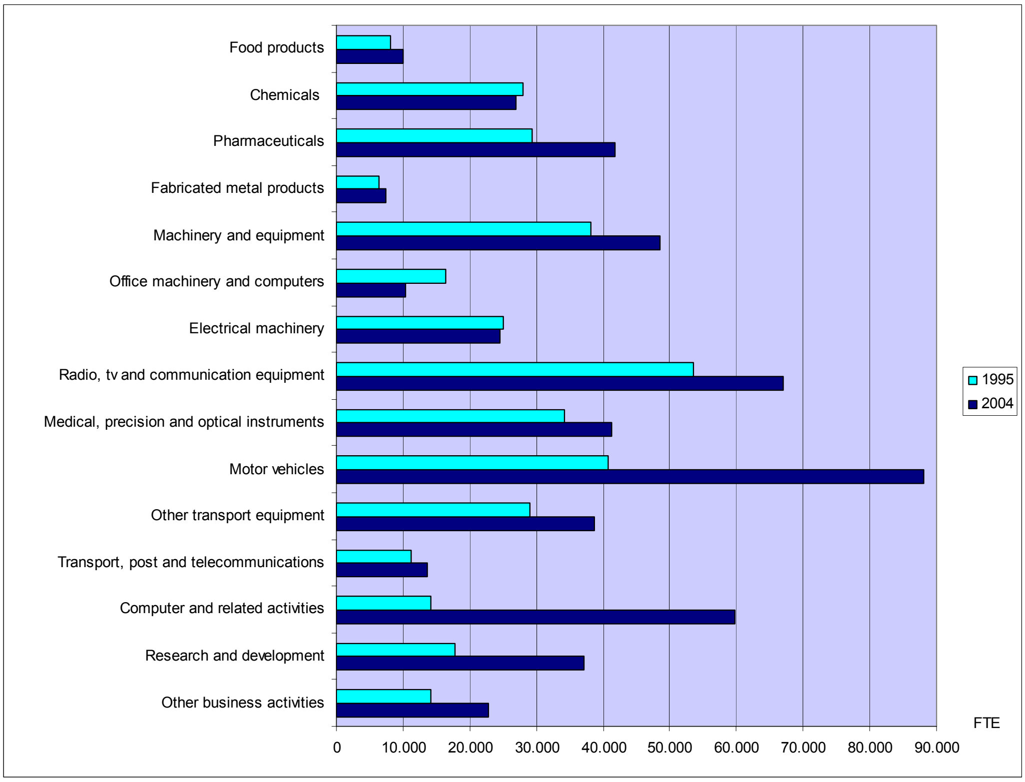
Source: IPTS with OECD and Eurostat data.

Although this can be partially due to an improvement in survey techniques and a larger coverage of enterprises, as well as to a re-classification of some activities as research for tax purposes, the size of the growth must also be due to an expansion of the business R&D system.

This growth in the stock of researchers in the business sector has not happened homogenously in all areas of activity. Whereas some sectors have lost researchers between 1995 and 2004 (chemicals, manufacture of office machinery and computers), other sectors have more than doubled their stock of researchers: manufacture of motor vehicles, computer and related activities, research and development.

During this period, the growth rate in the services sector was higher than in the manufacturing sector (average annual growth rate of 8% against 3%).

Figure 10. Researchers (FTE) in the business sector by selected NACE sectors in the EU25 (1995 and 2004)



Source: IPTS with Eurostat data.

However, data by sector must be analysed with some caution. For example, the research and development services sector has different classifications in different countries that sometimes change over time. A company that performs R&D services to other companies may be classified on this sector or in the other sectors for which its research is destined (e.g. pharmaceuticals, manufacture of mother vehicles).

Forecasting the number of researchers

The aim of this section is to give short-term (2005-07) and medium-term (2010) forecasts of the number of researchers. Econometric models have been applied to estimate the total number of researchers and the number of researchers in the different sectors, at the EU25 level.

Short-term forecasts (2004-2007): the growth of the number of researchers is expected to be 3.5% per year in the higher education sector and 3.2% per year in the business sector

According to our estimations, there will be about 1.95 million researchers HC in the EU25 in 2007. The increase will be about 9.2% from 2004 to 2007, i.e. 3% per year, which corresponds to about 165,000 more researchers (+55,000 per year).

The number of researchers in higher education is estimated to be about 970,000 in 2007, an increase of about 10.8% from 2004 (3.5% per year) i.e. an increase in the absolute number of researchers of about 94,000 researchers. The number of researchers in the government sector is estimated to be about 195,000 in 2007, more or less at the same level as in 2004. Therefore, in the public sector (if we add the higher education and the government sectors), the number of researchers is estimated to be 1.16 million in 2007 in the EU25 (an additional 94,000 researchers on the 2004-2007 period, i.e. +8.8%).

The number of researchers in the private non-for-profit sector is estimated to be about 21,000 in 2007, an increase of about 3,000 researchers from 2004.

According to the models, the number of researchers (HC) in the business sector in the EU25 will be around 770,000 in 2007. The increase is 9.8% (3.2% per year) compared to 2004, which corresponds to about 70,000 additional researchers.

On the period 2004-2007, in the EU25, the number of researchers in the business sector is expected to grow slightly more rapidly (in %) than the number of researchers in the public sector (3.2% against 2.8%, per year). However, in absolute numbers, the conclusion is different as the number of researchers is expected to increase more in the public sector than in the business sector (94,000 against 68,000).

Table 3. Number of researchers (HC) in 2004 (observed) and 2007 (estimated) in the EU25

	2004	2007	Variations	Growth rates (%)	Annual growth rates (%)
Public sector	1 068 000	1 162 000	94 000	8.8	2.8
HE	*873 000*	*967 000*	*94 000*	*10.8*	*3.5*
GOV	*195 000*	*195 000*	*0*	*0.0*	*0.0*
PNP	18 000	21 000	3 000	15.9	5.2
BES	700 000	769 000	68 000	9.8	3.2
TOTAL	**1 787 000**	**1 952 000**	**165 000**	**9.2**	**3.0**

Source: IPTS. Numbers are rounded.

Medium-term forecasts (2000-2010): an expected increase of 50,000 researchers per year, shared equally between the higher education sector and the business sector

It is possible to try to forecast the number of researchers to 2010. This is done simply with linear trend models. We found that nearly 2.1 million of researchers will be employed in the EU25 in 2010, nearly 1.24 million in the public sector and 830,000 in the business sector.

This corresponds to an increase of about 510,000 researchers on the period from 2000 to 2010, i.e. an increase of some 50,000 researchers per year, shared equally between the higher education (+25,000 per year) and the business (+25,000 per year) sectors.

The annual growth rate of the number of researchers is expected to be 2.8% on average, with 3.7% in the business sector and 2.8% in the higher education sector.

Table 4. Number of researchers (HC) in 2000 (observed) and 2010 (estimated) in the EU25

	2000	2010	Variations	Growth rates (%)	Annual growth rates (%)
Public sector	994 000	1 245 000	251 000	25.3	2.3
HE	*801 000*	*1 051 000*	*251 000*	*31.2*	*2.8*
GOV	*193 000*	*193 000*	*1 000*	*0.0*	*0.0*
PNP	17 000	23 000	6 000	35.3	3.1
BES	580 000	834 000	254 000	43.8	3.7
TOTAL	**1 591 000**	**2 102 000**	**511 000**	**32.1**	**2.8**

Source: IPTS. Estimations are based on linear trend models. Numbers are rounded.

Methodology

The stock of researchers

Excepting in the first section which presents and defines various populations (and notably HRST), throughout this fiche, it is used the Frascati Manual's definition for researcher, applied in R&D surveys, which are the source for Eurostat and OECD R&D statistics: "Researchers are professional engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned" – which targets highly qualified people, working either in enterprises or public institutions, being in charge of designing and managing research projects aimed at filling the needs of their employers (mostly basic research needs for public institutions and applied research and development needs for business enterprises)".

Full Time Equivalent was the unit used in most charts, since there is more data available than in Head Count. On the other hand, it allows for a clearer picture of the stock of researchers, since it measures the actual time devoted to research and not the amount of individuals that perform research, often on a part-time basis. However, in the nowcasting exercise, data in head counts have been preferred as it is more relevant in the perspective of a supply-demand analysis. Finally, the relations between HC and FTE data series are relatively close (the two series evolve in parallel) and generally one serie can be approximated very closely from the other.

Although the reference year for most countries in Figure 6 is 2004, data for Belgium, Germany, Greece, Luxembourg, Netherlands, Portugal and Sweden are from 2003. No information was found regarding the UK.

Data by country on Figure 8 was obtained from several sources: Eurostat, OECD and national statistical agencies. The values for Austria were estimated through annual growth rates, since the only available figures date from 1993, 1998 and 2002. The values for 2004 for France, Italy, Netherlands and the UK were also estimated, based on annual growth rates between 2001 and 2003.

The values by sector in Figure 8 were also obtained from several sources: Eurostat, OECD and national statistical agencies (France, UK and Finland). The EU total was estimated based on the sum of 19 countries, which concentrate 99% of the total Business researchers in Europe: Austria, Belgium, Czech Republic, Germany, Denmark, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Sweden, Slovenia and UK.

Forecasting

To evaluate the current values and the evolutions of the number of researchers in the near future on the basis of available information, as official data are generally delayed for two or three years, three models have been estimated, the first one with only GDP as an explanatory variable, the second one with GDP and a trend as explanatory variables (our “central” model), and the third one with only trend. The variable GDP captures the impact of general economic conditions whereas the trend variable is intended to capture the exogenous component in the number of researchers. GDP was chosen as it is forecasted on the next two years and thus can be used to nowcast the number of researchers.[11] The results presented in this fiche are those of the central model if not otherwise stated.[12]

Data

Data have been extracted on October 6th, 2006, from Eurostat database.

Definitions

Nowcasting concerns the inference on the current realization of random variables using information available until a recent past. The method tries to evaluate the current values of some series (e.g., R&D, GDP, inflation), on the basis of available and delayed data.

[11] To the contrary of R&D expenditures for example, which may have been more relevant but are generally not forecasted (and more, they are generally subject to delays as well), and thus can’t be used for our purpose.

[12] The results of the two other models are very similar and are not reported here for the clarity of the document.

Borrowing from the meteorological literature, this problem is called nowcasting rather than short-term prediction in order to emphasize the fact that when nowcasting, the time of availability of the data is not the same for all variables, in particular for the possible predictors, and to emphasize that the horizon of prediction is today rather than tomorrow (Moucharta et al. 2005).

Nowcasts are constructed at central banks using both simple models and qualitative judgment. Those exercises involve the analysis of a large amount of information and a judgment on the relative weight to attribute to various data series. As new information becomes available throughout the month, the nowcasts and forecasts may be adjusted in response to changes in both the values of the data series and the implicit relative weights applied to those series (Giannone et al. 2005).

Estimation methods

Three models have been estimated:

Model 1: $RES_t = \alpha + \beta GDP_t + u_t \qquad u_t \sim N\left(0;\sigma^2\right) \qquad t = 1995 \ldots 2004$

Model 2: $RES_t = \alpha + \beta GDP_t + \delta t + u_t \qquad u_t \sim N\left(0;\sigma^2\right) \qquad t = 1995 \ldots 2004$

Model 3: $RES_t = \alpha + \delta t + u_t \qquad u_t \sim N\left(0;\sigma^2\right) \qquad t = 1995 \ldots 2004$

where RES is the number of researchers (HC), GDP is the gross domestic product at constant prices (index 1995 = 100), t is the year, u is the error term, α, β and δ are the parameters to estimate.

These models have been applied to the total number of researchers, to the number of researchers in the different sectors taken individually (HE, GOV, PNP, BES) or grouped (total for HE-GOV-PNP).

Eurostat data have been used to feed the models.

Model 2 is our “central” model. It is generally preferred to the other models as its quality has proven to be higher, except in some cases when HE, GOV and PNP were considered separately.

Model 3 has mainly been used for the medium term forecasts to 2010 (it is a simple linear trend model).

Quality

The models are satisfactory in general as around 95-99% of the variance is explained, When HE, GOV and PNP are considered separately, the models perform less well as only about 40 to 50% of the variance is explained.

However, the nowcasts of the number of researchers are dependent upon the quality of the forecasts of GDP. A more general problem remains the impossibility to forecast the exogenous shocks (and notably policy measures). More complex models could be estimated but the added value is uncertain.

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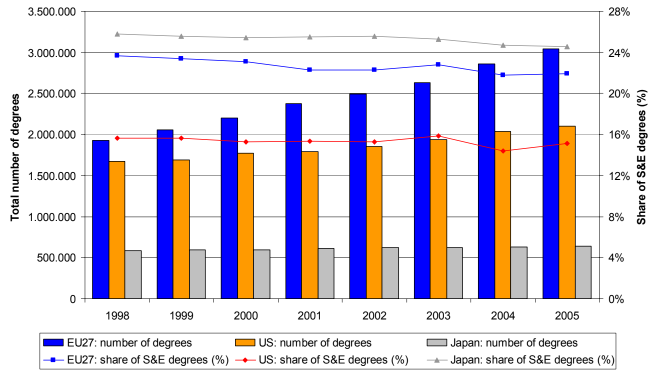
WP 1: Indicators on researchers' stock and career
Indicator 2: Number of researchers in the training phase and post-docs

Main Findings

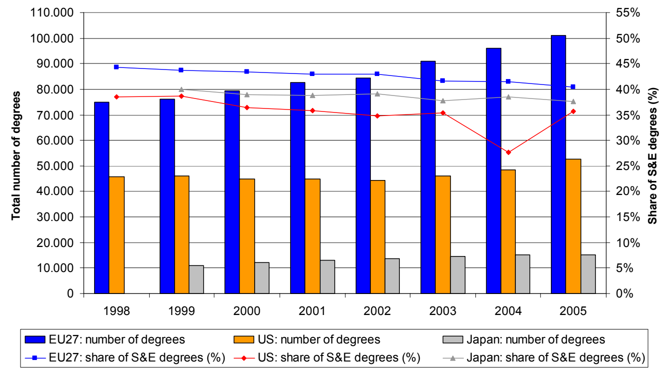
In order to estimate the potential evolution of the human resources in science and technology in Europe, the evolution of the number of higher education degrees with academic orientation and the number of doctoral degrees is analysed over the period 1998-2005.

- In 2005, 3 million of tertiary degrees with academic orientation were awarded in the EU27, against 2.1 million in the U.S. and 640,000 in Japan. From 1998 to 2005, a regular increase has been observed: the number of degrees increased by 6.7% per year on average in the EU27, 3.3% in the U.S. and 1.3% in Japan.
- In the EU27, the number of degrees in science, mathematics and computing increased by 6.8% per year on average between 1998 and 2005 (3.6% in the U.S. and 1.8% in Japan), while in engineering, manufacturing and construction, the increase was less pronounced, 4.5% per year (1.8% in the U.S. and 0.3% in Japan). All EU countries show a positive growth in the number of degrees in science, mathematics and computing, while in engineering, manufacturing and construction, five EU countries experienced a decrease.
- In 2005, some 100,000 doctoral degrees were awarded in the EU27, against 53,000 in the U.S. and 15,000 in Japan. From 1998 to 2005, the number of doctoral degrees increased respectively by 4.4% per year on average in the EU27, 2% in the U.S. and 5.7% in Japan.
- In the EU27, the number of doctoral degrees in science, mathematics and computing increased by 2.7% per year on average from 1998 to 2005, while in engineering, manufacturing and construction, it increased by 3.8% per year. Four EU countries show a decrease in science, mathematics and computing, and three EU countries in engineering, manufacturing and construction.

Number of tertiary degrees with academic orientation and share of science and engineering fields, in the EU27, U.S. and Japan (1998-2005)



Number of doctoral degrees and share of science and engineering fields, in the EU27, U.S. and Japan (1998-2005)



Higher education graduates in the EU

This fiche provides the evolution of the number of higher education degrees in the EU27 from 1998 to 2005. This fiche is devoted to the analysis of tertiary degrees with academic orientation (ISCED 5A) and to doctoral degrees (ISCED 6)[13], as they are the main component of the potential supply of scientists and researchers.

In the terminology of the International Standard Classification of Education (ISCED-97), ISCED level 5A programmes are tertiary programmes that are largely theoretically based and are intended to provide sufficient qualifications for gaining entry into advanced research programmes and profession with high skills requirements. The ISCED 6 level, "second stage of tertiary education leading to an advanced research qualification", is reserved for tertiary programmes which lead to the award of an advanced research qualification.

The cumulated number of tertiary degrees with academic orientation awarded on the period 1998-2005 in the EU27 reaches 19.6 millions (2.45 million each year on average) (cf. Table 5). In 2005, 3 millions of such degrees were awarded.[14]

The cumulated number of doctoral degrees over the same period has been of 686,000, i.e. 86,000 per year on average. In 2005, 101,000 doctoral degrees were granted.

In science, mathematics and computing, nearly 248,000 tertiary degrees with academic orientation and 24,800 doctoral degrees were awarded each year on average over the same period. The corresponding numbers for 2005 are 307,000 and 27,500.

In engineering, manufacturing and construction, 306,000 tertiary degrees with academic orientation and 11,600 doctoral degrees were awarded over 1998-2005. In 2005, these numbers were respectively 358,000 and 13,400.

Table 5. Number of higher education degrees awarded in the EU-27 (cumulated over 1998-2005 and in 2005)

	Tertiary degrees with academic orientation (ISCED 5A)			Doctoral degrees (second stage of tertiary education leading to an advanced research qualification) (ISCED 6)		
	Cumulated number 1998-2005	Average 1998-2005	2005	Cumulated number 1998-2005	Average 1998-2005	2005
Teacher training and education science	2.257.954	282.244	336.384	18.307	2.288	2.971
Humanities and arts	2.495.206	311.901	379.104	84.325	10.541	12.539
Social sciences, business and law	6.941.420	867.678	1.154.997	114.389	14.299	17.926
Science, mathematics and computing	1.980.122	247.515	307.402	198.688	24.836	27.450
Engineering, manufacturing and construction	2.444.536	305.567	358.473	92.519	11.565	13.395
Agriculture and veterinary	328.291	41.036	48.305	27.482	3.435	3.975
Health and welfare	1.911.622	238.953	340.263	141.897	17.737	21.584
Services	563.975	70.497	100.791	6.250	781	1.048
Unknown or not specified	680.609	85.076	14.046	1.878	235	257
Total	**19.603.735**	**2.450.467**	**3.039.765**	**685.735**	**85.717**	**101.145**

Source: IPTS with Eurostat data.

In the remaining of this fiche, we will first study the evolution of the number of tertiary degrees with academic orientation, by fields and countries, over 1998-2005. Then the evolution of doctoral degrees will be detailed over the same period. Finally some elements on the gender differences will be given.

[13] See methodology for more details.

[14] When the calculations were done (November 2007), data for 2005 were not complete for Italy. 2004 data were used instead for this country.

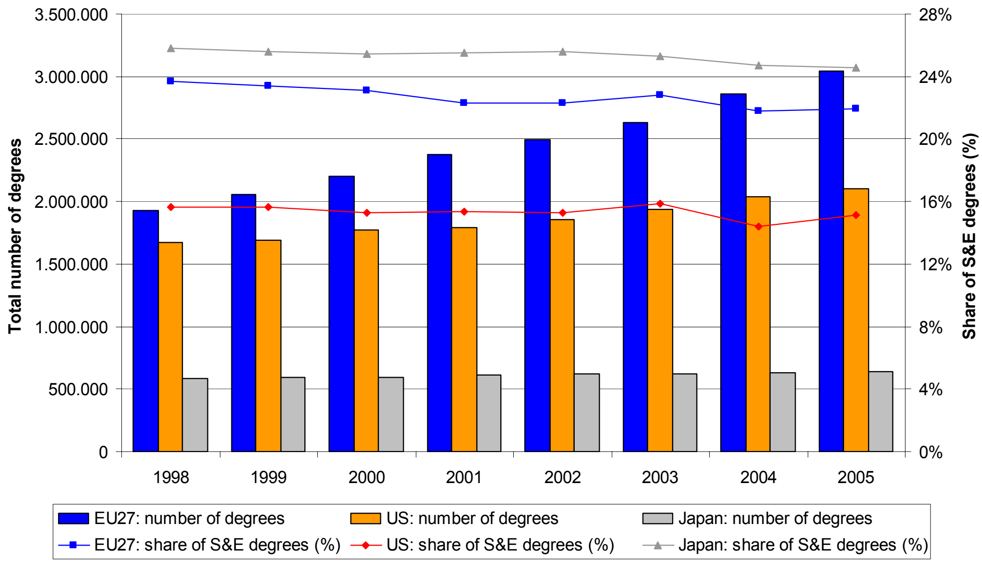
Tertiary degrees with academic orientation

Elements of international comparison

In 2005, 3 million of tertiary degrees with academic orientation were awarded in the EU27, against 2.1 million in the U.S. and 640,000 in Japan (Figure 11). From 1998 to 2005, a regular increase has been observed: the number of degrees increased by 6.7% per year on average in the EU27, 3.3% in the U.S. and 1.3% in Japan.

The share of science and engineering degrees in this total has tended to slightly decrease over the period in the EU27, from 23.7% in 1998 to 21.9% in 2005. In the U.S., the share of S&E degrees is lower and has been more or less stable, evolving between 14.4% and 15.9% over the period. In Japan, the share of S&E degrees, which is higher than in the U.S. and (slightly) higher than in the EU27, has been decreasing very slightly, from 25.8% to 24.5%.

Figure 11. Number of tertiary degrees with academic orientation and share of science and engineering degrees, in the EU27, U.S. and Japan (1998-2005)



Source: IPTS based on Eurostat data.

Separating science fields on the one hand and engineering fields on the other, we find that some 300,000 degrees in science were awarded in 2005 in the EU27, against 190,000 in the U.S. and 28,000 in Japan (Figure 12). In engineering, 60,000 degrees were granted in the EU27, 130,000 in the U.S. and 130,000 in Japan.

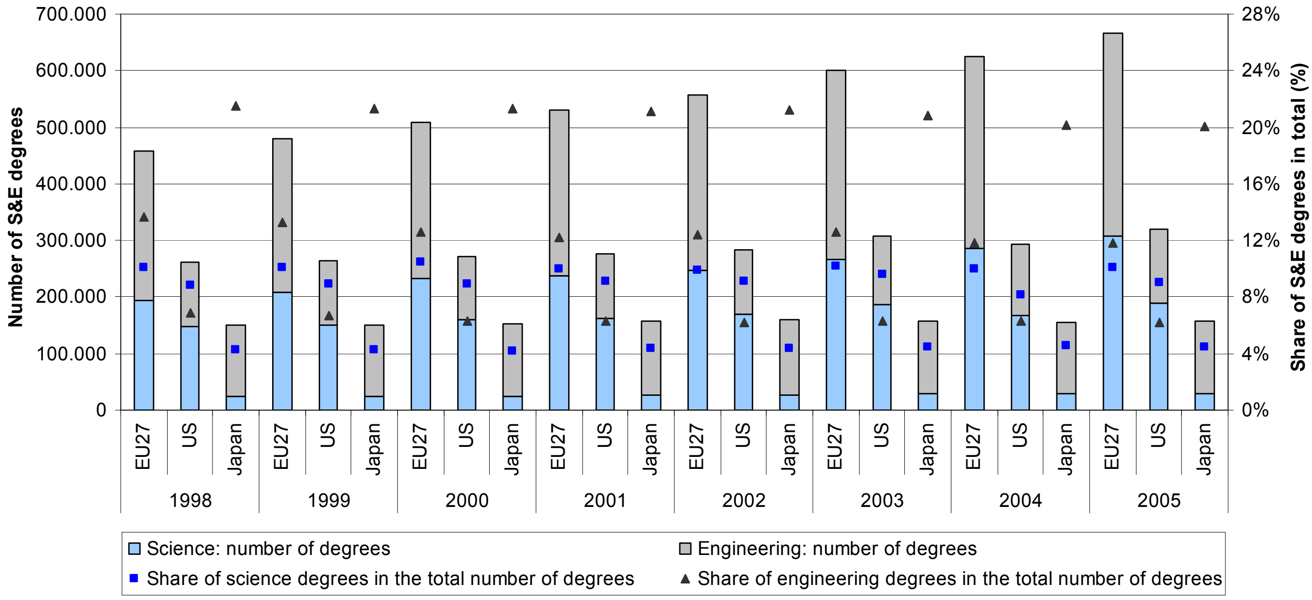
The share of science degrees in the total number of degrees with academic orientation is therefore slightly higher in the EU27 than in the U.S. and Japan, 10.1% against 9% and 4.4%. In engineering, the share of the number of degrees in the total is as well higher in the EU27 than in the U.S., 11.8% against 6.2%. In Japan however, the share of degrees in engineering is far higher, with 20.1%

From 1998 to 2005, the number of degrees in science has increased regularly by 6.8% per year on average in the EU27 (more ore less at the same pace as the total number of degrees). In the U.S. it has increased by 3.6% (slightly more than the total) and in Japan by 1.8% (slightly more than the total as well). In engineering, the growth in the number of degrees was less strong in the three areas, 4.5% on average in the EU27, 1.8% in the U.S. and 0.3% in Japan.

Therefore, the share of science degrees in the total number of degrees with academic orientation was relatively stable in the EU27 (around 10%), while the share of engineering degrees has slightly decreased. To the contrary, in the U.S., the share of science degrees has tended to grow slowly (except in 2004[15] and 2005), while the share of engineering degrees decreased slightly. In Japan, the share of science degrees remained relatively stable and the share of engineering degrees decreased slightly.

[15] A drop in the number of science graduates is observed that year. This may be related to a problem in data.

Figure 12. Number of science and engineering tertiary degrees with academic orientation and share in the total number of degrees, in the EU27, U.S. and Japan (1998-2005)



Source: IPTS based on Eurostat data.

EU27 level

The number of degrees with academic orientation awarded in the EU27 increased on average by 6.7% per year (+1.1 million degrees) between 1998 and 2005 (Table 6 and Figure 13). It increased in all fields but he highest growth is found in services (+12.7% p.a.), health and welfare (+10.0% p.a.) and social sciences, business and law (+8.7% p.a.).

In science, mathematics and computing, the number of degrees increased more or less at the same pace as the average, i.e. 6.8% p.a. (+113,000 degrees), while in engineering, manufacturing and construction, the increase was less pronounced (+4.5% p.a., +85,000 degrees).

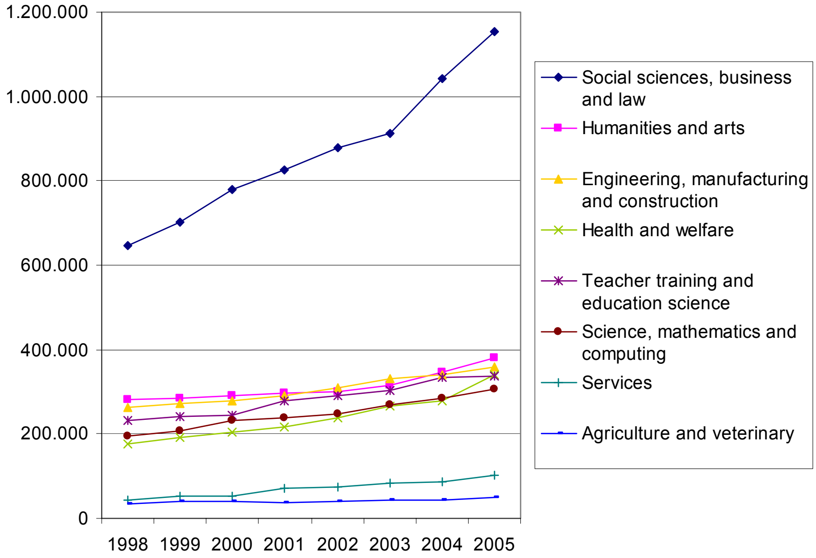
The evolution of the shares of degrees by disciplines in the total reflects these evolutions. The share of social sciences, business and law degrees in the total number of degrees with academic orientation increased from 34.6% in 1998 to 38.2% in 2005. There was stagnation for science, mathematics and computing degrees (from 10.4% to 10.2%) and decrease in engineering, manufacturing and construction (from 14.1% to 11.8%).

Table 6. Number of tertiary degrees with academic orientation awarded in the EU-27 by main fields (1998 and 2005)

	1998		2005		Evolution over 1998-2005		
	Number	%	Number	%	Variation	Growth rate	Annual growth rate
Teacher training and education science	231.356	12,4%	336.384	11,1%	105.028	45,4%	5,5%
Humanities and arts	280.871	15,0%	379.104	12,5%	98.233	35,0%	4,4%
Social sciences, business and law	645.884	34,6%	1.154.997	38,2%	509.113	78,8%	8,7%
Science, mathematics and computing	194.120	10,4%	307.402	10,2%	113.282	58,4%	6,8%
Engineering, manufacturing and construction	263.212	14,1%	358.473	11,8%	95.261	36,2%	4,5%
Agriculture and veterinary	34.600	1,9%	48.305	1,6%	13.705	39,6%	4,9%
Health and welfare	174.964	9,4%	340.263	11,2%	165.299	94,5%	10,0%
Services	43.577	2,3%	100.791	3,3%	57.214	131,3%	12,7%
Total	**1.868.584**	**100,0%**	**3.025.719**	**100,0%**	**1.157.135**	**61,9%**	**7,1%**
Unknown or not specified	62.033		14.046		-47.987	-77,4%	-19,1%
Total with unknown or not specified	**1.930.617**		**3.039.765**		**1.109.148**	**57,5%**	**6,7%**

Source: IPTS with Eurostat data.

Figure 13. Number of tertiary degrees with academic orientation in the EU27, by fields (1998-2005)



Source: IPTS based on Eurostat data.

Evolution by country

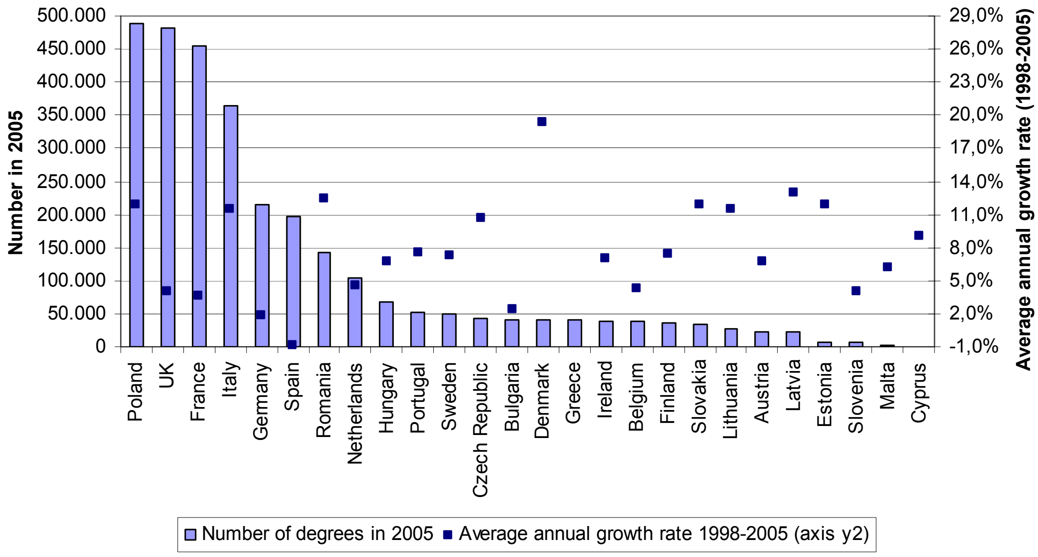
All fields

Poland[16], UK, France and Italy awarded the highest numbers of higher education degrees with academic orientation in 2005, between 350,000 and 500,000 each (Figure 14). Germany and Spain, the two following countries on the list, awarded around 200,000 degrees. These six top countries accounted for about 73% of the total number of degrees awarded in the EU27 in 2005. All the other countries awarded less than 150,000 degrees.

All countries experienced a growth of the number of degrees between 1998 and 2005, except Spain with a slight decrease of -0.8% on average per year. The highest growth rates over the period 1998-2005 are found in Denmark (19.4% p.a.), Latvia (13.0%) and Romania (12.4%).

[16] Very few degrees are awarded in the ISCED5B category in this country, according to Eurostat data.

Figure 14. Tertiary degrees with academic orientation: number in 2005 and average annual growth rate over 1998-2005, by country

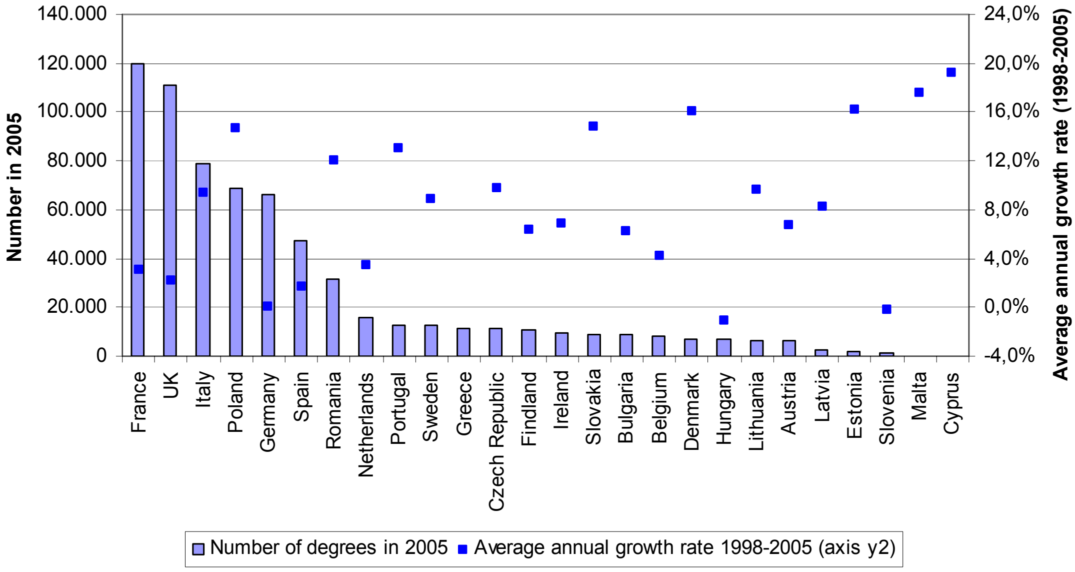


Source: IPTS based on Eurostat data. Number of degrees: 2005, except Italy 2004 and 2005. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Cyprus (1999-2005).

Science and engineering fields

In science and engineering fields (grouping the two fields "science, mathematics and computing" and "engineering, manufacturing and construction"), France and the UK awarded the highest number of tertiary degrees with academic orientation in 2005, respectively 120,000 and 110,000. The top following countries are Italy, Poland, Germany and Spain which delivered between 47,000 and 78,000 degrees. These six countries accounted for about 74% of the EU27 total in these fields. Except Romania which awarded 31,000 degrees, all the other countries delivered less than 16,000 degrees in these fields.

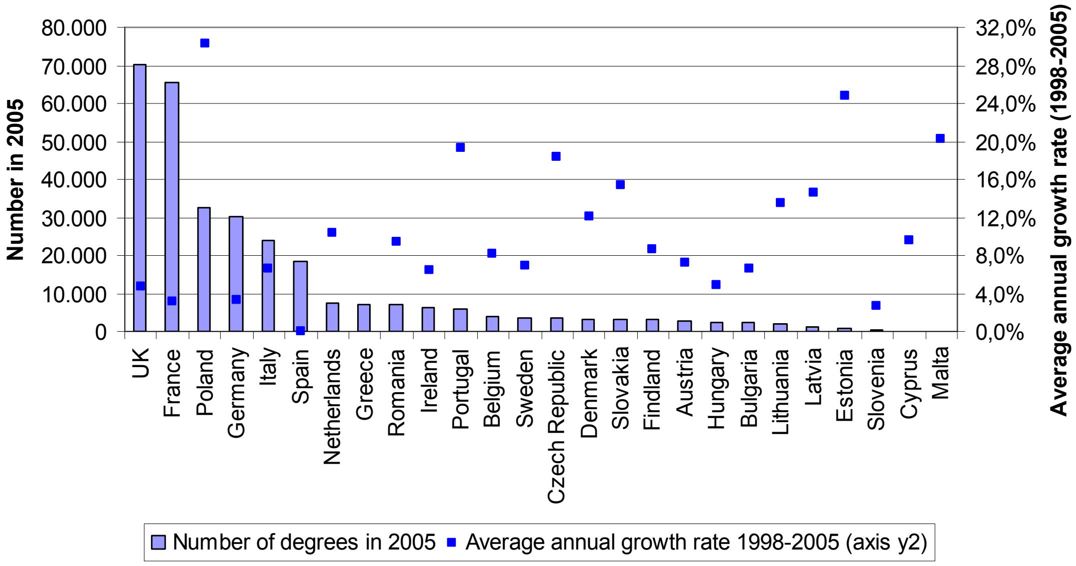
Figure 15. Tertiary degrees with academic orientation in science and engineering fields: number in 2005 and average annual growth rate over 1998-2005, by country



Source: IPTS based on Eurostat data. The two fields "science, mathematics and computing" and "engineering, manufacturing and construction" are grouped. Number of degrees: 2005, except Italy 2004 and 2005. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Cyprus (1999-2005).

Over 1998-2005, the number of degrees in S&E fields increased in all countries excepting Germany and Slovenia (quasi stability) and Hungary (slight decrease of 1.1% per year). The growth has been the strongest in Cyprus, Malta, Estonia, Denmark, Slovakia, Poland, Portugal and Romania (higher than 10% per year in each of these countries).

Figure 16. Tertiary degrees with academic orientation in science, mathematics and computing: number in 2005 and average annual growth rate over 1998-2005, by country



Source: IPTS based on Eurostat data. Number of degrees: 2005, except Italy 2004 and 2005. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Cyprus (1999-2005).

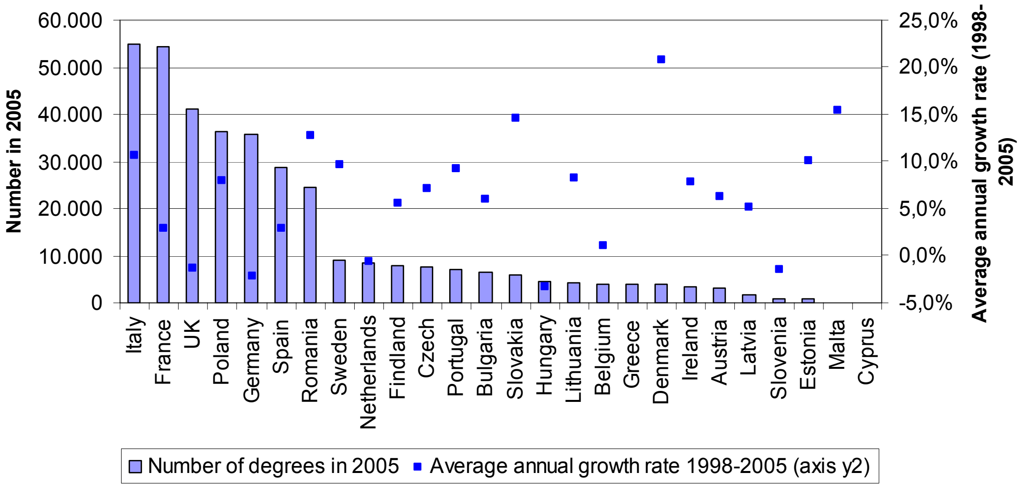
In science, mathematics and computing, the UK and France delivered the highest number of degrees with academic orientation in 2005, with respectively 70,000 and 66,000 degrees awarded (Figure 16)[17]. They are followed by Poland, Germany, Italy and Spain, which awarded between 18,000 and 32,000 degrees. These six countries accounted for about 78% of the EU27 total. All the other countries awarded less than 10,000 degrees in 2005.

All countries show a positive growth in the number of degrees with academic orientation in science, mathematics and computing awarded between 1998 and 2005. In the UK, a strong growth was observed from 1998 (50,900) to 2003 (79,300) that was interrupted in 2004 (69,400) and 2005 (70,200). In France, the number fluctuated between 53,200 in 1998 and 65,700 in 2005.[18] Poland, the third top country, had the strongest growth observed for all countries (+30% per year), going from 5100 degrees in 1998 to 32,600 in 2005. In Germany, decrease was observed from 1998 (24,100) to 2001 (19,400), followed by strong regular increase to 30,000 in 2005. In Italy, it was relatively stable over 1998-2001 and then strongly increased. In Spain, the number slightly increased over 1998-2001 and then decreased, which makes it stable over the whole period.

[17] See as well Figure 18where the detailed patterns of the number of science and engineering degrees over 1998-2005 are represented for the top 10 countries in terms of S&E degrees in 2005.

[18] Data are not complete however as for 2002 and 2004 no data are provided.

Figure 17. Tertiary degrees with academic orientation in engineering, manufacturing and construction: number in 2005 and average annual growth rate over 1998-2005, by country

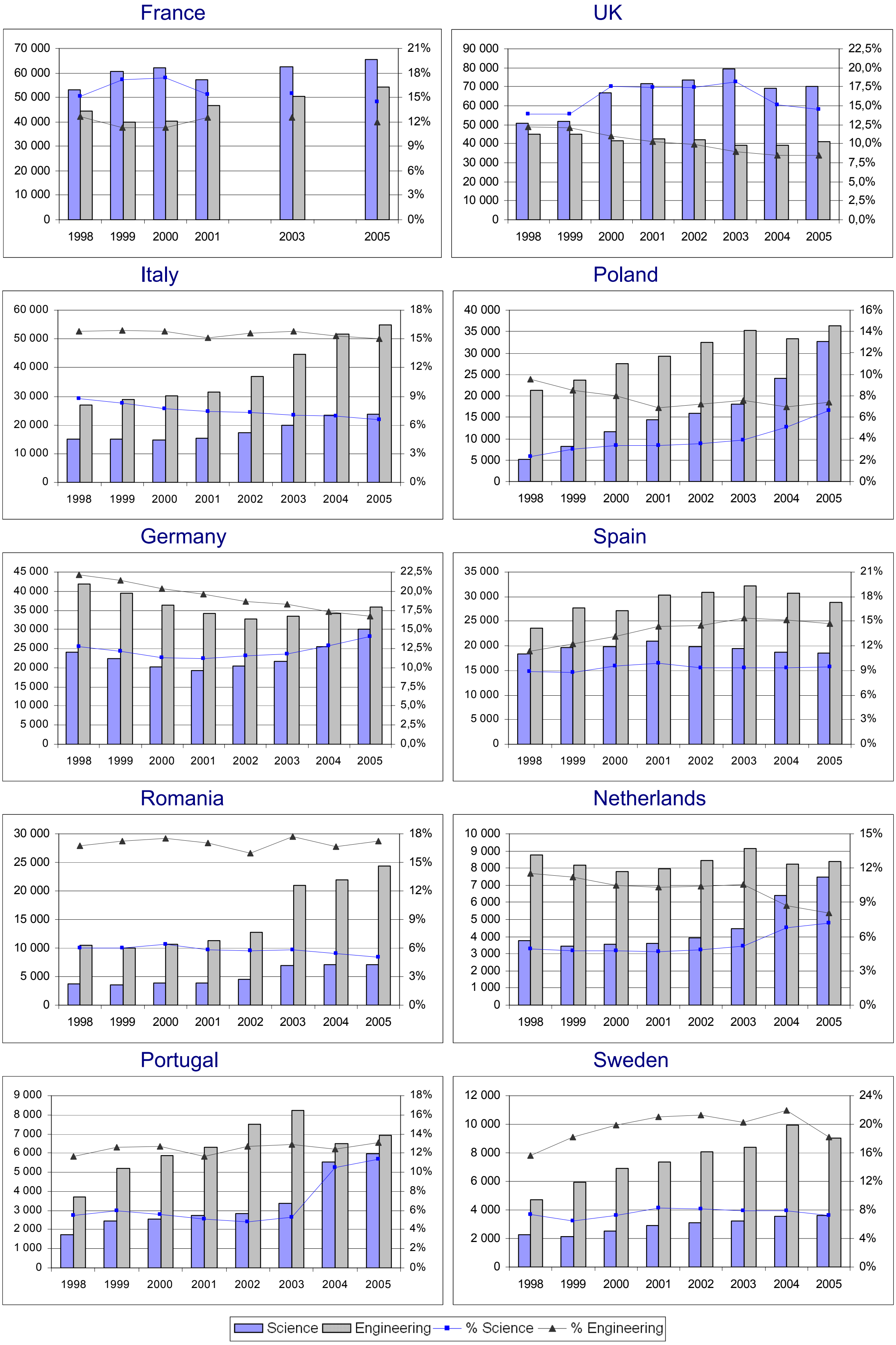


Source: IPTS based on Eurostat data. Number of degrees: 2005, except Italy 2004 and 2005. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Cyprus (1999-2005).

In engineering, manufacturing and construction, Italy and France awarded the highest number of tertiary degrees with academic orientation in 2005, respectively 54,900 and 54,300 (Figure 17). The UK, Poland, Germany and Spain are the top following countries, each of them awarding between 29,000 and 41,000 degrees. These six countries accounted for about 70% of the EU27 total. All the other countries awarded less than 10,000 degrees in these fields (except Romania, which awarded 24,000 degrees).

Over 1998-2005, the UK, Germany, the Netherlands, Hungary and Slovenia experienced a decrease in the number of degrees awarded in these fields. In the UK, the number of degrees declined from 1998 to 2004, but slightly increased in 2005. In Germany, the number of degrees decreased from 1998 to 2002, attaining a low level of 32,800, and then increased. In Italy, it strongly increased over the period and particularly from 2001 to 2005, and in France it decreased from 1998 to 1999, was stable and then increase from 2000 to 2005. In Spain, it grew from 1998 to 2003 and then decreased in 2004 and 2005.

Figure 18. Number of science and engineering degrees with academic orientation and share in the total number of degrees with academic orientation: evolution from 1998 to 2005, top 10 EU countries



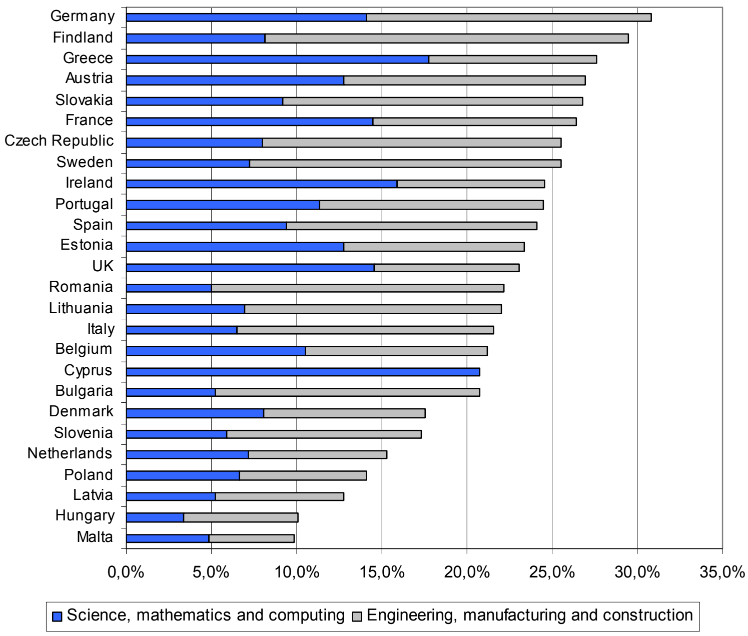
Source: IPTS based on Eurostat data.

Share of S&E fields

The highest share of science and engineering fields among the total number of degrees with academic orientation is found in Germany (30.8%) and Finland (29.5%) (cf. Figure 19).

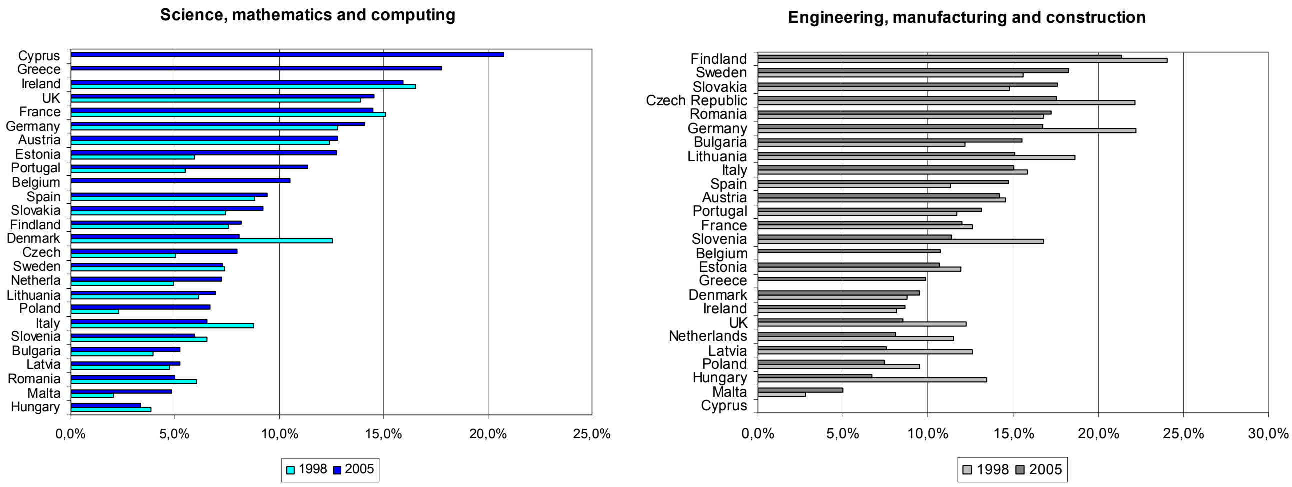
Decomposing between science on the one hand and engineering on the other, the highest share of science, mathematics and computing degrees is found in Cyprus with 20.8%[19], Greece (17.8%) and Ireland (15.9%). In engineering, manufacturing and construction, the highest share is found in Finland (21.4%), Sweden (18.3%) and Slovakia (17.6%).[20]

Figure 19. Share of science and engineering degrees in the total number of degrees with academic orientation in 2005, by country (%)



Source: IPTS based on Eurostat data.

Figure 20. Evolution of the share of science and engineering degrees in the total number of degrees with academic orientation between 1998 and 2005, by country (%)



Source: IPTS based on Eurostat data.

[19] 166 out of the 800 degrees however.

[20] The evolution of the share of science and engineering degrees is given in the Figure 20 and the detailed patterns can be found as well for the top 10 countries in terms of S&E degrees in Figure 18.

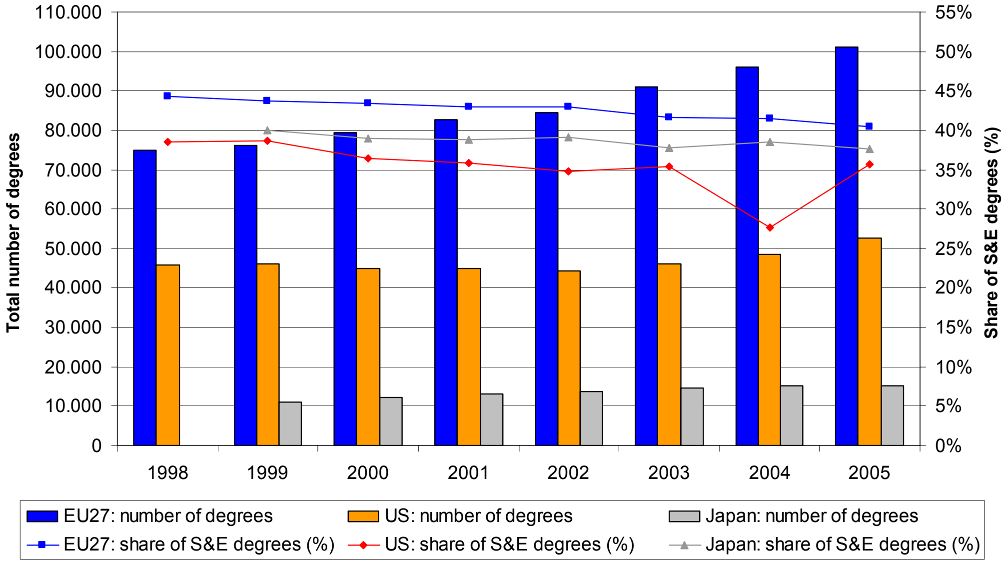
Doctoral degrees

Elements of international comparisons

In 2005, some 100,000 doctoral degrees were awarded in the EU27, against 53,000 in the U.S. and 15,000 in Japan (Figure 21). From 1998 to 2005 (from 1999 for Japan), the number of doctoral degrees increased respectively by 4.4% per year on average in the EU27, 2% in the U.S. and 5.7% in Japan. In the U.S., the number of doctoral degrees has tended to decrease from 1998-99 to 2002, and then has increased. In the EU27 and the U.S., the growth of doctoral degrees is lower than for tertiary degrees with academic orientation.

The share of science and engineering fields is relatively similar in the three areas, 40% in the EU27, 36% in the U.S. and 38% in Japan. This share decreased in the EU27 from 1998 to 2005 (nearly -4 percentage points). It decreased in the U.S. from 1998 to 2002 and then increased slightly (except for 2004[21]). In Japan, it tended to decrease very slightly as well.

Figure 21. Number of doctoral degrees and share of science and engineering fields, in the EU27, U.S. and Japan (1998-2005)



Source: IPTS with Eurostat data.

The number of science doctoral degrees awarded in the EU27 increased by 2.7% per year on average between 1998 and 2005. In the U.S. it slightly increased by 0.8% per year from 1998 to 2005 (it decreased from 1998 to 2002 and then increased[22]) and in Japan it increased by 6.9% per year.

In engineering, the number of doctoral degrees increased by 3.8% per year in the EU27, 1% in the U.S. (with a similar pattern: decrease from 1998 to 2002 and then increase) and 3.2% in Japan.

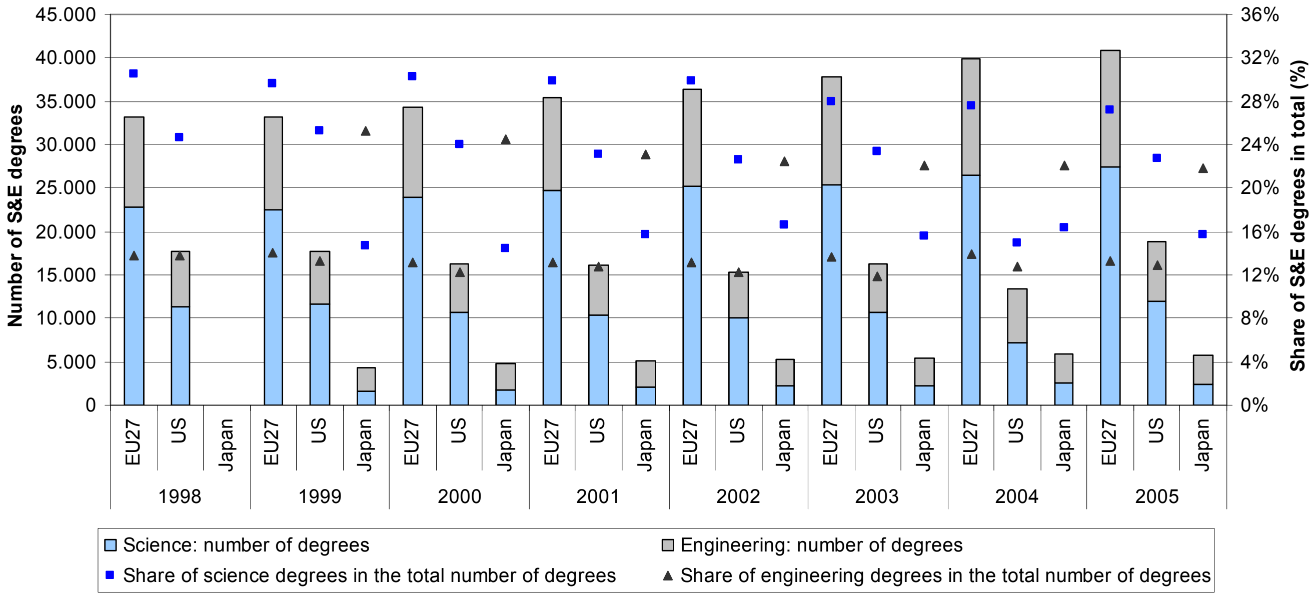
In 2005, the share of doctoral degrees in science fields in the total number of doctoral degrees was the highest in the EU27 (27%, against 23% in the U.S. and 16% in Japan; Figure 22). The share of engineering fields is relatively similar in the EU27 and U.S. (around 13%) while it is higher in Japan (22%).

In the EU27, the share of science fields in the total number of doctoral degrees decreased regularly over 1998-2005 (-3 percentage points), while the share of engineering was relatively stable. In the U.S., the share of science fields decreased slightly and the share of engineering was more or less stable. In Japan, the share of science fields increased very slightly while the share of engineering decreased.

[21] A problem in the data collected may not be excluded to explain this strong drop that year.

[22] Except the surprising drop of 2004 (see footnote above).

Figure 22. Number of science and engineering doctoral degrees and shares in the total number of doctoral degrees, in the EU27, U.S. and Japan (1998-2005)



Source: IPTS with Eurostat data.

EU27 level

The number of doctoral degrees awarded in the EU27 increased on average by 4.4% per year between 1998 and 2005 (+26,000 degrees) (Cf. Figure 23 and Table 7)[23], less than the growth observed for second degrees with academic orientation. It increased in all fields but the highest growth is found in services (+10.2% p.a.) and teacher training and education sciences (+10.2% p.a.).

In science, mathematics and computing, the number of doctoral degrees increased by 2.7% per year on average (+4,600 degrees). In engineering, manufacturing and construction, the increase has been of 3.8% per year (+3,100 degrees).

Table 7. Number of doctoral degrees awarded in the EU-27 by main fields (1998 and 2005)

	1998		2005		Evolution over 1998-2005		
	Number	%	Number	%	Variation	Growth rate	Annual growth rate
Teacher training and education science	1.506	2,0%	2.971	2,9%	1.465	97,3%	10,2%
Humanities and arts	8.351	11,2%	12.539	12,4%	4.188	50,1%	6,0%
Social sciences, business and law	12.095	16,2%	17.926	17,8%	5.831	48,2%	5,8%
Science, mathematics and computing	22.826	30,5%	27.450	27,2%	4.624	20,3%	2,7%
Engineering, manufacturing and construction	10.321	13,8%	13.395	13,3%	3.074	29,8%	3,8%
Agriculture and veterinary	3.285	4,4%	3.975	3,9%	690	21,0%	2,8%
Health and welfare	15.886	21,2%	21.584	21,4%	5.698	35,9%	4,5%
Services	530	0,7%	1.048	1,0%	518	97,7%	10,2%
Total	**74.800**	**100,0%**	**100.888**	**100,0%**	**26.088**	**34,9%**	**4,4%**
Unknown or not specified	124		257		133	107,3%	11,0%
Total with unknown or not specified	**74.924**		**101.145**		**26.221**	**35,0%**	**4,4%**

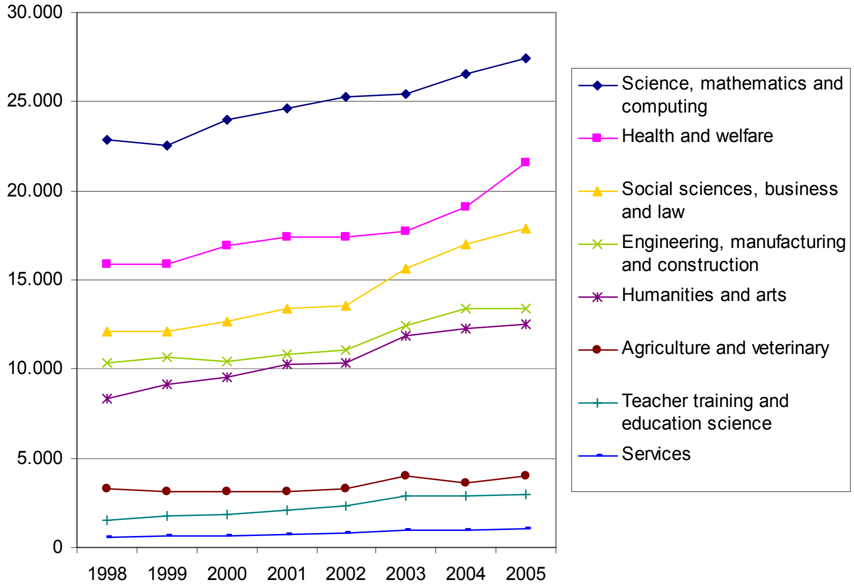
Source: IPTS with Eurostat data.

The evolution of the shares of degrees by field in the total number of degrees awarded reflects these evolutions. The share of science, mathematics and computing doctoral degrees decreased from 30.5% in 1998 to 27.2% in 2005. However, the share of science, mathematics and computing remains far higher compared to the tertiary

[23] This growth may be slightly over-estimated as data for Romania are only available from 2003. In addition, the 2005 data for Italy were not available when the calculations were done (November 2007). 2004 data were used instead for this country.

degrees with academic orientation (10.3%). In engineering, manufacturing and construction, the shares slightly decreased from 13.8% in 1998 to 13.3% in 2005. The share of all the other fields (except agriculture and veterinary) increased.

Figure 23. Number of doctoral degrees in the EU27, by fields (1998-2005)



Source: IPTS with Eurostat data.

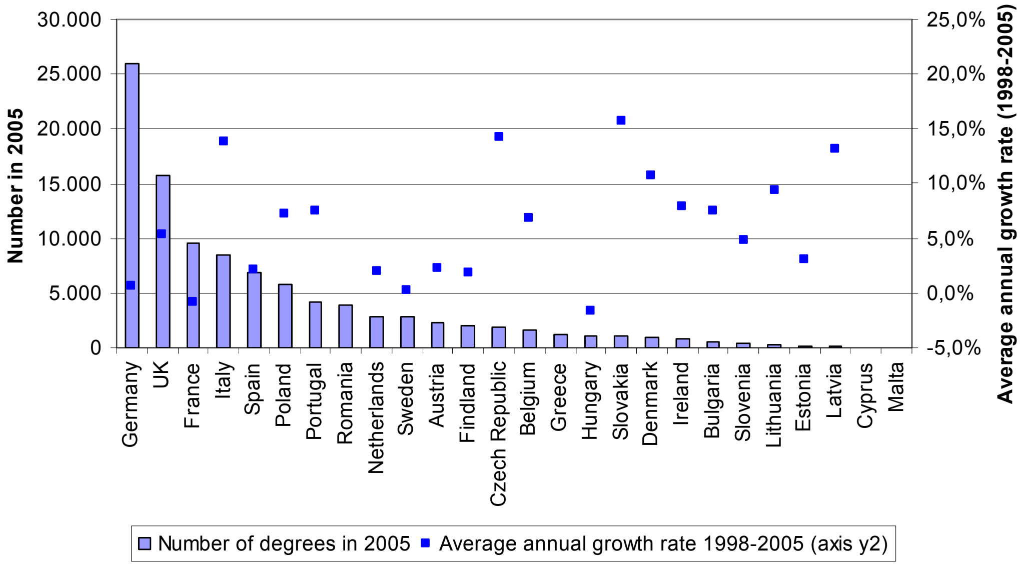
Evolutions by country

All fields

Germany, UK, France, Italy, Spain and Poland rank top in the number of doctoral degrees awarded in 2005 (Figure 24). These 6 countries accounted for about 72% of the EU27 total. Among these six countries, Italy, Poland and the UK experienced the strongest growth over 1998-2005, with average annual growth rates of more than 5%. In the UK, the number of doctoral degrees regularly increased between 1998 and 2005 from 11,000 to 15,800. In Italy, the number of doctoral degrees fluctuated between 3,500 and 4,500 between 1998 and 2002, and then increased sharply (6,400 in 2003 and 8,500 in 2004). In Poland, the increase is quite regular as well, from 3,500 in 1998 to 5,700 in 2005.

In contrast, France experienced a slight decrease in its number of doctoral degrees. In Spain, the number of doctoral degrees shows a positive trend from 1998 to 2004, attaining the highest level of 8,200, and then declined in 2005 (6,900). In Germany, the number of doctoral degrees fluctuated around 23,000-26,000 on the same period.

Figure 24. Doctoral degrees: number in 2005 and average annual growth rate over 1998-2005, by country



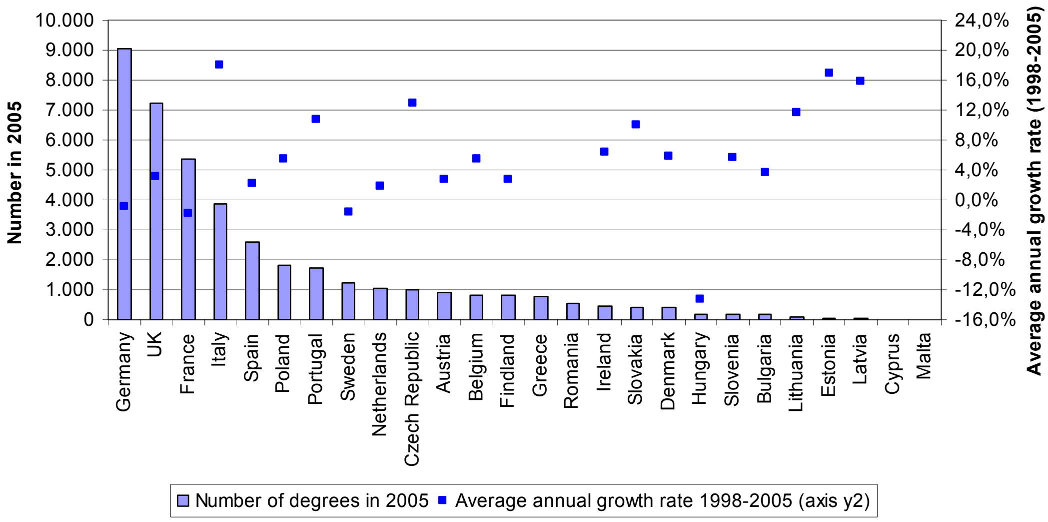
Source: IPTS based on Eurostat data. Number of degrees: 2005, except Italy 2004. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Italy (1998-2004).

Science and engineering fields

In science and engineering (grouping the two fields "science, mathematics and computing" and "engineering, manufacturing and construction"), three countries awarded more than 5,000 doctoral degrees each in 2005: Germany, UK and France. The three following top countries, Italy, Spain and Poland, delivered between 1,800 and 3,900 doctoral degrees in these fields. These six countries accounted for about 73% of the EU27 total. Except Portugal which delivered 1,700 doctoral degrees, all the other countries awarded less than 1,500 degrees.

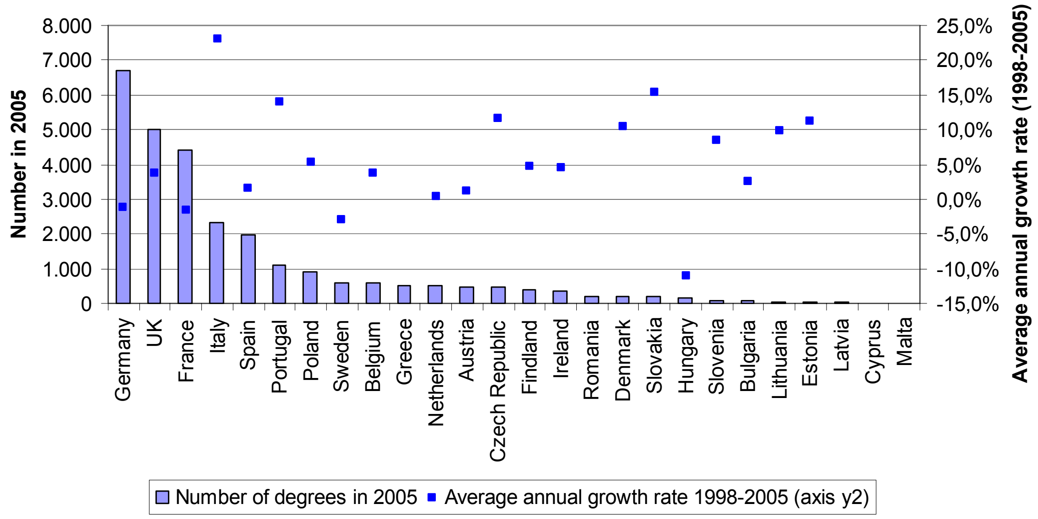
Four countries experienced a decrease in the number of doctoral degrees awarded between 1998 and 2005 (Hungary, France, Sweden and Germany). To the contrary, the highest growth has been observed in Italy, Estonia, Latvia, Czech Republic, Lithuania, Portugal and Slovakia (with average annual growth rates higher than 10%).

Figure 25. Doctoral degrees in science and engineering: number in 2005 and average annual growth rate over 1998-2005, by country



Source: IPTS based on Eurostat data. The two fields "science, mathematics and computing" and "engineering, manufacturing and construction" are grouped. Number of degrees: 2005, except Italy 2004. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Italy (1998-2004).

Figure 26. Doctoral degrees in science, mathematics and computing: number in 2005 and average annual growth rate over 1998-2005, by country



Source: IPTS based on Eurostat data. Number of degrees: 2005, except Italy 2004. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Italy (1998-2004).

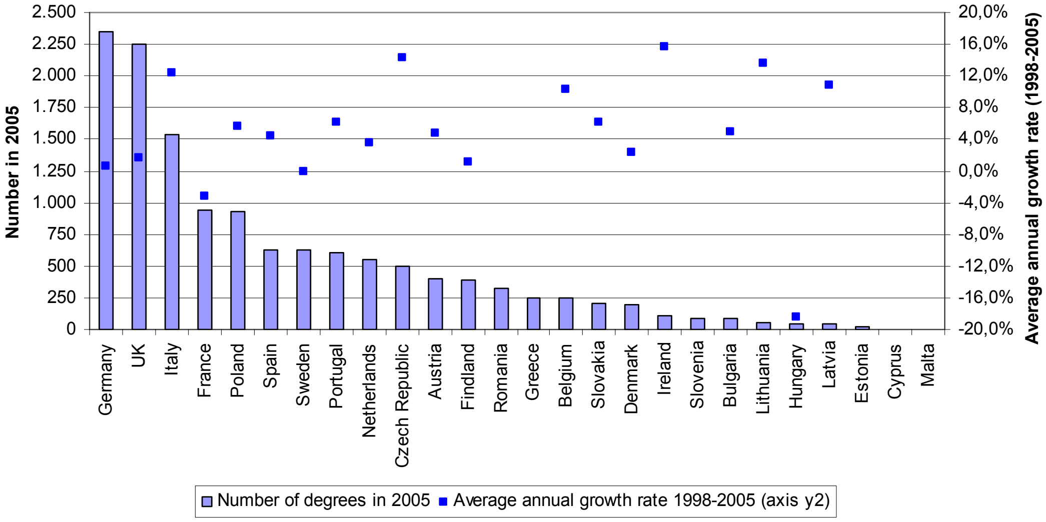
In science, mathematics and computing, Germany, the UK and France rank top in the number of doctoral degrees awarded in 2005, with respectively 6,700, 5,000 and 4,400 (Figure 26). The three following top countries are Italy, Spain and Portugal. These six countries accounted for about 78% of the EU27 total.

Four countries show a decrease in the number of doctoral degrees awarded between 1998 and 2005 (Germany, France, Sweden and Hungary)[24]. In Germany, it has tended to decrease, with some fluctuations, between 1998 (7,300) and 2004 (6,000), before increasing in 2005 (6,700). In France, it was relatively stable over 1998-2001 and seems to have decreased since then.[25] In the UK, the upward trend observed from 1998 (3,800 degrees) to 2003 (5,300 degrees) has been interrupted in 2004 (4,800), before slightly increasing in 2005 (5,000). In Italy, strong growth was observed particularly on the last three years (from 700 in 1998 to 2,300 in 2004). In Spain, the stability observed from 1998 to 2001 (around 1,800 degrees each year) was followed by an increase to 2004 (2,200 degrees) which seems to be interrupted in 2005 (2,000 degrees). In Portugal, the number of doctoral degrees was stable from 1998 to 2001 (400-450 degrees each year), increased slightly in 2002 and 2003 (650 degrees) and then strongly increased in 2004 and 2005 to attain 1,100 degrees awarded that year.

[24] Cf. as well the detailed patterns over 1998-2005 in Figure 28.

[25] The data are not complete however.

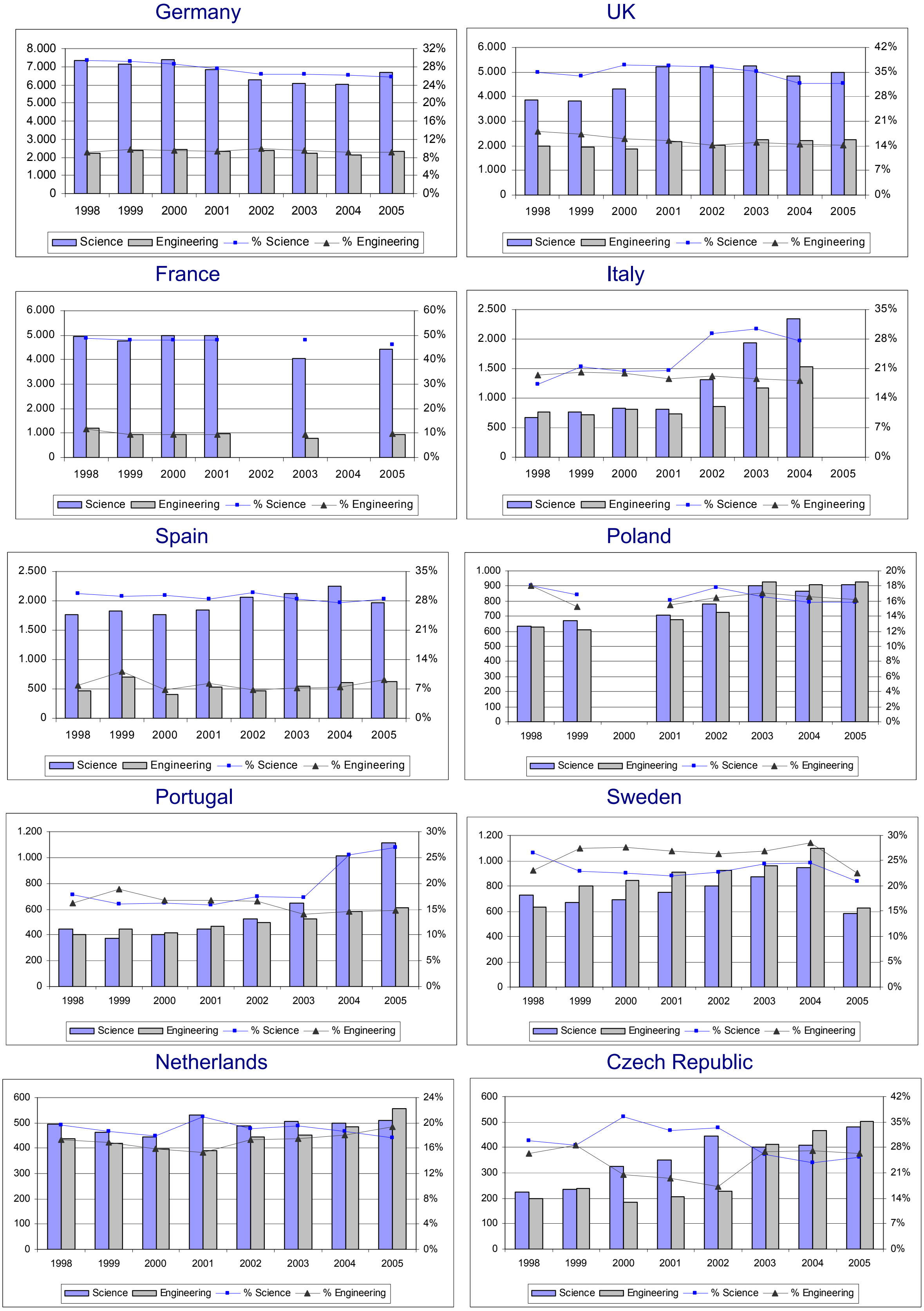
Figure 27. Doctoral degrees in engineering, manufacturing and construction: number in 2005 and average annual growth rate over 1998-2005, by country



Source: IPTS based on Eurostat data. Number of degrees: 2005, except Italy 2004. Average annual growth rates calculated over 1998-2005 except Belgium (2000-2005), Italy (1998-2004).

In engineering, manufacturing and construction, Germany, UK, Italy, France, Poland and Spain rank top for the number of doctoral degrees awarded in 2005 (Figure 27). These six countries accounted for about 64% of the EU27 total. The number of degrees in these fields decreased in France between 1998 and 2005, slightly increased in Germany and the UK, and increased more strongly in Spain, Poland and Italy (Cf. as well Figure 28). Two other countries saw the number of their degrees decreased, Hungary and Sweden (quasi stability however for this last country).

Figure 28. Number of science and engineering doctoral degrees and share among the total number of doctoral degrees: evolution from 1998 to 2005, top 10 EU countries



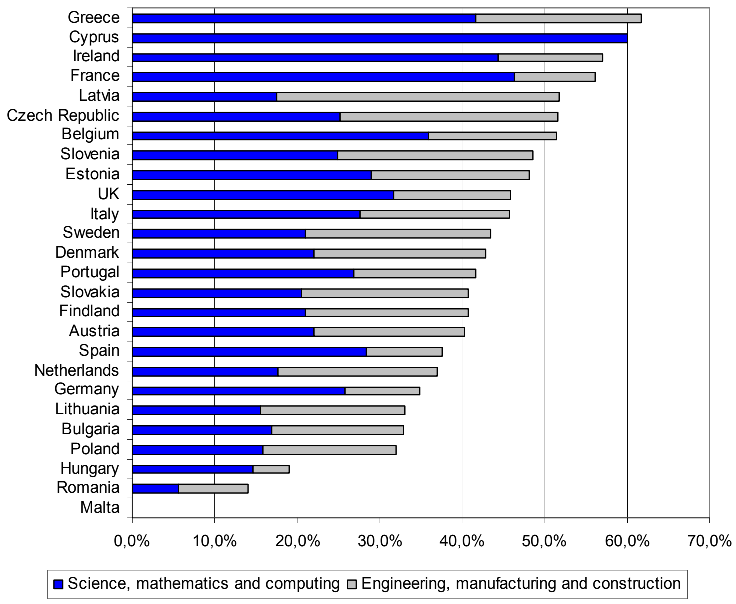
Source: IPTS based on Eurostat data.

Share of S&E fields

The share of doctoral degrees in science and engineering in the total number of doctoral degrees was the highest in Greece (62%), Cyprus (60%), Ireland (57%) and France (56%) in 2005 (Figure 29). Three other countries are above 50% (Latvia, Czech Republic and Belgium). Looking at science on the one hand and engineering on the other, the ranking of countries is different. For science, mathematics and computing, the same four countries rank top (Cyprus, France, Ireland and Greece), with shares raking between 41% and 60%. In engineering, manufacturing and construction, Latvia, Czech Republic, Slovakia and Sweden rank top (between 23% and 34%).

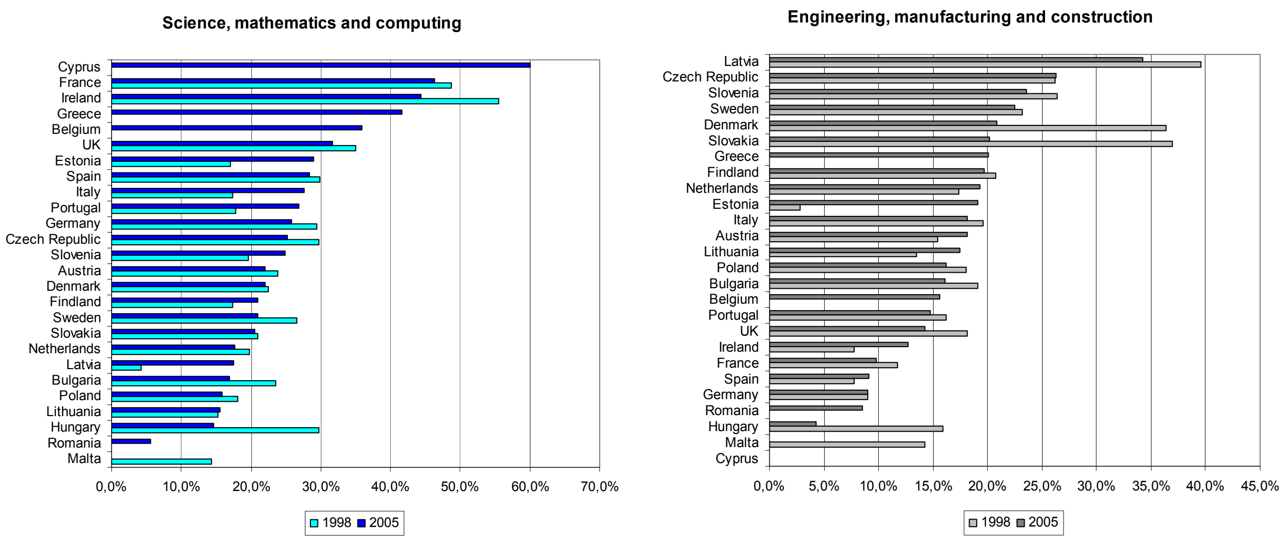
In 17 countries, the share of science doctoral degrees is higher than the share of engineering doctoral degrees. The difference is particularly marked in France (46% in science, 10% in engineering) and Ireland (44% in science, 12% in engineering). The evolution of the share of science and engineering fields by country are displayed in Figure 30.

Figure 29. Share of science and engineering doctoral degrees in the total number of doctoral degrees in 2005, by country (%)



Source: IPTS based on Eurostat data.

Figure 30. Evolution of the share of science and engineering doctoral degrees in the total number of doctoral degrees between 1998 and 2005, by country (%)

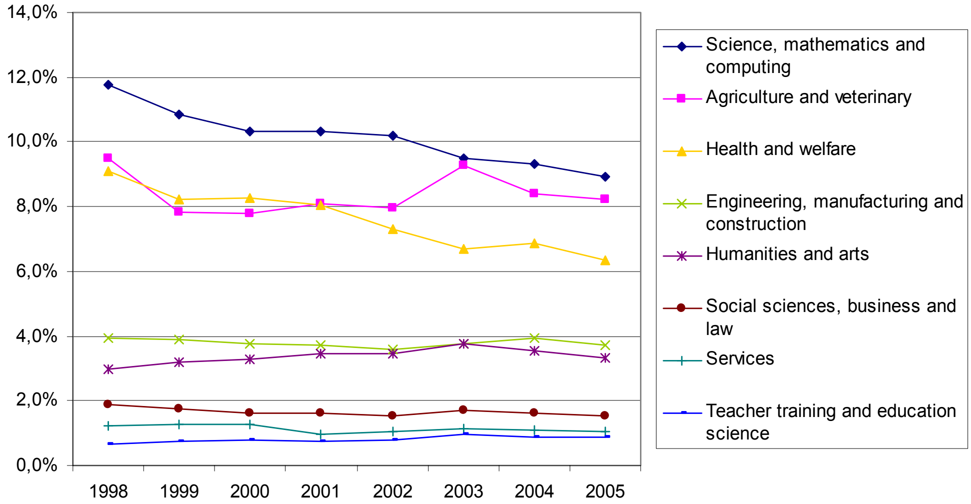


Source: IPTS based on Eurostat data.

Comparative evolution of tertiary degrees with academic orientation and doctoral degrees over 1998-2005

The ratio of doctoral degrees to tertiary degrees with academic orientation has tended to slightly decrease over the period 1998-2005 (Figure 31). The different paces of evolution of the number of degrees at the two levels[26], generally lower at the doctoral level, explain the evolution of this ratio. On average, doctoral degrees accounted for 3.9% of tertiary degrees with academic orientation in 1998 and 3.3% in 2005. The decrease is the highest in science, mathematics and computing, from 11.8% in 1998 to 8.9% in 2005.

Figure 31. Ratio of doctoral degrees to tertiary degree with academic orientation in the EU27, by fields (1998-2005)



Source: IPTS based on Eurostat data.

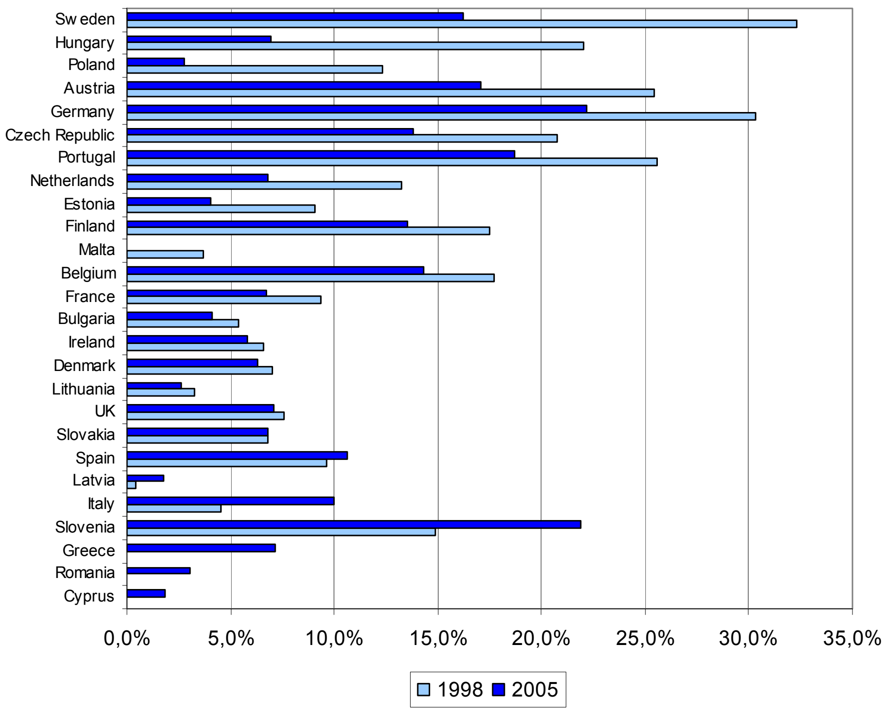
To study more precisely what is at stake in the field of science, mathematics and computing, we calculated this ratio for each country and for each year. This ratio is given for 1998 and 2005 in the following figure. It appears that for most countries, this ratio has tended to decrease between 1998 and 2005. It means that the growth in the number of tertiary degrees with academic orientation has been fastest than the growth in the number of doctoral degrees between these two years.

---

[26] This ratio is indeed explained by the relative evolution at the two levels, which can be approximated as the difference between the two growth rates. Suppose X_0 and X_t are the numbers of tertiary degrees with academic orientation at time 0 and time t, and that Y_0 and Y_t are the numbers of doctoral degrees at time 0 and time t. The ratios we calculate are $r_0 = \frac{Y_0}{X_0}$ and $r_t = \frac{Y_t}{X_t}$.

Calling x and y the growth rates between 0 and t for each level, r_t can be rewritten as: $r_t = \frac{Y_0(1+y)}{X_0(1+x)} = r_0\left(\frac{1+y}{1+x}\right) \approx r_0(y-x)$ (the approximation is true for x and y "sufficiently small").

Figure 32. Ratio of doctoral graduates to tertiary degree with academic orientation in science, mathematics and computing, by country (1998 and 2005)

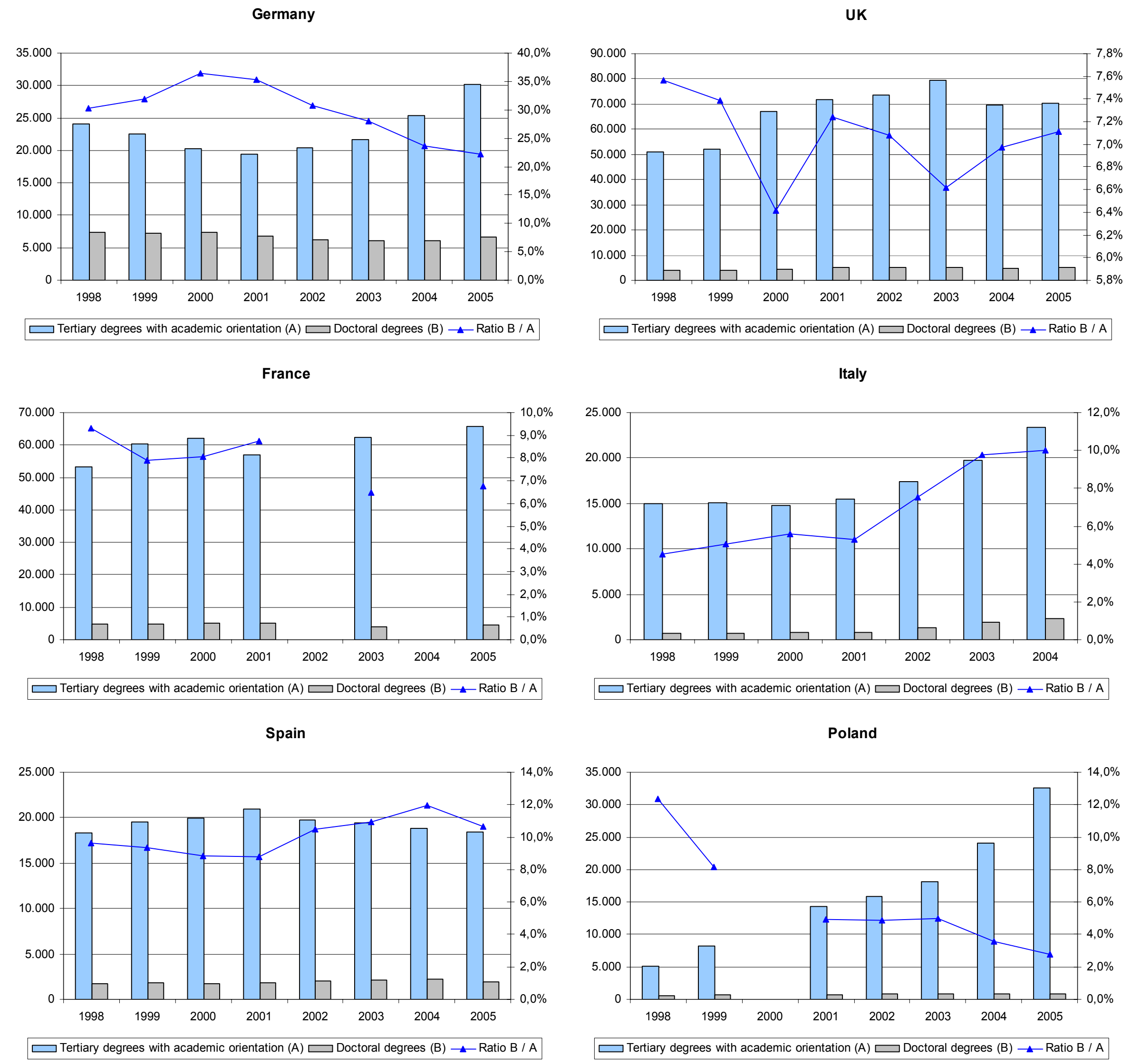


Source: IPTS based on Eurostat data.

However, only two points in time are taken into account in the previous graph which hides the evolution between 1998 and 2005. Therefore we give the profiles of this ratio from 1998 to 2005 in Figure 33 for Germany, UK, France, Italy, Spain and Poland (the six countries which awarded the highest number of tertiary degrees with academic orientation in science, mathematics and computing in 2005). The levels and the profiles are quite different from one country to another.

Germany has the highest ratio of doctoral degrees to tertiary degrees with academic orientation and this ratio has been decreasing since 2000. This is the consequence of the strong growth observed in the number of tertiary degrees with academic orientation and the stability and then slight growth of the doctoral degrees. In the UK, the ratio has tended to decrease but with some fluctuations, and it has been on the increase since 2003. In France, the ratio has tended to decrease but seems to be stable in 2003 and 2005. In Italy, the ratio has increased from 1998 to 2004, which reflects the strong growth of the number of doctoral degrees (which has been stronger than the growth of the number of tertiary degrees with academic orientation). In Spain, the ratio has slightly increased (with fluctuations) over the period, but at both level the number of degrees has been relatively stable. In Poland, the ration has decreased which is mainly explained by the strong growth in the number of tertiary degrees with academic orientation.

Figure 33. Science, mathematics and computing: number of tertiary degrees with academic orientation, number of doctoral degrees and ratio of doctoral degrees to tertiary degrees with academic orientation, for the top six countries (1998-2005)



Source: IPTS based on Eurostat data.

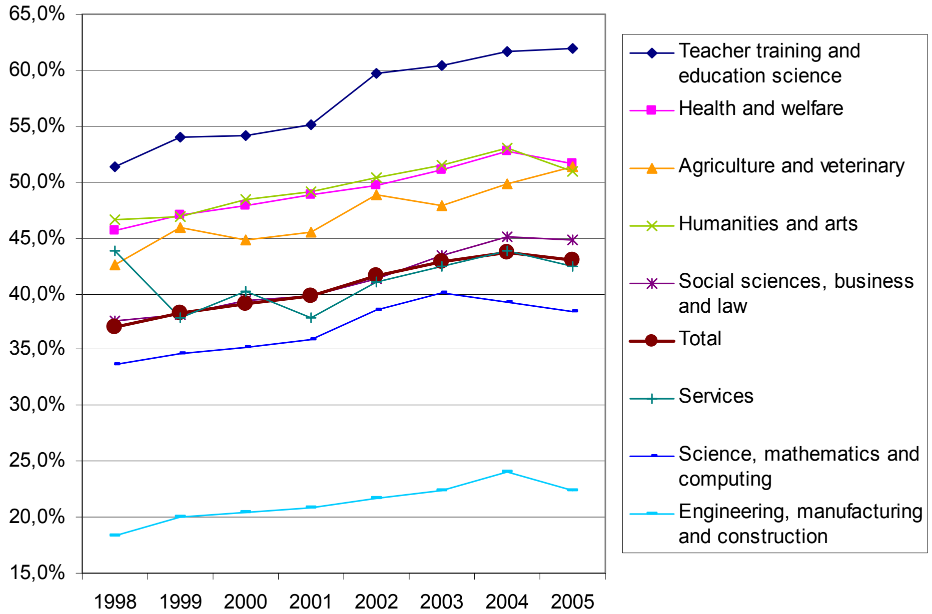
Gender differences

The percentage of females earning doctoral degrees in the EU27 increased from 37% in 1998 to 43% in 2005 (Figure 34). A stabilisation seems however to be observed in the end of the period, from 2003 to 2005. In all the fields except services, an increase was observed but important differences by fields remain. Indeed, in engineering, only 22% of doctoral degrees are earned by females whereas this is the case of 62% of doctoral degrees in teacher training and education science. Females account for more than 50% of doctoral degrees in this field, as well as in health and welfare, agriculture and veterinary, and, humanities and arts. In science, mathematics and computing, the share of females is 38%.

In percentage points, the increase of the share of females from 1998 to 2005 has been the highest in teacher training and education (+10.6), agriculture and veterinary (+8.7) and social sciences, business and law (+7.2). To the contrary, the increase was less strong notably in science, mathematics and computing (+4.8) and engineering, manufacturing and construction (+4.1).

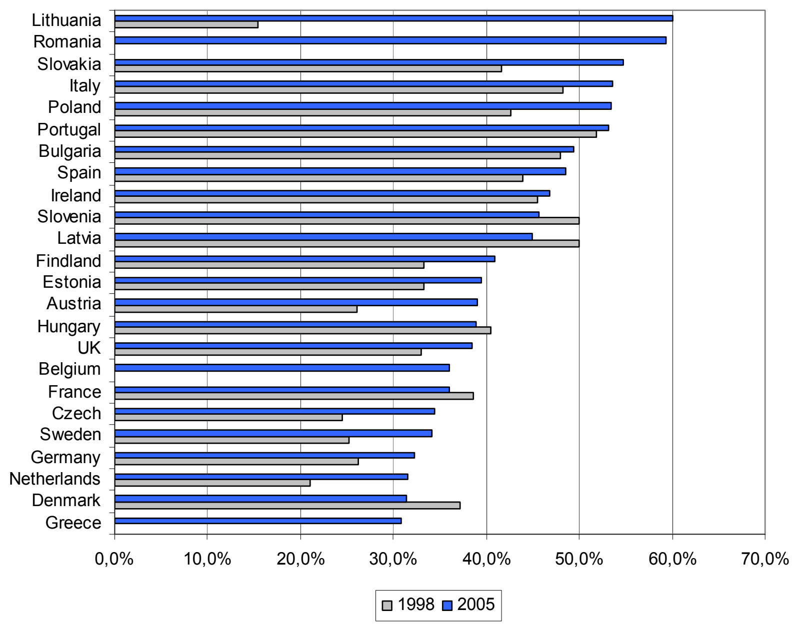
In science, mathematics and computing, the share of females among doctoral degrees ranges from 60% in Lithuania and Romania to 31% in Denmark and Greece (Figure 35). Four other countries have shares of women higher than 50%: Slovakia, Italy, Poland and Portugal. In all countries except Slovenia, Latvia, Hungary, France and Denmark, the share of women was higher in 2005 than in 1998.

Figure 34. Percentages of doctoral degrees awarded to females in the EU27, by fields (1998-2005)



Source: IPTS with Eurostat data.

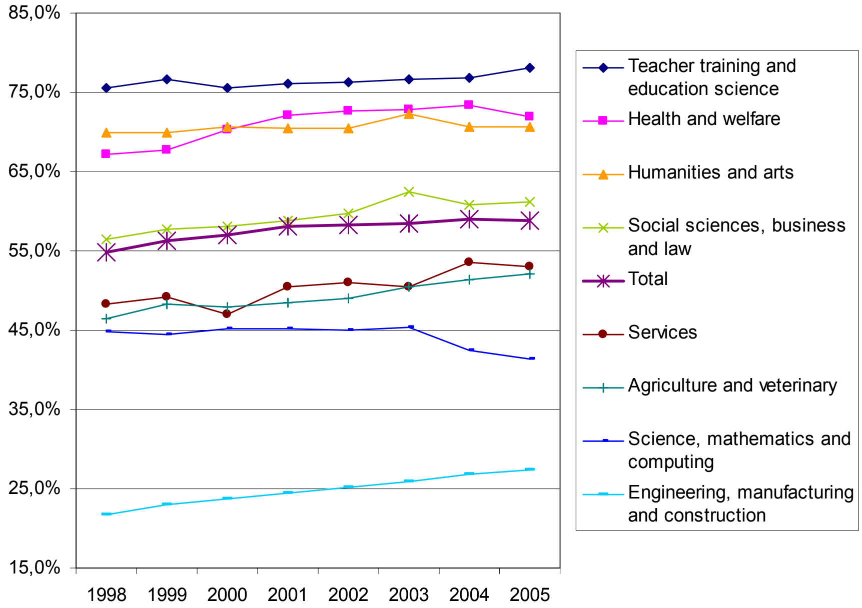
Figure 35. Percentages of doctoral degrees awarded to females in science, mathematics and computing, by country (1998 and 2005)



Source: IPTS with Eurostat data.

Contrary to the doctoral level, females earned more than half (59%) of the tertiary degrees with academic orientation awarded in the EU27, on average all fields considered together, in 2005. Only two fields, science, mathematics and computing, and engineering, manufacturing and construction, have a lower than half share of females, respectively 41% and 27%.

Figure 36. Percentages of tertiary degrees with academic orientation awarded to females in the EU27, by fields (1998-2005)



Post-doctoral researchers in the EU

In Europe, information on postdoctorates is scarce and no comprehensive and comparable data at the EU level are available. Therefore, in this section we present the results of the estimation of the number of postdoctorates in life sciences, engineering and social sciences in the EU based on the results from two ad-hoc surveys commissioned by IPTS.

To construct indicators on the number of post-doctoral researchers at the EU level, the methodology consists in combining Eurostat aggregated data and data from the two pilot ad-hoc surveys carried out on a sample of EU countries, the NetReAct survey (2005) – for life sciences – and the Rescar survey (2007) – for engineering and social sciences. These surveys collected information on doctoral candidates and post-doctorates in 9 EU countries (Czech Rebpublic, Germany, Spain, France, Hungary, Italy, Portugal, Sweden and UK), through questionnaires addressed to the heads of university-based research teams.

Two methods have been used to estimate the number of postdoctorates (see methodology for more details). The first one uses only the NetReAct and Rescar surveys and is based on the identification of research teams and the average number of postdocs. The second method combines the NetReAct and Rescar survey and Eurostat data. It is based on the NetReAct and Rescar structure of research teams and the Eurostat number of doctoral candidates. Results based on the second method are likely to be more reliable, the first method being based on two (NetReAct) or three (Rescar) different steps, each step being a potential source of error. The methodology of the second method is likely to limit the uncertainty as it is partly based on Eurostat data and not only on the results of the surveys.

Life sciences and engineering

In life sciences and engineering, the total numbers of postdocs in the EU27 given by the two methods are relatively similar.

In life sciences, there would be about 22,000 postdocs according to the first method and about 25,000 according to the second method.

In engineering, the first method gives 37,000 postdoctoral researchers against 43,000 for the second method.

In life sciences, we found that the highest number of postdoctoral researchers is in the UK (5,700 with method 1 and 5,900 with method 2). The ranking of countries is about the same with the two methods of calculations. As it was just said, the first method ranks the UK first. It is followed by France (2,800) and Germany (2,700). The three top countries with the second method are the UK, Germany (4,200) and France (3,500).

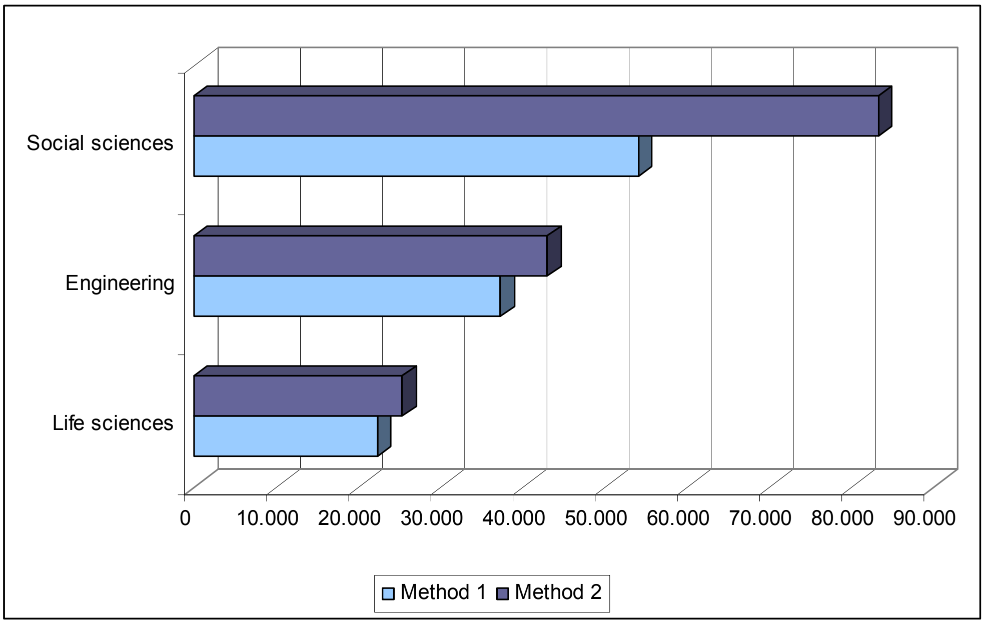
In engineering, with method 1, we find that the number of postdocs is the highest in Spain (about 6,100), followed by Germany (5,200) and the UK (4,200). With method 2, Spain observes the far highest number of postdocs (about 10,000), followed by Italy (5,000) and the UK (4,700).

Social sciences

In social sciences, there would be about 54,000 postdoctoral researchers according to the first method and about 83,000 according to the second method.

With method 1, the highest numbers of postdocs are found in Germany (8,700), Spain (8,600) and the UK (7,800). With method 2, the ranking of countries is about the same (but the numbers are far different, except for the UK), with Germany (20,000), Spain (13,200) and the UK (8,300) ranking top.

Figure 37. Estimated number of postdoctoral researchers in life sciences, engineering and social sciences in the EU27 (2004)



Source: IPTS. See text for details.

Table 8. Estimated number of postdoctoral researchers life sciences, engineering and social sciences, in 9 EU countries, according to method 1 and 2

	Method 1			Method 2		
	Life sciences	Engineering	Social sciences	Life sciences	Engineering	Social sciences
CZ	415	1.599	1.728	717	3.105	3.156
DE	2.749	5.189	8.686	4.043	3.309	19.892
ES	1.613	6.098	8.589	1.905	10.331	13.224
FR	2.768	3.125	5.016	3.494	1.475	6.287
HU	364	368	507	207	383	780
IT	2.094	3.897	6.206	2.278	5.009	6.371
PT	573	1.078	660	526	764	2.539
SE	910	510	1.535	497	969	2.298
UK	5.717	4.205	7.849	5.878	4.695	8.254
EU27	22.262	37.290	54.012	25.294	42.970	83.185

Source: IPTS. See text for details.

Assessment of results

Calculating the number of postdoctoral researchers is therefore problematic, especially in social sciences (for more details on the statistical analysis of differences between the two methods, please see methodology). Various explanations can be advanced to try to explain the difficulties of estimations:

- In the Rescar survey, the response rate was low (13%).
- The definition of social sciences may be loose, compared to natural sciences and engineering, and subject to various interpretations in different data sources.
- The identification of departments and teams is uncertain, and probably more difficult in social sciences than in engineering.

- There is some uncertainty around the number of doctoral candidates calculated with Eurostat data, particularly for Germany for which no data are given by Eurostat.
- In the two surveys, the definition of postdoctorate was not specified and was let to the interpretation of the heads of unit. There is not an agreement on a definition of postdoctorate, except that it is a "temporary" research position, generally based in the academic sector. National and disciplinary traditions may vary considerably on that respect. If the term postdoc may be particularly obvious in some disciplines – notably in life sciences – and in some countries – notably in the UK – it is likely to lead to different interpretations in many countries and many disciplines – and particularly in social sciences. In the frame of the NetReAct and Rescar surveys, postdoctorates may be assimilated to non tenured, non permanent academic positions.

The extrapolation which is done at the EU27 level is likely to be valid as the number of doctoral graduates in the 9 countries under consideration account for 77% of the EU27 total in life sciences, 70% in engineering and 76% in social sciences.

However, the results calculated here are broad estimations of the number of postdoctoral researchers in the EU27. They have to be interpreted with caution as they are based on the results of surveys, with a limited number of observations. Large margins of error are likely to exist around the point estimates given here. This is particularly the case for the social sciences.

More precise and detailed results would require other types of data, such as cohort data, the collection of which is very costly in terms of time and money. Such data only exist in very few countries (notably in some Nordic European countries).

Methodology

Higher education graduates

Data come from Eurostat databases on the number of ISCED 5A and 6 graduates, by levels and fields, on the period 1998-2004. Data were extracted at the end of November 2007. Calculations are from IPTS.

The EU27 totals for 2005 are estimations. They have been reconstructed based on 2005 data for all countries except Italy, data for 2004. The growth rates calculated over 1998-2005 at the EU27 level may be slightly over-estimated as data for Romania are only available from 2003. Average annual growth rates calculated by country are over 1998-2005, except Italy (1998-2004), Belgium (2000-2005) and Cyprus (1999-2005).

The International Standard Classification of Education (ISCED) is a framework for the compilation and presentation of national and international education statistics and indicators, which is maintained by the UNESCO Institute for Statistics[27]. It has been designed to serve as an instrument suitable for assembling, compiling and presenting comparable indicators and statistics of education both within individual countries and internationally. It is a classification both of levels of education and of fields of study.

In the terminology of the ISCED-97 classification, the level ISCED 5 includes tertiary programmes with academic orientation (type A), which are largely theoretically based, and tertiary programmes with occupation orientation (type B), which are typically shorter than type A programmes and geared for entry into the labour market. These more professional degrees (5B) were here excluded from the analysis.

More precisely, ISCED 5A programmes “are largely theoretically based and are intended to provide sufficient qualifications for gaining entry into advanced research programmes and professions with high skills requirements […] The minimum cumulative theoretical duration (at tertiary level) is of three years (FTE). The faculty must have advanced research credentials. Completion of a research project or thesis may be involved.” (OECD 1999, p. 23).

ISCED 5B programmes “are generally more practical/technical/occupationally specific than ISCED 5A programmes. […] They do not prepare students for direct access to advanced research programmes. They have a minimum of two years full-time equivalent duration. The programme content is typically designed to prepare students to enter a particular occupation.” (OECD 1999 p. 23). Qualifications in category 5B are typically shorter than those in 5A and focus on occupationally specific skills geared for entry into the labour market, although some theoretical foundations may be covered in the respective programme. The content of ISCED level 5B programmes is practically oriented/occupationally specific and is mainly designed for participants to acquire the practical skills, and know-how needed for employment in a particular occupation or trade or class of occupations or trades.

In some countries, the differentiation between more academic and more professional degrees is not relevant whereas in others the distinction between the two is clear (cf. Tauch and Rauhvargers 2002).

The level ISCED 6 “is reserved for tertiary programmes that lead to the award of an advanced research qualification. The programmes are devoted to advanced study and original research. The level requires the submission of a thesis or dissertation of publishable quality that is the product of original research and represents a significant contribution to knowledge. It is not solely based on course-work. It prepares graduates for faculty posts in institutions offering ISCED 5A programmes, as well as research posts in government and industry.” (OECD 1999 p. 23).

ISCED-97 classifies the fields of education in 25 fields and establishes broad groups composed of fields of education having similarities. The following broad groups are used in this fiche:

1. Teacher training and education science.
2. Humanities and arts.
3. Social sciences, business and law.
4. Science, mathematics and computing.
5. Engineering, manufacturing and construction.
6. Agriculture and veterinary.

[27] http://www.uis.unesco.org/ev.php?ID=3813_201&ID2=DO_TOPIC

7. Health and welfare.
8. Services.
9. Not known or not specified.

In this fiche when we refer to “science” this means group 4 “Science, mathematics and computing” which includes:

- Life sciences: biology, botany, bacteriology, toxicology, microbiology, zoology, entomology, ornithology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences.
- Physical sciences: astronomy and space sciences, physics, other allied subjects, chemistry, other allied subjects, geology, geophysics, mineralogy, physical anthropology, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, marine science, vulcanology, palaeoecology.
- Mathematics and statistics: mathematics, operations research, numerical analysis, actuarial science, statistics and other allied fields.
- Computing: computer sciences: system design, computer programming, data processing, networks, operating systems - software development only (hardware development should be classified with the engineering fields).

When referring to “engineering”, we mean group 5 “Engineering, manufacturing and construction” which includes:

- Engineering and engineering trades: engineering drawing, mechanics, metal work, electricity, electronics, telecommunications, energy and chemical engineering, vehicle maintenance, surveying.
- Manufacturing and processing: food and drink processing, textiles, clothes, footwear, leather, materials (wood, paper, plastic, glass, etc.), mining and extraction.
- Architecture and building: architecture and town planning: structural architecture, landscape architecture, community planning, cartography; Building, construction; Civil engineering.

When speaking of “science and engineering” (S&E), we refer to the two previous groups 4 and 5.

References

OECD (1999), *Classifying Educational Programmes. Manual for ISCED-97 Implementation in OECD countries. 1999 Edition*, OECD, Paris.

Tauch C. and Rauhvargers A. (2002), Survey on Master Degrees and Joint Degrees in Europe, EUA-DG Education and Culture.

Post-doctoral researchers

Data

The research population identified by the NetReAct project[28] consists of 7,732 teams working in life sciences, from 359 universities. Strata for sampling were built according to country and a simple importance indicator derived from the webometric analysis. Overall 1,773 teams were selected for the sample. After sampling and eliminating the not usable responses, the number of usable questionnaire in the sample was 468 teams, which corresponds to 26% of the respondents included in the sample.

The Rescar survey[29] identified a universe of 5,500 university departments in social sciences and engineering from 539 universities. A sample of 1,200 departments was drawn using random stratified sampling. In this sample, 4,700 teams were identified and approached. A questionnaire was implemented and sent to the heads of units of these research teams. 595 valid questionnaires were completed, giving a lower than expected response rate of 13%.

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[28] The Role of Networking in Research Activities, Deliverable D3.2 “Post-docs in the life sciences”, Empirica, Gesellschaft für Kommunikations- und Technologieforschung mbH, EU Contract No. 22540-2004-12 F1ED SEV DE, Issued by IPTS, http://www.netreact-eu.org/

[29] Cf. Draft Report Work Package 2 (WP2) for the Specific Contract “Collection and Analysis of existing data on researchers careers and Implementation of new data collection activities”, Submitted to the IPTS by the ERAWATCH NETWORK ASBL, Prepared by: EMPIRICA, FHNW, University of Wolverhampton, August 2007. Framework Service Contract Nr -150176-2005-F1SC-BE.

Methodology

Method 1

The first method consists in estimating the number of postdocs using only the survey results (NetReAct on the one hand, Rescar on the other). Only the EU extrapolation depends on external data (Eurostat). The method is slightly different for life sciences and for social sciences and engineering.

Postdocs in life sciences

The number of postdocs in the country i can be decomposed as:

$$\hat{N}_i^P = T_i \hat{P}_i$$

where Ti is the NetReAct number of life sciences teams identified in country i and Pi is the NetReAct estimated average number of postdoctorates per team in the country i.

Pi has been estimated on a sample of ni teams, each team l in the country i having an estimated number of postdoctorates pil:

$$\hat{P}_i = \frac{1}{n_i}\sum_{l=1}^{n_i} \hat{p}_{il}$$

The total number of postdocs in the EU27 is then extrapolated based on an inflation factor:

$$\hat{N}_{EU27}^P = \frac{\sum_{i \in D} \hat{N}_i^P}{f}$$

with D = (CZ, DE, ES, FR, HU, IT, PT, SE, UK).

The inflation factor is the ratio of the number of doctoral candidates in the 9 countries to the total number of doctoral candidates in the 27 countries[30], estimated with Eurostat data:

$$f = \frac{\sum_{i \in D} N_i^C}{\sum_{i=1}^{27} N_i^C}$$

Postdocs in engineering and social sciences

Compared to the method used for life sciences, a supplementary step is necessary. Indeed, contrary to the NetReAct survey, the universe of teams has not been identified in the Rescar survey, only the universe of university departments. Therefore, it is necessary to calculate first the number of teams in each field which can be estimated as the product of the number of departments in each field identified (in the universe) and the average number of teams per department in each field (estimated from the sample).

Using the same expressions as before, Ti the number of teams identified in country i, has now to be decomposed as:

$$\hat{T}_i = ND_i \hat{a}_i$$

Where NDi is the number of departments in engineering/social sciences and ai is the average number of teams per department (estimated from the sample), in the country i.

Once we have the total number of teams by country, we calculate the total number of postdocs by country, in a similar way as for life sciences, by multiplying it by the average number of postdocs per team, and we extrapolate similarly the results at the EU27 level.

[30] The implicit assumption behind this factor is that the share of the 9 countries in the EU27 total is equal for doctoral candidates and postdoctorates.

Method 2

The second method combines NetReAct/Rescar survey results and Eurostat data. More precisely, it is based on the structure of research teams calculated with the NetReAct/Rescar survey and the number of doctoral candidates estimated with Eurostat data. The number of postdocs is calculated as the product of the number of doctoral candidates and the average ratio of postdocs to doctoral candidates per team.

More precisely, the number of postdocs in each field in the country i is calculated as the product of the number of doctoral candidates in the country i and the ratio of the NetReAct/Rescar estimated average number of postdoctorates per team in the country i to the NetReAct/Rescar estimated average number of doctoral candidates per team in the country i. The average number of postdoctorates (as above) and the average number of doctoral candidates per team in each field by country has been estimated on a sample of ni teams with the NetReAct/Rescar data.

Formally, the number of postdocs in the country i is calculated as follows:

$$\hat{N}_i^{*P} = \hat{r}_i N_i^C$$

Where $\hat{r}_i = \frac{\hat{P}_i}{\hat{C}_i}$

is the ratio of the NetReAct/Rescar estimated average number of postdoctorates per team in the country i (Pi) to the NetReAct/Rescar estimated average number of doctoral candidates per team in the country i (Ci).

Pi is defined as above and Ci is defined similarly as:

$$\hat{C}_i = \frac{1}{n_i} \sum_{l=1}^{n_i} \hat{c}_{il}$$

The total number of postdocs in the EU27 is then extrapolated in the same way as before with an inflation factor:

$$\hat{N}_{EU27}^{*P} = \frac{\sum_{i \in D} \hat{N}_i^{*P}}{f}$$

with D = (CZ, DE, ES, FR, HU, IT, PT, SE, UK).

Comparisons of the two methods

In life sciences, the difference in the total number of postdocs in the EU27 between method 1 and 2 is 13.6%. The highest discrepancy in absolute terms is found for Germany – the first method giving a number of postdocs of about 2,700 and the second method 4,000.

For the engineering field, the difference between method 1 and 2 is about 15%. The highest difference in absolute terms is observed for Spain (the first method gives 6,100 postdocs and the second 10,300), far over the other country differences.

For social sciences, the differences between methods 1 and 2 are far higher than for life sciences and engineering. The first method gives a total number of postdocs in the EU27 of about 54,000 while the second method gives 83,000, 54% more. For all 9 countries, the second method gives a higher number of postdocs than the first method, contrary to life sciences and engineering where no systematic bias was found. In absolute terms, the highest discrepancies are found in Germany (a difference of 11,200) – for which the second method gives a number of postdocs more than double the one calculated with the first method, 19,900 against 8,700 – and Spain (4,600) – 13,200 for the first method and 8,600 for the second.

These discrepancies can be explained by the differences in calculation methods 1 and 2.[31]

If we compute the following statistics, which is the modulus of the difference for each country:

[31] For life sciences, this can be attributed as well to the evolution of the number of postdocs between 2003 and 2004. With the second method, we have used data on the number of doctoral candidates in 2004, contrary to the first method which corresponds to 2003. Indeed, with the first method, it is not possible to estimate the situation in 2004 as NetReAct provides the structure of research teams in 2003.

$$d_i^m = \left| N_i^{*P} - N_i^P \right|$$

(where N_i^P and N_i^{*P} are respectively the number of postdocs estimated with method 1 and 2)

and divide it by the sum, i.e. $\frac{d_i^m}{\sum_j d_j^m}$, we find that:

- For life sciences, Germany alone explains 36% of the total discrepancy, followed by France with 20% and Sweden with 11%.

- For engineering, results for Spain explain 36% of the total discrepancy calculated in modulus, followed by Germany (16%) and France (14%).

- For social sciences, results for Germany explain half of the sum of differences calculated in modulus, followed by Spain (21%) and Portugal (9%).

Table 9. Number of postdoctorates in life sciences: differences in modulus between method 1 and 2

	Differences in modulus (d_i^m)	%
CZ	302	8%
DE	1.294	36%
ES	293	8%
FR	726	20%
HU	156	4%
IT	184	5%
PT	46	1%
SE	413	12%
UK	161	5%
All 9 countries	3.574	100%

Source: IPTS.

Table 10. Number of postdoctorates in engineering and social sciences: differences in modulus between method 1 and 2

	Engineering		Social sciences	
	Difference in modulus (d_i^m)	%	Difference in modulus (d_i^m)	%
CZ	1.505	13%	1.429	6%
DE	1.880	16%	11.206	51%
ES	4.233	36%	4.635	21%
FR	1.650	14%	1.270	6%
HU	15	0%	273	1%
IT	1.113	10%	166	1%
PT	314	3%	1.879	9%
SE	459	4%	763	3%
UK	490	4%	404	2%
Sum	11.658	100%	22.025	100%

Source: IPTS.

WP 1: Indicators on researchers' mobility

Indicator 3: Number of researchers recruited under a permanent contract in R&D

We tried to construct indicator 3 but as no data was available we had to base it on an uncertain modelling approach. Therefore, based on the recommendations of the experts involved in the peer-review process, it has been agreed with DG RTD to abandon this indicator given the impossibility to construct it on a strong basis.

The idea was to model the indicator 3 as no comprehensive information data source is available, to estimate the number of researchers on permanent positions at the doctoral level in the HE and GOV sectors (in the BES sector, we expected this number would even be more difficult or impossible to estimate). We intended then to compare these numbers to the number of doctoral graduates annually awarded. The advantage of this approach is that we hoped to have indicators relatively comparable between countries and that we should have been able to extrapolate the results at the EU level and to "forecast" the evolution of the system on a few years.

In most countries, it is impossible to know directly the annual flow of new permanent positions (at the doctoral level) in the academic and public sectors. The annual number of new permanent positions at the doctoral level in HE and GOV sectors (noted T_h hereafter) was however estimated like the following:

(1) $$T_h = \frac{P(1-s)(1+m)}{N_h}$$

where P is the total number of permanent positions in universities and public labs at the doctoral level.

N_h is the average number of years in activity.

s is the percentage of permanent positions replaced by temporary positions. It captures the substitution of temporary (e.g., postdocs) to permanent positions recently observed in some countries (it is likely to be difficult to estimate).

m is the percentage of permanent staff who leave their positions to another sector (may be difficult to estimate as well).

It is obvious that if it is not possible to get reliable information on the parameters s and m, the model simplifies as

$$T_h = \frac{P}{N_h}$$

The main hypothesis of this estimation was the steady state hypothesis.

For the BES sector, data limitations were more important. We simply estimated the annual flow of doctoral researchers in the BES sector like the following:

(2) $$T_b = \frac{R}{N_b}$$

R is the total number of researchers at the doctoral level in the BES sector (the number of permanent positions was impossible to estimate) and N_b is the average number of years in activity.

The estimation of T_b was more uncertain than the estimation of T_h for HE and GOV as the estimation of R was difficult.

It was then possible calculate the annual flow of "permanent" positions available in R&D at the doctoral level:

(3) $$T = T_h + T_b$$

That was compared to the annual number of new doctoral graduates. For example we calculated the % of new doctoral graduates (potentially) employed in permanent positions in R&D like the following:

(4) $$t = \frac{T}{D(1-f)}$$

with D the annual number of new doctoral graduates and f the % of doctoral graduates who return to their home country after graduation.

However, a number of problems emerged. Information on P (the total number of permanent positions in universities and public labs at the doctoral level) is not available in Eurostat or any other data source. What is available is the number of researchers at the doctoral level but for a few countries only (BE, CZ, EE, ES, IE, CY, LV, IT, HU, MT, AT, PL, PT, SL, SK), for a few years only and sometimes not for all sectors in general, and it is not possible to distinguish disciplines. In addition, as the number of researchers reported may include doctoral candidates, we tried to calculate the number of researchers excluding doctoral candidates. The problem was that the way doctoral candidates are included, excluded or partly included in the number of researchers varies by country (it may include all, part – those who are funded – or no doctoral candidate).

Other problems difficulties were identified. In the sample, small countries were over-represented compared to “big” countries. The interpretation of these indicators for small numbers was problematic as the number of researchers and ISCED6 graduates is low and the extrapolation was uncertain. These calculations were particularly sensitive to the year chosen. The classification of disciplines was not probably directly comparable between researchers and ISCED6 graduates. The problem of the type of contract remained unsolved. A general incertitude remained about the calculations as they were based on strong hypothesis, notably for the number of doctoral candidates (hypothesis on the duration of doctoral studies) and for the annual number of new researchers positions (hypothesis on the number of years in activity).

WP 1: Indicators on researchers' mobility

Indicator 4: Average time from graduation to a first regular employment contract in R&D

No data are available to construct this indicator. Therefore, its construction was based on the calculations of indicator 3, and all its uncertainties. Therefore, as for indicator 3, based on the recommendations of experts, it was decided, in agreement with DG RTD, to abandon the construction of this indicator.

This indicator was based on the calculations of indicator 3. With the definitions adopted in the fiche 3, this indicator was estimated like this:

$$A = \frac{1}{t}$$

It was interpreted as the duration for all the individuals of an annual cohort of doctoral graduates to be employed on R&D positions (if no other cohort of doctoral graduates would be produced).

It was mainly based on the hypothesis that all new doctoral graduates intend to have a career in R&D (in the public/academic or private sectors). However, it suffered from the same major uncertainties as indicator 3 (problems of calculations and interpretation based on strong necessary assumptions).

WP 2: Indicators on researchers' mobility

Indicator 5: Circulation of researchers within Europe

Main Findings

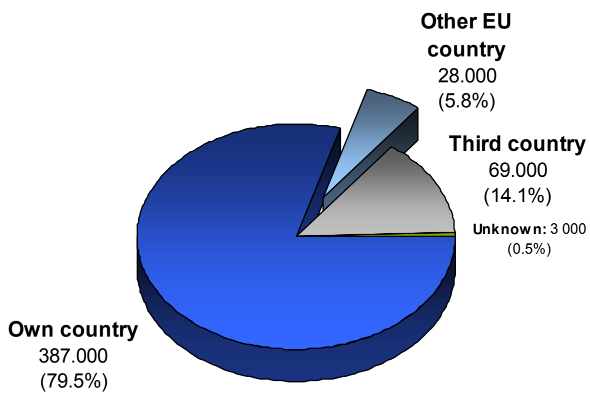
In 2005, in the European Union (based on 21 countries reporting data), among the 487,000 doctoral candidates, 28,000 have the nationality of another EU Member State, accounting for nearly 6%.

The UK had the highest number of doctoral candidates of EU origin, some 11,500, in 2005. It is followed by France (5,400) and Spain (3,100). All the other countries have less than 2,000 doctoral candidates having the nationality of another Member State. As share of the total number of doctoral candidates of the reporting country, the UK, Austria and Belgium are the three top countries, having respectively 12.5%, 12.5% and 12.1% of their doctoral candidates with citizenship of another EU country. In 13 countries out of 21, foreign EU candidates account for less than 5% of enrolments at the doctoral level.

The United Kingdom is the most important intra-EU net gainer, in absolute and relative terms, of the intra-EU exchanges of doctoral candidates, with a intra-EU net gain of 5,300 doctoral candidates, accounting for 5.8% of the total number of doctoral candidates in the UK. The other countries with a positive intra-EU net gain are France, Spain, Austria, Sweden, Czech Republic, Finland and Belgium.

Using two pilot ad-hoc surveys commissioned by IPTS, we have estimated that, in the EU27, 9% of doctoral candidates in life sciences, 8% in engineering and 7% in social sciences are EU nationals who work in another EU country. For post-doctoral researchers, with the same two surveys, the corresponding percentages are slightly higher: the "intra-EU" in-mobility accounts for respectively 18% of postdoctoral researchers in life sciences, 11% in engineering and 9% in social sciences.

Number and percentage of doctoral candidates in the EU according to their country of citizenship (2005)



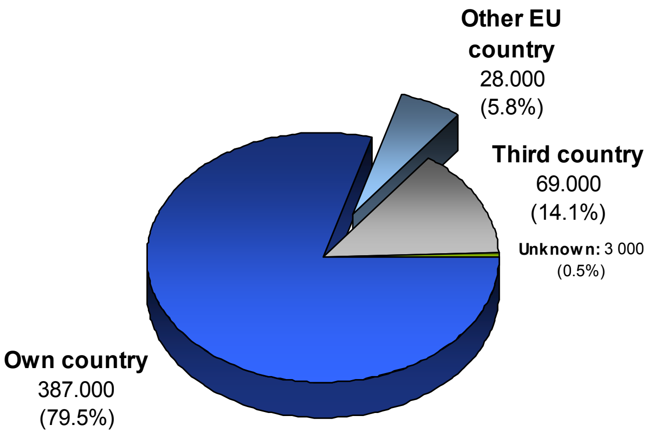
Source: IPTS based on Eurostat data.

Doctoral candidates and post-doctoral researchers in the EU

Doctoral candidates in the EU: all fields

In the European Union (based on 21 EU countries having reported data to Eurostat)[32], in 2005, among the 487,000 doctoral candidates, 79.5% are citizens of the country in which they work, 5.8% have the nationality of another Member State (accounting for about 28,000 doctoral candidates) and 14.1% come from third countries (and 0.5% are of unknown citizenships) (cf. Figure 38)[33].

Figure 38. Number and percentage of doctoral candidates in the EU according to their country of citizenship (2005)



Source: IPTS with Eurostat data. Calculations are based on 21 EU countries.

Intra-EU inflows

The number and percentage of doctoral candidates with the citizenship of another Member State is given in Figure 39 for each of the 21 countries reporting data.

The UK had the highest number of doctoral candidates of EU origin, some 11,500, in 2005. It is followed by France (5,400) and Spain (3,100). These three countries accounted for about 70% of the 28,000 doctoral candidates with the citizenship of another Member State (40% alone for the UK). All the other countries have less than 2,000 doctoral candidates having the nationality of another Member State.

As share of the total number of doctoral candidates of the reporting country, the UK, Austria and Belgium are the three top countries, having respectively 12.5%, 12.5% and 12.1% of their doctoral candidates with citizenship of another EU country. The following top countries are Cyprus, Sweden, France, Denmark and Hungary, with shares between 5% and 10%. In the remaining 13 countries (out of 21), foreign EU candidates account for less than 5% of enrolments at the doctoral level.

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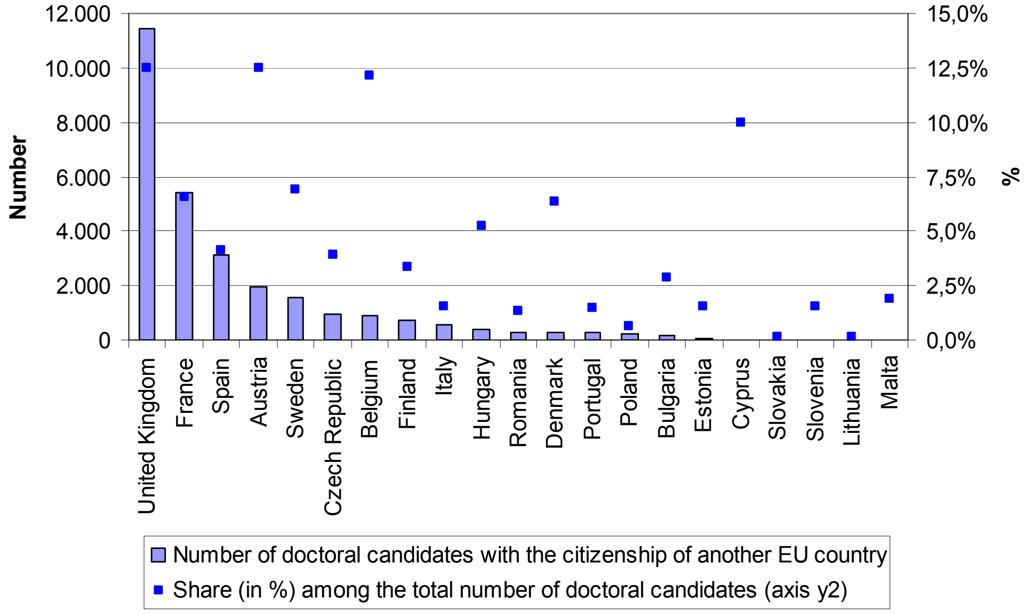
[32] The six missing countries are: Germany, Ireland, Greece, Latvia, Luxembourg and The Netherlands.

[33] Looking at the nationality breakdown of the total EU working age population, it is found that third country nationals account for 3.4% and other EU-25 nationals account for 1.5%. Only Belgium, Ireland and Luxembourg have a higher share of EU-25 nationals (respectively 4.7%, 4.6% and 33.1%) than third country nationals (2.8%, 2.7% and 3.2%).

Figure 39. Number and percentage of doctoral candidates with the citizenship of another EU Member State in the reporting country (2005)



Source: IPTS. Number: number of doctoral candidates with the citizenship of a Member State other than that of the reporting country. %: percentage among the total number of doctoral candidates in the reporting country.

Intra-EU outflows

For a given nationality, the number of doctoral candidates abroad is calculated by summing up the numbers provided for this nationality by the 21 receiving EU countries for which data are available.

To have a picture of the situation in relative terms, it is then possible to divide these numbers by[34]:

- The total number of doctoral candidates in the considered country. It can be interpreted as the outflow of doctoral candidates of a given nationality relative to the size of the total population of doctoral candidates in the corresponding country.
- The total number of doctoral candidates of this nationality, including those within the home country. It can be interpreted as the relative mobility of doctoral candidates of a given nationality.

Results are presented in the following figure.

In absolute terms, we find that 4,000 Greeks, 3,900 Germans and 3,600 Italians are pursuing doctoral studies in a Member State other than their country of citizenship. The following top nationalities are Portuguese, Romanian and French.

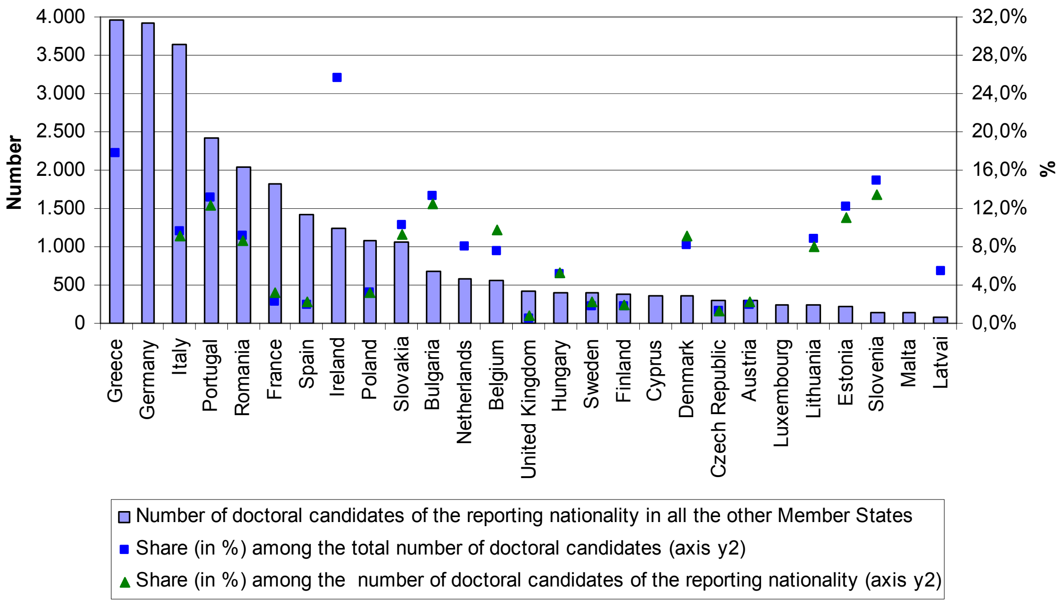
The ratio of the number of expatriates' doctoral candidates in the 21 EU countries reporting data to the total number of doctoral candidates in the considered country (first ratio) is the highest for Ireland (25.7%), Greece (17.8%), Slovenia (14.8%) and Portugal (13%)[35]. It is the lowest (below 3%) in the UK, Czech Republic, Finland, Sweden, Austria, Spain and France.

The percentage of doctoral candidates continuing their doctoral education in a EU country other than their country of citizenship (second ratio) is the highest in Slovenia (13.5%), Bulgaria (12.5%), Portugal (12.4%) and Estonia (11%). It is the lowest (below 3.5%) for the UK, Czech Republic, Finland, Sweden, Spain, Austria, France and Poland.

[34] The two ratios provide very similar results as they differ only by the share of doctoral candidates from outside the EU.

[35] If we except Malta and Cyprus which have very high ratios, respectively 257% and 144%, due to the limited number of doctoral candidates in these two countries.

Figure 40. Number and percentage of doctoral candidates of the reporting nationality in all the other Member States (2005)



Source: IPTS. Eurostat data. Number: for a given nationality, the number of doctoral candidates abroad is calculated by summing up the numbers provided for this nationality by the receiving EU countries. Share 1: the number is divided by the total number of doctoral candidates in the considered country whatever their nationality (it was not possible to calculate this ratio for Germany and Luxembourg which do not provide the total number of doctoral candidates). Share 2: the number is divided by the total number of doctoral candidates of this nationality including those within the home country (it was not possible to calculate this ratio, in addition to the two previous countries, for Greece Ireland, Netherlands and Latvia which do not report data by nationality).

Intra-EU net "gains" and "losses"

The intra-EU net gains have been calculated as the differences between the number of doctoral candidates of EU nationality in the reporting country and the number of its citizens' doctoral candidates in the other Member States[36].

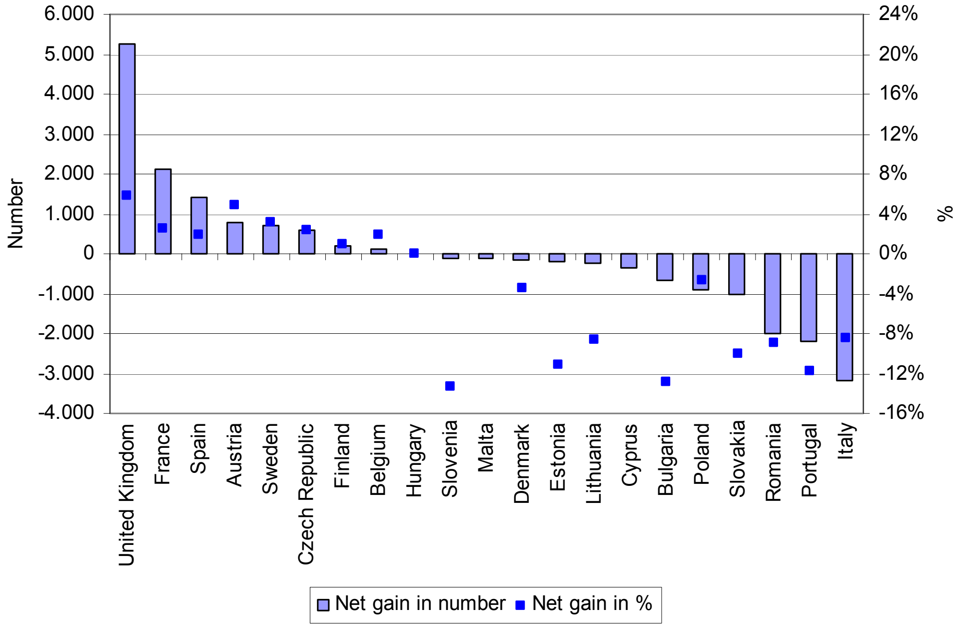
The United Kingdom is the most important intra-EU net gainer, in absolute and relative terms, of the intra-EU exchanges of doctoral candidates, with a net gain of 5,300 doctoral candidates, accounting for 5.8% of the total number of doctoral candidates in the UK.

The other countries with a positive intra-EU net gain are France, Spain, Austria, Sweden, Czech Republic, Finland and Belgium, accounting for between 0.9% (in Finland) and 4.9% (in Austria) of their total number of doctoral candidates.

The highest intra-EU net losses in absolute terms are found in Italy, Portugal and Romania, accounting for respectively 8.5%, 11.8% and 8.9% of their number of doctoral candidates.

[36] excluding the nationalities corresponding to countries for which data are not provided, i.e. we have worked with a 21x21 matrix.

Figure 41. Intra-EU "net gain" of doctoral candidates: differences between the number of doctoral candidates of EU nationality in the reporting country and the number of its citizens doctoral candidates in other Member State (2005)



Source: IPTS with Eurostat data. The net loss in % is not represented on the figure, as it is 143% for Cyprus and 257% for Malta.

Origin of doctoral candidates in the EU in three fields (life sciences, social sciences, engineering)

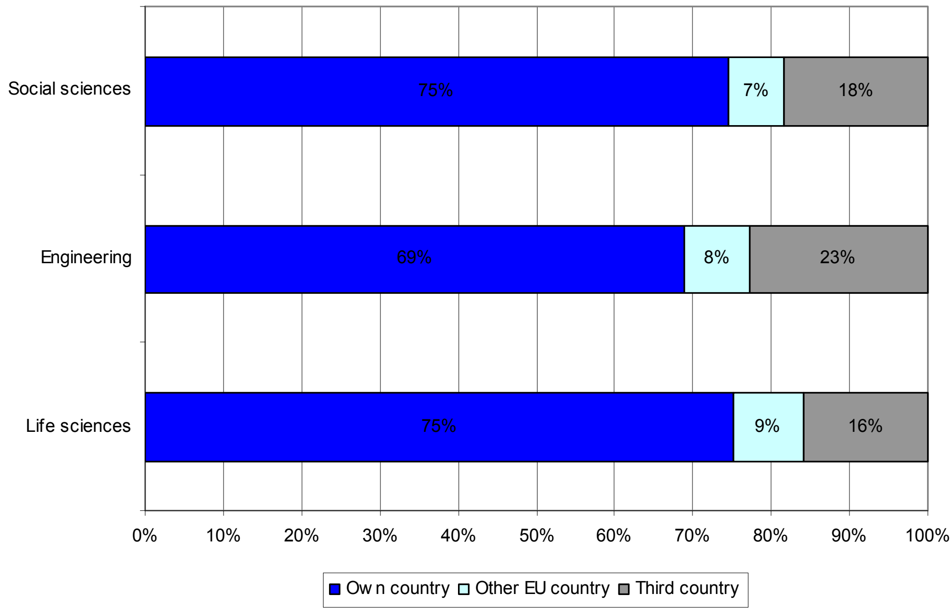
As in Eurostat data the number of doctoral candidates by nationality is not disaggregated by fields, we have constructed indicators using the two pilot ad-hoc surveys commissioned by IPTS. As for indicator 2 (section on the number of postdoctorates), the methodology[37] consists in combining Eurostat aggregated data and data from the two pilot ad-hoc surveys carried out on a sample of EU countries, the NetReAct survey (2005) – for life sciences – and the Rescar survey (2007) – for engineering and social sciences.

In the NetReAct and Rescar surveys, information on the origin of doctoral candidates is available. To have an EU picture of the origin of doctoral candidates in life sciences, social sciences and engineering, we apply the following method (see methodology for more details). First, we extract the distribution of doctoral candidates by country of origin from the NetReAct and Rescar surveys. Second, we apply these percentages to the number of doctoral candidates from Eurostat data, we calculate the sum for the 9 countries and we extrapolate the results at the EU27 level. The same method is applied separately for each field (life sciences, social sciences and engineering). Results are given in the following graph.

We found that 75% of doctoral candidates in life sciences, 69% of doctoral candidates in engineering and 75% of doctoral candidates in social sciences in the EU27 undertake doctoral studies in their country of origin. Therefore, 25% of doctoral candidates in life sciences, 31% in engineering and 25% in social sciences are of foreign origin. That can be decomposed as 9% in life sciences (respectively 8% in engineering and 7% in social sciences) from other EU countries ("intra-EU") and 16% in life sciences (respectively 23% in engineering and 18% in social sciences) from third countries ("extra-EU").

[37] For more details on these surveys and on the methodology, please refers to indicator 2.

Figure 42. Percentage of doctoral candidates in the EU27 according to their country of origin, in life sciences, engineering and social sciences (2004)



Source: IPTS.

Origin of postdoctoral researchers in the EU in three fields (life sciences, social sciences, engineering)

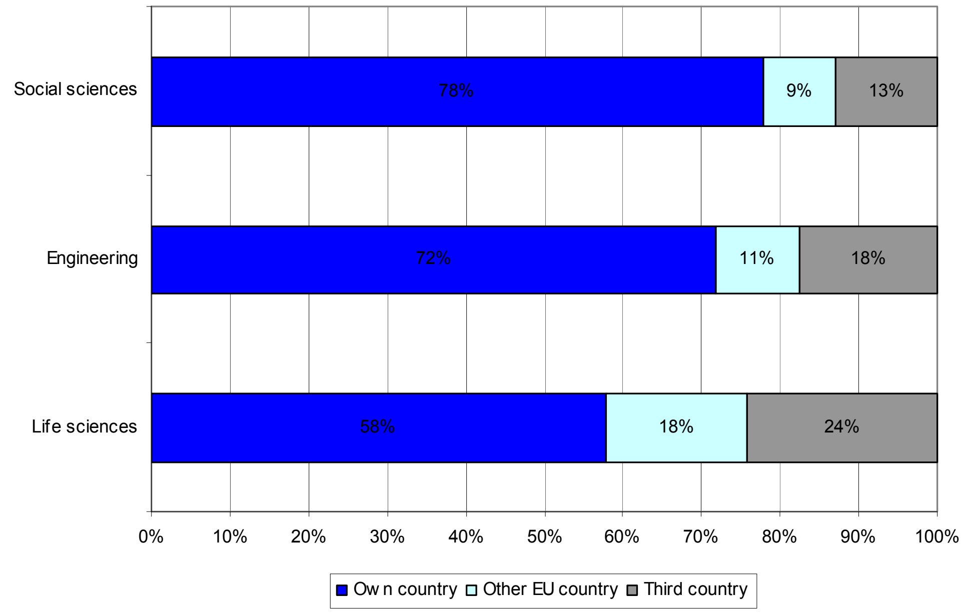
In Europe, information on postdoctorates is scarce and no comprehensive and comparable data at the EU level are available. Therefore, in this section we present the results of the estimation of the origin of postdoctorates in life sciences, engineering and social sciences, based on the results of the two same ad-hoc pilot surveys (see above and indicator 2).

Based on the estimated number of postdoctorates (see indicator 2) and on the information provided in the NetReAct and Rescar surveys on the origin of postdoctorates, we can estimate the origin of postdoctorates in life sciences, engineering and social sciences in the EU27. We follow a similar methodology as above (origin of doctoral candidates in three fields). First, we extract the distribution of postdoctorates by country of origin from the NetReAct and Rescar surveys. Second, we apply these percentages to the number of postdoctorates previously calculated for indicator 2[38]. Third, we calculate the sum for the 9 countries and we extrapolate the results at the EU27 level. Results are given in the following graph.

We find that 58% of postdoctorates in life sciences, 72% of postdoctorates in engineering and 78% of postdoctorates in social sciences work in their country of origin. Therefore, 42% of postdocs in life sciences, 28% in engineering and 22% in social sciences are of foreign origin. That can be decomposed as 18% in life sciences (respectively 11% in engineering and 9% in social sciences) from other EU countries (“intra-EU”) and 24% in life sciences (respectively 18% in engineering and 13% in social sciences) from third countries (“extra-EU”).

[38] We give the results for the second method only as the results of this method are likely to be more reliable. In addition, the results in percentages are close for the two methods.

Figure 43. Percentage of postdoctoral researchers in the EU27 according to their country of origin, in life sciences, engineering and social sciences (2004)



Source: IPTS.

Methodology

Doctoral candidates in the EU

Data are from Eurostat. They have been extracted on November 29th, 2006.

Calculations are based on 21 countries only as data on the remaining countries are not available. These 21 countries are: Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Spain, France, Italy, Cyprus, Lithuania, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, United Kingdom. The following are missing: Germany, Ireland, Greece, Latvia, Luxembourg and The Netherlands.

Here, "mobile"/"international" students are defined on the basis of their country of citizenship. The data collected on mobile/international students has changed in the Unesco-OECD-Eurostat data collection in 2005.[39] However, the changes are not fully implemented yet and can not be used here as it is still in a pilot phase. This change has been motivated by the fact that the data collected previously to the 2005 UOE data collection are not appropriate for measuring all mobile/international students. Observations based on this criterion are affected by the differences in legislation governing the acquisition of nationality. Certain foreign students may thus have lived in their host countries for many years and completed some or all of their prior education in the same country, and, therefore, they may have never been "mobile". Citizenship alone is not a sufficient variable to measure in-coming and out-going students. New concepts are introduced in the 2005 UOE data collection to better capture student mobility across countries: country of citizenship, country of permanent residence and country of prior education.

Data on foreign students refer here to citizenship. Students are non-citizens students if they do not have the citizenship of the country for which the data are collected. Normally citizenship corresponds to the nationality of the passport which the student holds or would hold. Countries unable to provide data or estimates for non-citizens on the basis of the passport held should fill other parts of the data collection on mobile/international students depending on the concept available in their data sources (country of permanent or usual residence, country of prior education).

Origin of doctoral candidates in the EU in three fields

In the NetReAct and Rescar surveys, information on the origin of doctoral candidates is available (for more details on the surveys, please see indicator 2). To have an EU picture of the origin of doctoral candidates in each of the three fields, we apply the following method.

First, we extract the distribution of doctoral candidates by country of origin from the surveys. Second, we apply these percentages to the number of doctoral candidates from Eurostat data, we calculate the sum for the 9 countries and we extrapolate the results at the EU27 level. The same method is applied separately for life sciences, social sciences and engineering.

More precisely, the number of doctoral candidates in the country i from region m is the product of the percentage of doctoral candidates in the considered field (life sciences/social sciences/engineering) of country i from the region m in the Rescar survey and the number of doctoral candidates in the corresponding field estimated with Eurostat data in the country i. The extrapolation is done using an inflation factor which is the ratio of the number of doctoral candidates in each field in the 9 countries to the total number of doctoral candidates in the corresponding field in the 27 countries, estimated with Eurostat data.

Formally, if αim is the percentage of doctoral candidates in life sciences (respectively social sciences, engineering) of country i from the region m in the NetReAct/Rescar survey, we estimate the number of doctoral candidates in the country i from region m Dim as follows:

$$\hat{D}_{im} = \hat{\alpha}_{im} N_i^C$$

---

[39] Cf. Unesco-OECD-Eurostat, *UOE data collection on education systems, Manual: Concepts, definitions and classifications*, Volume1, (Montreal, Paris, Luxembourg: 2005).

Where N_i^C is the number of doctoral candidates in the corresponding field estimated with Eurostat data in the country i.

The total number of doctoral candidates in life sciences (respectively social sciences, engineering) in the EU27 from the region m is extrapolated with an inflation factor f from the total for the 9 countries as:

$$\hat{D}_{EU27,m} = \frac{\sum_{i \in D} \hat{D}_{im}}{f}$$

with D = (CZ, DE, ES, FR, HU, IT, PT, SE, UK).

The inflation factor corresponding to each discipline is the ratio of the number of doctoral candidates in social sciences/engineering in the 9 countries to the total number of doctoral candidates in the corresponding field in the 27 countries, estimated with Eurostat data:

$$f = \frac{\sum_{i \in D} N_i^C}{\sum_{i=1}^{27} N_i^C}$$

with D = (CZ, DE, ES, FR, HU, IT, PT, SE, UK).

Origin of postdoctoral researchers

The same methodology as above is applied for postdoctoral researchers. See as well indicator for more details on the surveys and on the calculation methods.

WP 2: Indicators on researchers' mobility

Indicator 6: Number of researchers leaving Europe

Main Findings

European doctoral graduates in the U.S.

- 43,300 doctorates were granted by U.S. universities in 2005. Of the 2005 doctorate recipients with known citizenships, about 35% were non-U.S. citizens. The top countries in terms of the number of doctorates awarded to its citizens are China (which accounts for 9.4% of all doctorates awarded by U.S. universities), South Korea (3.8%), India (3.1), Taiwan (1.8%) and Canada (1.4%).
- The eight top EU countries are: Germany (11th), Romania (12th), Italy (14th), the UK (15th), France (17th), Spain (20th), Greece (23rd) and Bulgaria (26th). These eight EU countries account for 3.1% of the total number of doctorates awarded by U.S. institutions (or 9% of the number of non-U.S. citizens earning doctorates).
- On average, U.S. universities award about 1.8 doctorates to citizens of these eight countries for every 100 granted at home. This ratio ranges from 17.4% for Bulgaria to 1% for Germany.
- In S&E fields, some 26,300 doctorates were awarded by U.S. universities in 2004. 40% were awarded to non-U.S. citizens (among those with known citizenships), 26.9% to Asians and 6.6% to Europeans (all Europe). Citizens from the UK, Germany and France account for 1.5% (about 400 individuals) while all the other European countries account for 5.1% (about 1,300 individuals).

Scholars of EU origin in the U.S.

- In 2005-06, nearly 97,000 foreign scholars were working in the U.S. Asia is the leading place of origin for foreign scholars in the U.S. with some 48,000 individuals. Nearly 25,000 scholars hosted in the U.S. come from the EU-27. They account for about 29% of the total number of foreign scholars in the U.S.
- In 2005/06, the top countries of origin of foreign scholars in the U.S. are China (with some 19,000 individuals), Korea (8,900), India (8,800) and Japan (5,600). Among the top 10 countries of origin of foreign scholars in the U.S., there are four EU countries: Germany 5th (5,100), France 7th (3,400), the UK 8th (3,300) and Italy 9th (3,000).
- Compared to the size of the local academic workforce, 2.3 scholars hold position in the U.S. per 100 working at home on average for the EU. This ratio is the highest for Cyprus (7.4), Ireland (4.7), the Netherlands (4.7), Romania (4.6) and Italy (4.0).

European doctoral graduates in the U.S.

Origin of doctoral recipients in the U.S.: all disciplines

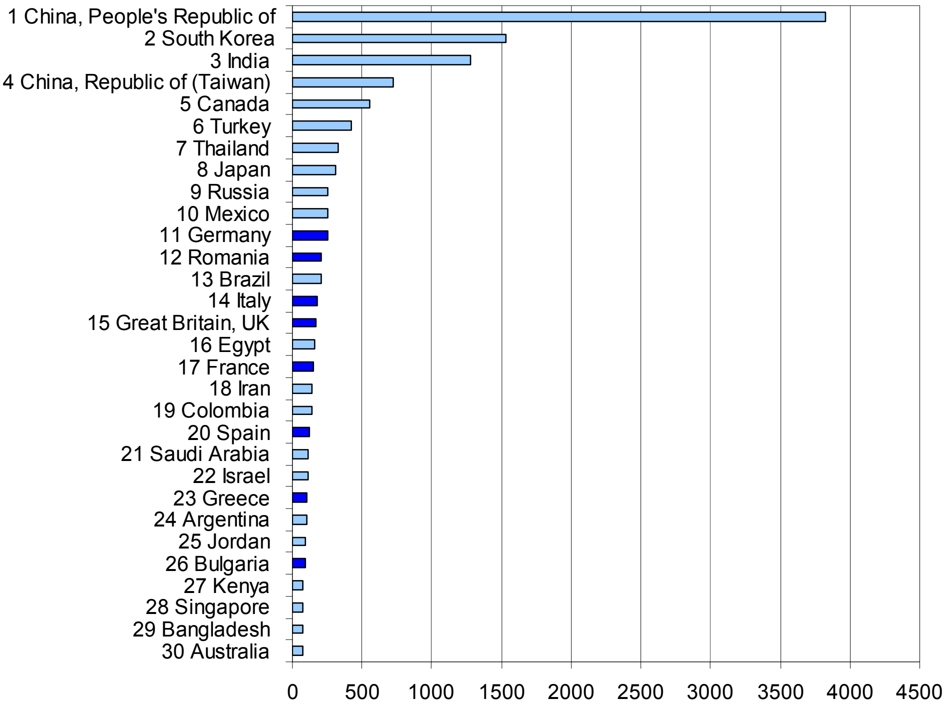
43,300 doctorates were granted by U.S. universities in 2005.[40] Of the 2005 doctorate recipients with known citizenships[41], about 35% were non-U.S. citizens (4% non-U.S. citizens with permanent resident visas and 31% non-U.S. citizens with temporary visas).

Top countries of origin

In the U.S., the top country in terms of the number of doctorates awarded to its citizens is China, which accounts for 9.4% of all doctorates awarded by U.S. universities with known citizenships (or 27% of the number of doctoral recipients non-US citizens) (Figure 44). The top following countries are: South Korea (3.8% of all doctorates with known citizenships), India (3.1%), Taiwan (1.8%) and Canada (1.4%).

Among the top 30 countries[42], there are eight EU countries that rank like the following: Germany (11th, 0.61%), Romania (12th, 0.52%), Italy (14th, 0.45%), the UK (15th, 0.41%), France (17th, 0.37%), Spain (20th, 0.30%), Greece (23rd, 0.26%) and Bulgaria (26th, 0.23%). There were nearly 1,300 doctoral recipients from these eight EU countries in the U.S. in 2005. That account for 3.1% of the total number of doctorates with known citizenships awarded by U.S. institutions (or 9% of the number of non-U.S. citizens earning doctorates). Data for the other countries are not publicly available.

Figure 44. Top 30 countries of origin of non-U.S. citizens earning doctorates in the U.S. (2005)



Source: IPTS with NSF/NIH/USED/NEH/USDA/NASA, 2005 Survey of Earned Doctorates.

[40] Hoffer, T.B., V. Welch, Jr., K. Webber, K. Williams, B. Lisek, M. Hess, D. Loew, and I. Guzman-Barron (2006). *Doctorate Recipients from United States Universities: Summary Report 2005.* Chicago: National Opinion Research Center.

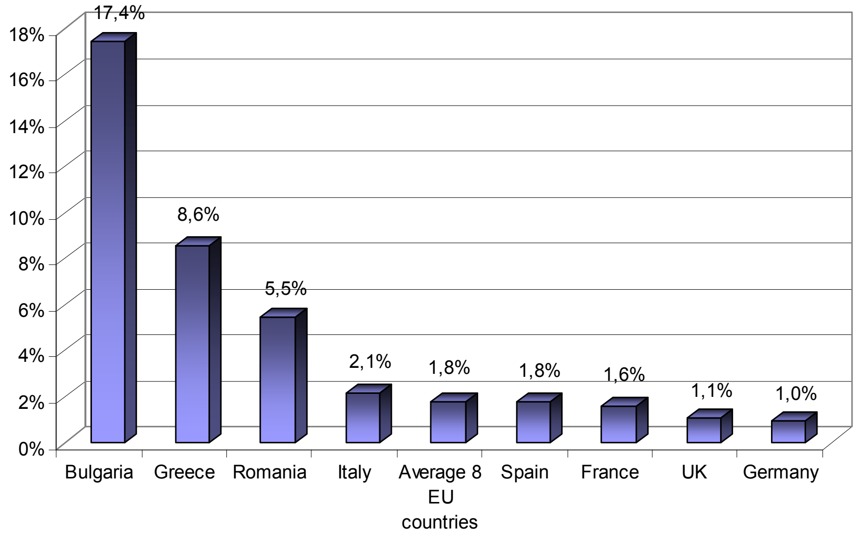
[41] About 40,700 with known citizenships and 2,600 with unknown citizenships.

[42] Unfortunately, we can't have the full list of countries with the data publicly available.

Out migration of doctoral recipients of EU origin: a relative measure

For these eight EU countries, we calculated the ratio of the number of doctorates earned in the U.S. to the number of doctorates awarded at home. On average, it is 1.8% i.e. U.S. universities award about 1.8 doctorate to citizens of these eight countries for every 100 granted at home. This ratio ranges from 17.4% for Bulgaria to 1% for Germany (Figure 45).

Figure 45. Ratio of doctorates earned in the U.S. to doctorates awarded at home (%)



Source: IPTS with Eurostat data and NSF/NIH/USED/NEH/USDA/NASA 2005 Survey of Earned Doctorates. Data for the U.S.: 2005. Data for EU countries: 2005, except Italy: 2004.

Origin of doctoral recipients in the U.S.: S&E disciplines

Main regions of origin: recent evolution

26,275 doctorates were awarded in S&E fields[43] by U.S. universities in 2004. 10,040 were awarded to non-US citizens, i.e. 40% among those with known citizenships.[44]

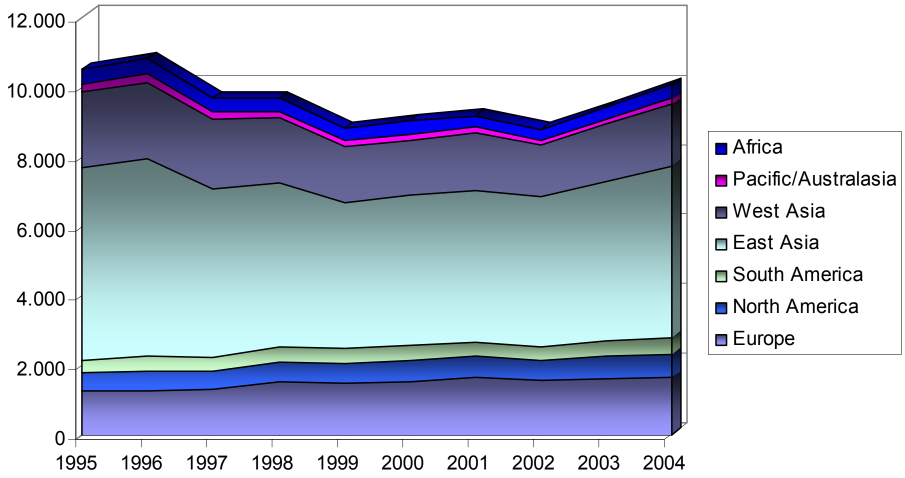
The evolution of the number of foreign doctoral graduates by main regions of origin over 1995-2004 is given in the Figure 46. The number of doctoral candidates with European citizenship[45] has evolved around 1,500 from 1998 to 2004. The number of doctoral candidates from Asia (East and West Asia grouped together) is clearly higher (7,800 in 1995 and 6,700 in 2004). Therefore, Europeans and Asians account respectively for about 6.6% and 26.9% of S&E doctoral graduates with known citizenships awarded in the U.S.

[43] "U.S. definition" i.e. including social sciences. Cf. National Science Foundation, Division of Science Resources Statistics, *Science and Engineering Doctorate Awards: 2004*, NSF 06-308, Project Officer, Susan T. Hill (Arlington, VA 2006).

[44] In S&E fields, 1,432 are of unknown nationalities in 2005.

[45] All Europe, including East European countries.

Figure 46. Non-U.S. citizens awarded U.S. doctorates in S&E, by main region of origin (1995–2004)



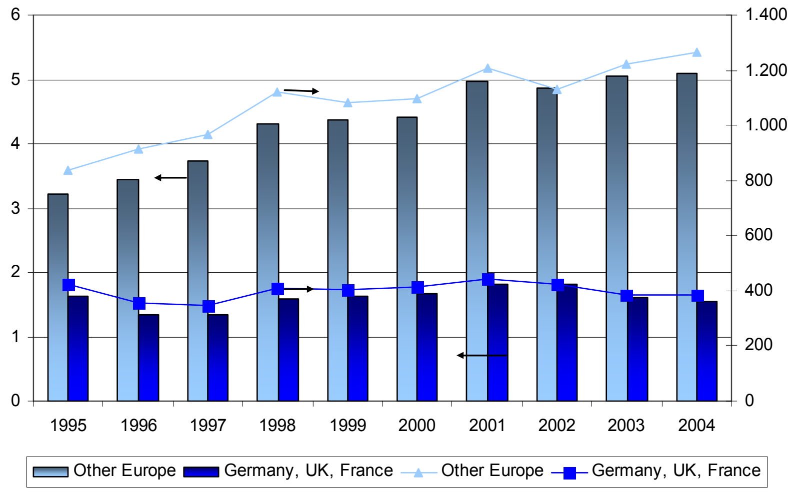
Source: IPTS with National Science Foundation/Division of Science Resources Statistics, Survey of Earned Doctorates.

Doctoral recipients of EU origin

Data are publicly available for four European citizenships: Germany, UK, France and Belgium. Respectively 184, 110 and 91 S&E doctoral graduates were awarded to citizens from Germany, the UK and France, in the U.S. in 2004. These three citizenships together account for 1.5% of the total number of S&E doctoral graduates (with known nationalities) awarded by U.S. universities that year. All the other European countries (including East European countries) account for 5.1%.

The evolution of the number and percentage of S&E doctorates awarded to Europeans (isolating the "three big" from all the other European countries) over 1995-2004 is given in the Figure 47. The number (and percentage) of S&E doctorates awarded to citizens from the "three big" has tended to stay relatively stable over time, whereas the number (and percentage) of S&E doctoral awarded to citizens from all the rest of Europe has tended to increase. This increase may be attributed to East European countries rather than to EU countries however.[46]

Figure 47. Number and percentage of U.S. S&E doctorates awarded to European citizens (1995-2004)



Source: IPTS with National Science Foundation/Division of Science Resources Statistics, Survey of Earned Doctorates. Number of doctorates awarded to citizens from Germany, France and the UK, and to other European countries (right axis). Percentage: among the total number of S&E doctorates with known citizenships (left axis).

[46] With the data publicly available we can't go further in the analysis.

Scholars of EU origin in the U.S.

Foreign scholars in the U.S.

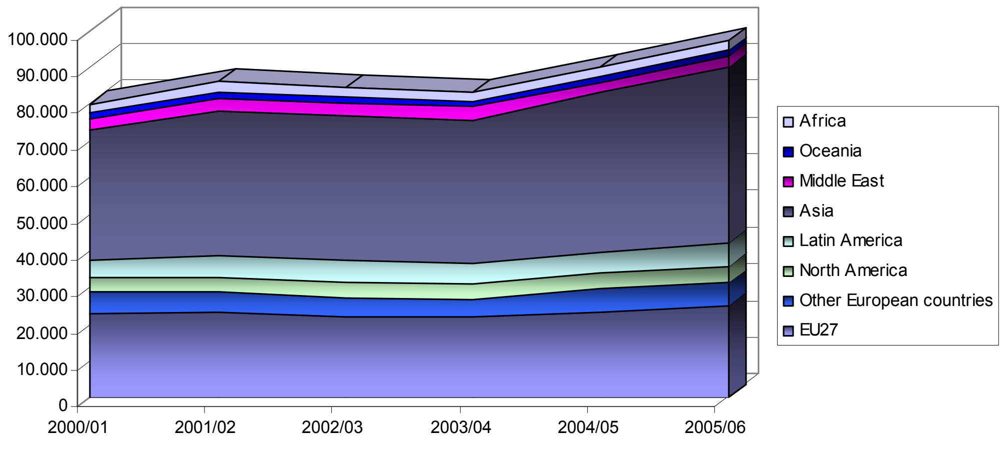
Recent evolution by broad regions of origin

In 2005-06, nearly 97,000 foreign scholars were working in the U.S. (Figure 48). The population of foreign scholars in the U.S. increased from 80,000 in 2000/01 to 86,000 in 2001/02, slightly decreased in 2002/03 and 2003/04, and then increased in 2004/05 (90,000) and 2005/06 (97,000).

Asia is the leading place of origin for foreign scholars in the U.S. with some 48,000 individuals in 2005/06 (55.6% of the total number of foreign scholars hosted in the U.S.). The number of Asians was 36,000 in 2000/01. It remained relatively stable from 2001/02 to 2003/04 at a level of about 39,000, and then increased. The share of Asians (among the total number of foreign scholars in the U.S.) increased as well from about 45% from 2000/01 to 2002/03, to 50.8% in 2004/05 and 55.6% in 2005/06.

In 2005-06, nearly 25,000 scholars hosted in the U.S. come from the EU-27. They account for about 29% of the total number of foreign scholars in the U.S. The number of scholars of EU origin was relatively stable at about 23,000 in 2000/01 and 2001/02. It decreased in 2002/03 at 21,700 and then increased slightly over the rest of the period to reach 24,900 in 2005/06. The share of scholars of EU origin decreased from 28.8% in 2000/01 to 25.2% n 2002/03 and then increased to reach 29% in 2005/06.

Figure 48. Number of international scholars in the U.S. by broad regions of origin (2001-2006)



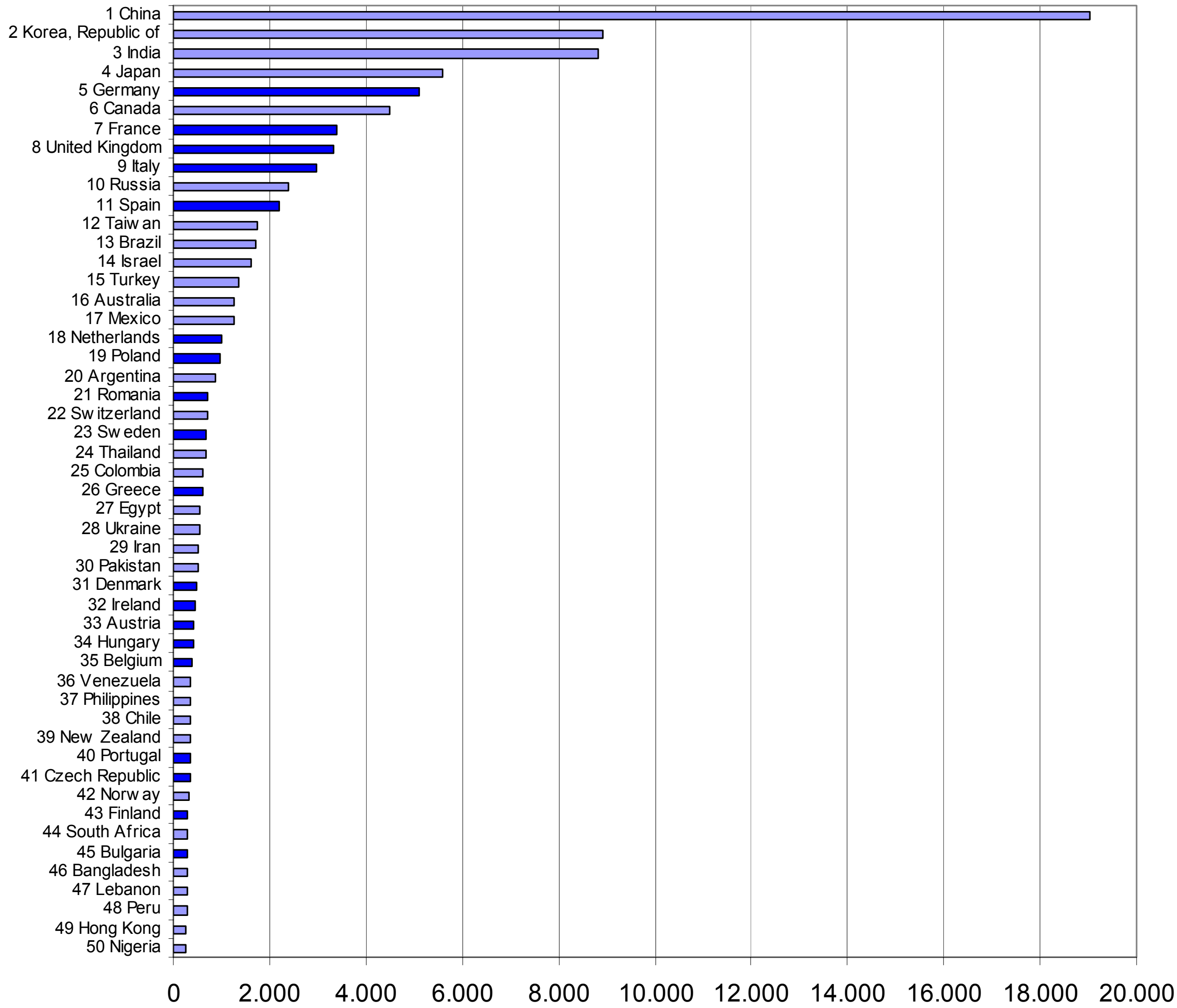
Source: IPTS with Open Doors data.

Top 50 countries of origin

The top country of origin of foreign scholars in the U.S. is China with some 19,000 individuals (Figure 49), which accounts for about one fifth of the total number of foreign scholars in the U.S. It is followed by Korea (8,900), India (8,800) and Japan (5,600). The first EU country, Germany, ranks fifth with 5,100 individuals. These top 5 countries account for nearly half of the total number of foreign scholars hosted in the U.S.

Among the top 10 countries of origin of foreign scholars in the U.S. in 2005-06[47], there are four EU countries (Germany 5th, France 7th, the UK 8th and Italy 9th).

Figure 49. Top 50 countries of origin of foreign scholars in the U.S. (2005-06)



Source: IPTS with Open Doors data.

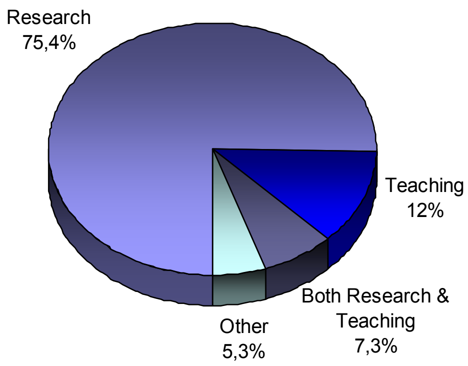
Main functions and main fields

In 2005/06, three quarters of foreign scholars in the U.S. have research as primary function, 12% teaching, 7% both research and teaching and 5% other functions (Figure 50). Over the last few years, these shares have remained relatively stable.

In 2005/06, 43% of foreign scholars hosted in the U.S. are in life and health sciences (23% in life and biological sciences and 20% in health), 12% in physical sciences and 11% in engineering (Figure 51). The other disciplines represent each less than 5%. Over the last few years, these proportions have been relatively stable.

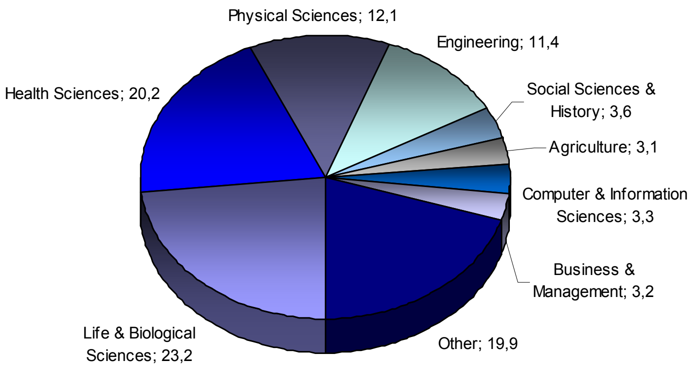
[47] These ten countries account for two thirds of the total number of foreign scholars.

Figure 50. Primary function of foreign scholars in the U.S. (2005/06)



Source: IPTS with Open Doors data.

Figure 51. Fields of specialisation of foreign scholars in the U.S. (2005/06)



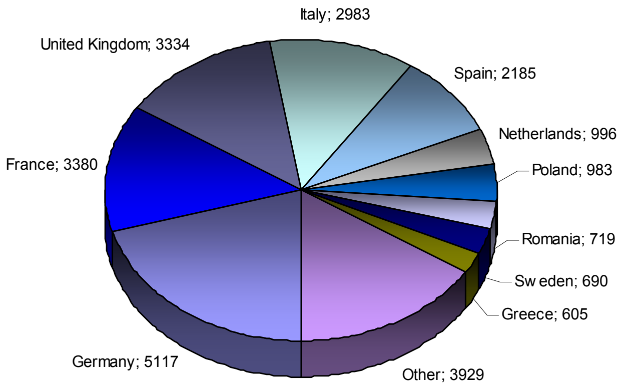
Source: IPTS with Open Doors data.

Scholars of EU origin in the U.S.

Leading countries of origin

In 2005-06, there were some 25,000 scholars of EU origin in the U.S. Germany ranked first with 5,100 scholars, France 2nd with 3,400 scholars, the UK 3rd with 3,300 scholars and Italy 4th with 3,000 scholars. The first ten EU countries account for 84% of the total number of scholars of EU origin in the U.S. (Figure 52).

Figure 52. Scholars of EU origin in the U.S., by country of origin (2005-06)

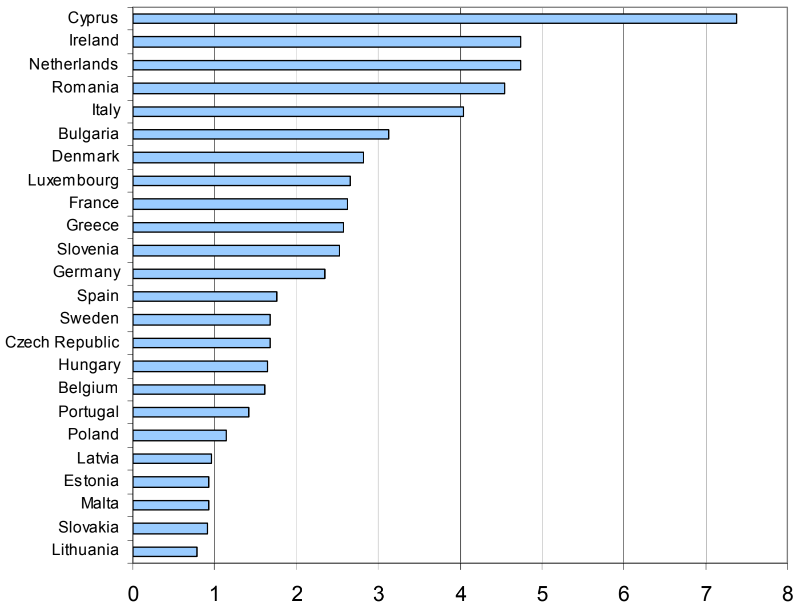


Source: IPTS with Open Doors.

A measure of the relative out mobility per country

Compared to the size of the local academic workforce – measured as the total number of researchers HC in the higher education and government sectors[48] – 2.3 scholars hold position in the U.S. per 100 working at home on average in the EU.[49] This ratio (Figure 53) is the highest for Cyprus (7.4), Ireland (4.7), the Netherlands (4.7), Romania (4.6) and Italy (4.0).

Figure 53. Ratio of the number of scholars in the U.S. to the number of researchers in the higher education and government sectors at home, per country (in %)



Source: IPTS. The number of scholars, year 2005-06, is from Open Doors. The number of researchers comes from Eurostat (2003, the last most complete year).

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[48] Unfortunately, a more appropriate indicator does not exist.

[49] Where data are available, i.e. for 24 EU countries. According to our calculations with Eurostat data, 901,000 researchers HC were working in the 24 EU countries in 2003 (data are not available for the UK, Austria and Finland), whereas there were some 21,000 scholars from these 24 EU countries in the U.S. in 2005-06.

Methodology

European doctorates in the U.S.

These calculations are based on data from the U.S. NSF/NIH/USED/NEH/USDA/NASA Survey of Earned Doctorates.[50] The Survey of Earned Doctorates is a federal agency survey sponsored by the National Science Foundation and five other federal agencies (National Institutes of Health, U.S. Department of Education, National Endowment for the Humanities, U.S. Department of Agriculture, and National Aeronautics and Space Administration). NORC at the University of Chicago is the current contractor selected by the National Science Foundation to conduct the SED.

The Survey of Earned Doctorates began in 1957–58 to collect data continuously on the number and characteristics of individuals receiving research doctoral degrees from all accredited U.S. institutions. The results of this annual survey are used to assess characteristics and trends in doctorate education and degrees. Today, the SED gathers information annually from about 45,000 new U.S. research doctorate graduates about their educational histories, funding sources, and post-doctoral plans.

European scholars in the U.S.

Data

OpenDoors presents comprehensive information on the international students in the United States and on U.S. students who sojourn abroad as part of their academic experience.

OpenDoors is a source for basic trends in:

- international students coming to study in US,
- international scholars for a short or long term visiting US,
- US students studying abroad.

The Institute of International Education Research department sends surveys to accredited institutions of higher education in the United States each year. The institutions report on foreign students who are enrolled at their colleges and universities. The data presented are obtained each year through a survey conducted the prior fall and spring semesters of campus officials at 2,700 accredited U.S. institutions, with a response rate of approximately 90%. Separate surveys were conducted for foreign scholars and U.S. study abroad.

OpenDoors uses the 2000 Carnegie classification, www.carnegiefoundation.org/classification

The classifications are organized around three key questions: What is taught? To whom? In what setting? It focuses on the instructional program (on the undergraduate program, and one on the graduate program) and the profile of enrolled students (the undergraduate and graduate/professional students).

Definitions

An international student is defined as an individual who is enrolled for courses at a higher education institution in the US on a temporary visa, and who is not an immigrant, a refugee or an illegal alien.

Foreign scholars are defined as non-immigrants, non-student academics (teachers and /or researchers, administrators) in the US. The survey was limited to doctoral degree-granting institutions where most J visa scholars were based. Institutions were asked about the primary function of the scholars (research, teaching, both, or other), geographic origin, field of specialization, sex and visa status.

Study abroad student is narrowly defined as only those students who received academic credit from a U.S. accredited institution of higher education after they returned from their study abroad experience.

[50] http://www.nsf.gov/statistics/srvydoctorates/

Estimates

Total international student enrolments, US study abroad totals, international scholar totals and the various percentages herein are calculated directly from campus-based survey responses.

Other student counts are determined by imputation, since not all campuses are able to provide detailed breakdowns by the various categories, such as place of origin, field of study, etc. Estimates of the number of students for each of the variables collected by the various surveys are imputed from the total number of students reported. For each imputation, base or raw counts are multiplied by a correction factor that reflects the ration of difference between the sum of categories being imputed and the total number of students reported by institutions. For this reason student totals may vary slightly within different tables. In addition, due to rounding, percentages do not always add up to 100%.

Estimates to account for non-reporting universities for International students and study abroad are based upon the prior year's number adjusted by the average percent change among institutions that reported in the prior and current academic years. For international scholars, estimates were based on numbers reported in the previous year with no additional adjustment.

WP 2: Indicators on researchers' mobility
Indicator 7: Number of researchers coming into Europe

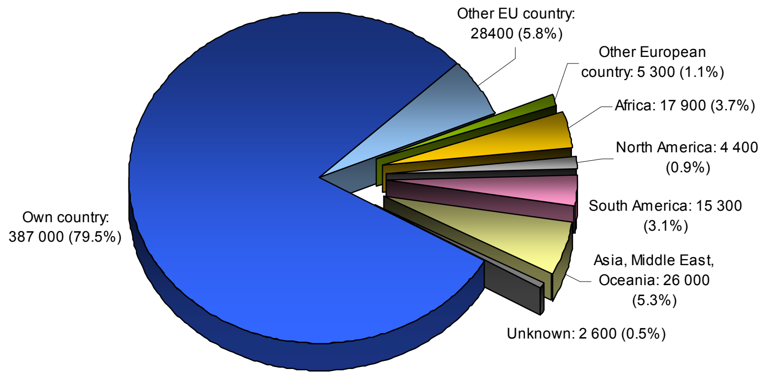
Main Findings

In 2005, in the European Union (based on 21 EU countries having reported data to Eurostat), of the 487,000 doctoral candidates, nearly 69,000 are citizens of third countries, accounting for 14.1%: 5.3% are from Asia, Middle East and Oceania, 3.7% from Africa, 3.1% from South and Central America, 1.1% from other European countries (outside the EU-27) and 0.9% from North America. The share of North American citizens is below 1% in all of the 21 reporting Member States except in the UK (3.7%).

China ranks top for the number of its citizens doctoral candidates in the EU, about 5,200, accounting for 7.5% of the total number of doctoral candidates from third countries in the EU. Mexico and Morocco ranks second and third. The U.S. ranks fourth, with 3,000 individuals, accounting for about 4.4% of doctoral candidates from third countries (or 0.62% of the total number of doctoral candidates) in the EU. 2,400 of these U.S. citizens are located in the UK.

The three major EU receiving countries (out of 21) of doctoral candidates from third countries are the UK, France and Spain, with respectively 24,100, 23,000 and 11,300. All three together received 58,400 doctoral candidates from third countries, accounting for 84.8% of the EU total from third countries. The following top countries each received less than 2,000 individuals. As percentage of the total number of doctoral candidates in the reporting country, France, the UK, Belgium and Spain received the highest share of doctoral candidates from third countries, respectively 27.9%, 26.3%, 18.7% and 14.8%. All the other countries are below 10%.

Number and percentage of doctoral candidates in the EU according to their country of citizenship (2005)



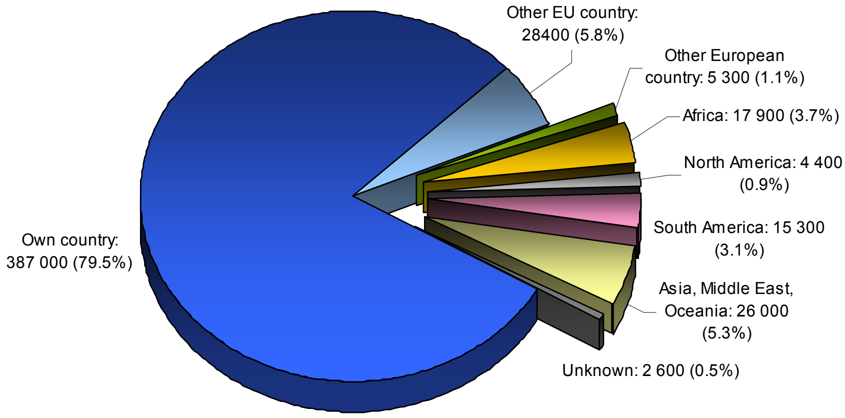
Source: IPTS with Eurostat data.

Origin of doctoral candidates in the EU

Origin of doctoral candidates in the EU

In 2005, in the European Union (based on 21 EU countries having reported data to Eurostat)[51], of the 487,000 doctoral candidates, nearly 69,000 are citizens of third countries, accounting for 14.1%[52] (Figure 54 and Table 11): 5.3% are from Asia, Middle East and Oceania, 3.7% from Africa, 3.1% from South and Central America, 1.1% from other European countries (outside the EU-27) and 0.9% from North America.[53]

Figure 54. Number and percentage of doctoral candidates in the EU according to their country of citizenship (2005)



Source: IPTS with Eurostat data. The category "unknown" has not been taken into account.

The top 30 countries of origin of doctoral candidates in the 21 EU countries having reported data are given in Figure 55. These 30 top citizenships account for 74% of doctoral candidates from third countries in the EU21.

Chinese doctoral candidates are the most numerous, about 5,200, accounting for 7.5% of the total number of doctoral candidates from third countries (or 1.1% of the total number of doctoral candidates) in the EU21. The three top receiving countries of Chinese doctoral candidates are the UK (3,200), France (1,000) and Sweden (360).

Mexico ranks second with some 3,800 doctoral candidates. Mexican doctoral candidates are mainly found in Spain (2,400), the UK (800) and France (500).

Morocco ranks third, with 3,200 doctoral candidates. 2,500 of them are located in France, 460 in Spain and 110 in Belgium.

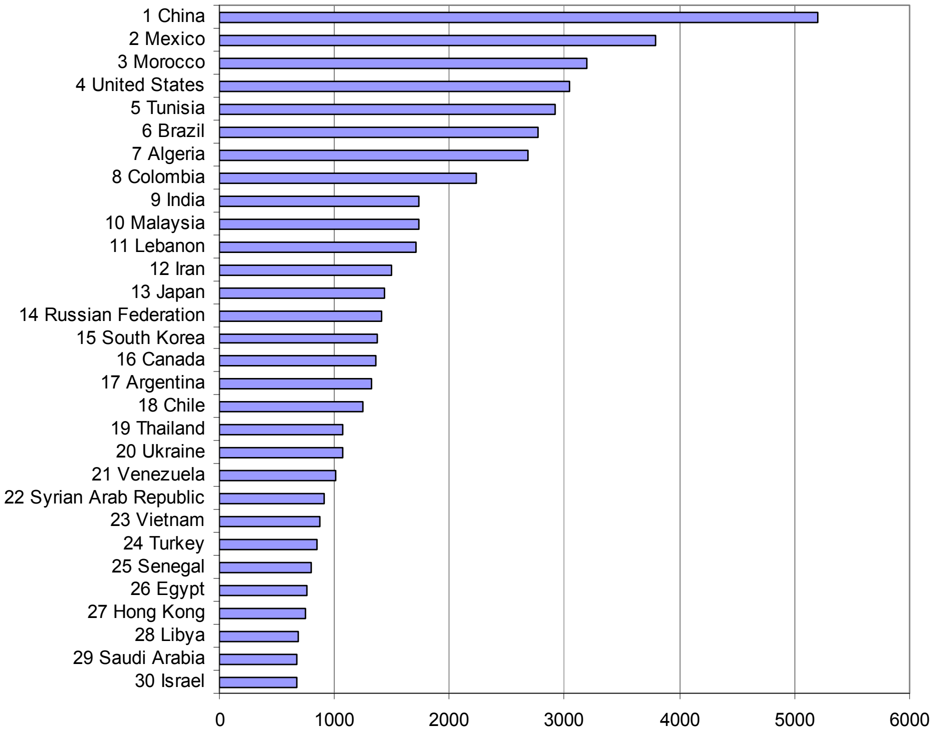
[51] The six missing countries are: Germany, Ireland, Greece, Latvia, Luxembourg and The Netherlands.

[52] Please see Fiche indicator No. 5 for results on the intra-EU mobility of doctoral candidates.

[53] 0.5% are of unknown citizenships.

The U.S. ranks fourth, with about 3,000 individuals, accounting for about 4.4% of doctoral candidates from third countries (or 0.62% of the total number of doctoral candidates) in the 21 Member States. The three top receiving countries of U.S. citizens are the UK (2,400), France (200) and Spain (200).

Figure 55. Top 30 countries of origin for foreign doctoral candidates from third countries (2005)



Source: IPTS with Eurostat data. Calculations based on 21 Member States reporting data.

EU Receiving countries

The three major receiving countries (among the 21 countries reporting data) of doctoral candidates from third countries, are the UK, France and Spain, with respectively 24,100, 23,000 and 11,300 (Figure 56). All three together received 58,400 doctoral candidates from third countries, accounting for 84.8% of the total of 68,900 received by the 21 countries, while the UK, France and Spain account for only 51.4% of the total number of doctoral candidates. The following top countries each received less than 2,000 doctoral candidates from third countries.

As percentage of the total number of doctoral candidates in the reporting country (Figure 57), France, the UK, Belgium and Spain received the highest share, respectively 27.9%, 26.3%, 18.7% and 14.8%. All the other countries are below 10%. The share of North American citizens is below 1% in all of the 21 Member States except in the UK, 3.7% (Cf. Table 11).

In the UK, 15,200 doctoral candidates are from Asia, Middle East or Oceania, the top region of origin, accounting for 16.5% of the total number of doctoral candidates in this country. 3,400 come from North America, accounting for 3.7% of the stock of doctoral candidates: 2,400 are from the U.S. (accounting for about 78% of the total number of doctoral candidates from this country in the 21 Member States reporting data) and 1,000 from Canada (of the 1,350 Canadians in the EU21)[54]. 2,700 doctoral candidates in the UK are from Africa, accounting for 3%, 1,900 are from South and Central America, accounting for 2%, and 1.1% from other European countries outside EU.

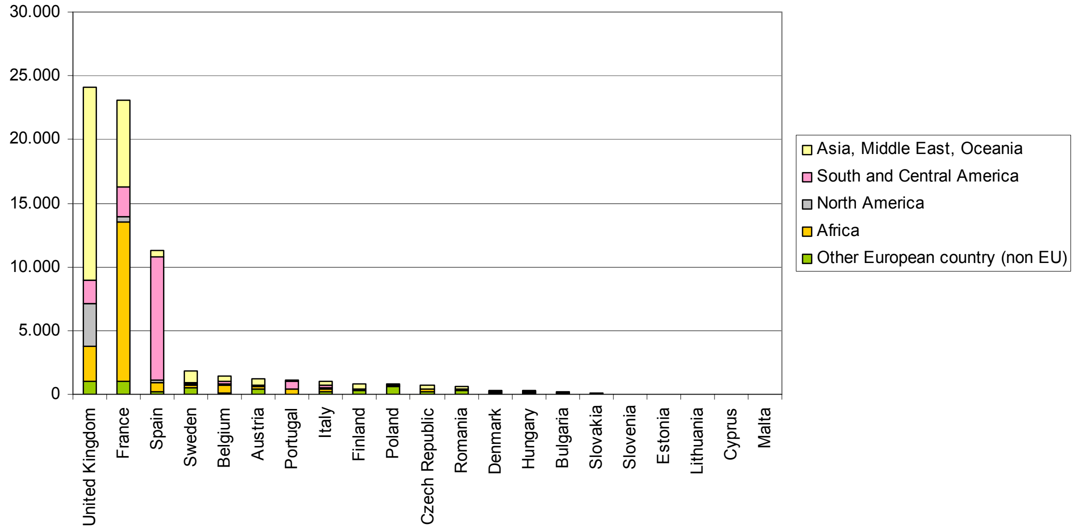
In France, the top region of origin of doctoral candidates is Africa: 12,500 doctoral candidates are from this region accounting for 15.1% of the total number of doctoral candidates. 6,800 doctoral candidates are from Asia, Middle East and Oceania, accounting for 8.2% of doctoral candidates. 2,350 (2.8%) are from South and Central America

[54] See as well Table 12.

and 1,000 (1.3%) from other European countries outside EU. North America accounts for 427 doctoral candidates (0.5%): 225 from Canada and 200 from the U.S.

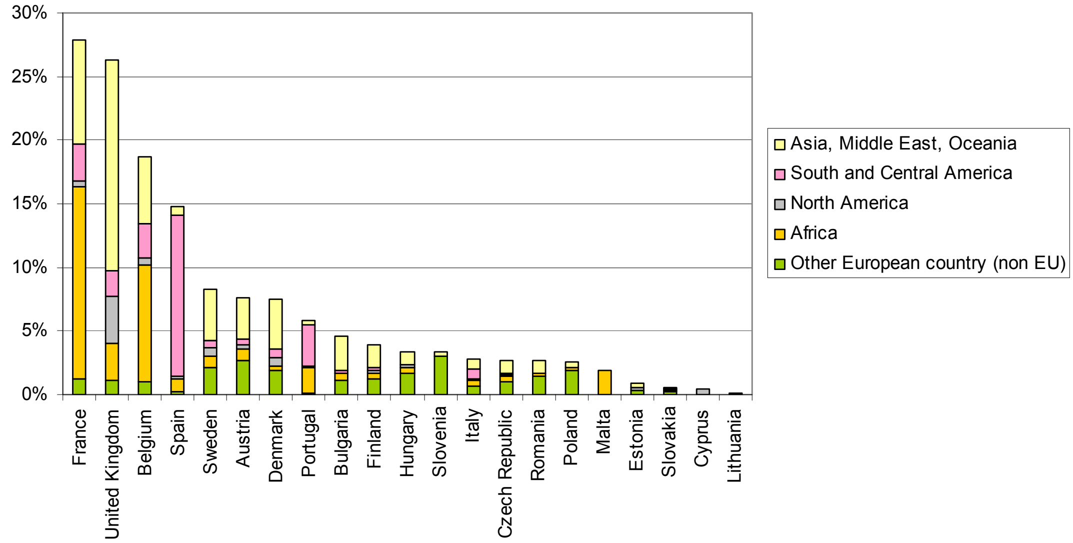
In Spain, the top region of origin is South and Central America, with 9,700 doctoral candidates, accounting for 12.7% of doctoral candidates in Spain. The second top region of origin is Africa, with 700 individuals (0.9%). Asia, Middle East and Oceania ranks third, accounting for 470 individuals (0.6%).

Figure 56. Number of doctoral candidates non-EU citizens by receiving Member State, according to citizenship (2005)



Source: IPTS based on Eurostat data.

Figure 57. Number of doctoral candidates non-EU citizens, according to citizenship, as percentage of the total number of doctoral candidates in receiving Member States (2005)



Source: IPTS based on Eurostat data.

Table 11. Origin of doctoral candidates in each of the 21 EU countries, per broad areas of origin (%)

	Nationals	EU27	Other Europe	Africa	North America	South and Central America	Asia, Middle East, Oceania	Unknown	TOTAL
Belgium	69,2%	12,1%	1,0%	9,2%	0,6%	2,7%	5,3%	0,1%	100,0%
Bulgaria	92,5%	2,9%	1,1%	0,6%	0,0%	0,3%	2,7%	0,0%	100,0%
Czech Republic	92,8%	3,9%	1,0%	0,5%	0,1%	0,2%	1,0%	0,6%	100,0%
Denmark	81,5%	6,4%	1,9%	0,3%	0,7%	0,6%	4,0%	4,6%	100,0%
Estonia	97,5%	1,6%	0,4%	0,0%	0,2%	0,0%	0,3%	0,0%	100,0%
Spain	81,1%	4,1%	0,3%	0,9%	0,3%	12,7%	0,6%	0,0%	100,0%
France	65,6%	6,6%	1,3%	15,1%	0,5%	2,8%	8,2%	0,0%	100,0%
Italy	95,7%	1,5%	0,6%	0,5%	0,1%	0,8%	0,8%	0,0%	100,0%
Cyprus	89,6%	10,0%	0,0%	0,0%	0,4%	0,0%	0,0%	0,0%	100,0%
Lithuania	99,7%	0,1%	0,0%	0,0%	0,0%	0,0%	0,1%	0,0%	100,0%
Hungary	91,4%	5,2%	1,7%	0,5%	0,2%	0,0%	1,0%	0,0%	100,0%
Malta	96,2%	1,9%	0,0%	1,9%	0,0%	0,0%	0,0%	0,0%	100,0%
Austria	79,8%	12,5%	2,7%	1,0%	0,2%	0,5%	3,3%	0,0%	100,0%
Poland	96,8%	0,6%	1,9%	0,2%	0,0%	0,0%	0,5%	0,0%	100,0%
Portugal	92,7%	1,4%	0,1%	2,0%	0,1%	3,2%	0,4%	0,0%	100,0%
Romania	96,0%	1,3%	1,4%	0,2%	0,1%	0,0%	1,0%	0,1%	100,0%
Slovenia	95,1%	1,6%	3,0%	0,0%	0,0%	0,0%	0,3%	0,0%	100,0%
Slovakia	99,2%	0,2%	0,2%	0,2%	0,0%	0,0%	0,2%	0,0%	100,0%
Finland	92,7%	3,3%	1,2%	0,4%	0,2%	0,2%	1,9%	0,0%	100,0%
Sweden	79,7%	6,9%	2,2%	0,9%	0,6%	0,6%	4,0%	5,1%	100,0%
United Kingdom	60,0%	12,5%	1,1%	3,0%	3,7%	2,0%	16,5%	1,2%	100,0%
TOTAL	**79,5%**	**5,8%**	**1,1%**	**3,7%**	**0,9%**	**3,1%**	**5,3%**	**0,5%**	**100,0%**

Source: IPTS with Eurostat data. How to read: 16.5% of doctoral candidates in the UK are from Asia, Middle East and Oceania.

Table 12. Destination of doctoral candidates from each broad region of origin, according to receiving country (%)

	Nationals	EU27	Other Europe	Africa	North America	South and Central America	Asia, Middle East, Oceania	Unknown	TOTAL
Belgium	1,3%	3,2%	1,3%	3,8%	1,0%	1,3%	1,5%	0,2%	**1,5%**
Bulgaria	1,2%	0,5%	1,0%	0,2%	0,0%	0,1%	0,5%	0,0%	**1,0%**
Czech Republic	6,0%	3,4%	4,5%	0,7%	0,5%	0,3%	0,9%	6,0%	**5,1%**
Denmark	0,9%	1,0%	1,6%	0,1%	0,7%	0,2%	0,7%	7,7%	**0,9%**
Estonia	0,5%	0,1%	0,1%	0,0%	0,1%	0,0%	0,0%	0,0%	**0,4%**
Spain	16,0%	11,1%	3,8%	4,0%	4,9%	63,1%	1,8%	0,0%	**15,6%**
France	14,0%	19,1%	19,7%	69,6%	9,7%	15,4%	26,0%	0,6%	**17,0%**
Italy	9,3%	2,0%	4,6%	1,1%	0,7%	1,8%	1,1%	0,0%	**7,7%**
Cyprus	0,1%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	**0,1%**
Lithuania	0,7%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	**0,6%**
Hungary	1,9%	1,5%	2,6%	0,2%	0,4%	0,0%	0,3%	0,0%	**1,6%**
Malta	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	**0,0%**
Austria	3,3%	7,0%	8,0%	0,8%	0,8%	0,5%	2,0%	0,3%	**3,2%**
Poland	8,3%	0,7%	11,9%	0,3%	0,2%	0,0%	0,6%	0,0%	**6,8%**
Portugal	4,4%	0,9%	0,5%	2,0%	0,4%	3,9%	0,3%	0,0%	**3,8%**
Romania	5,5%	1,0%	6,0%	0,3%	0,4%	0,0%	0,8%	0,5%	**4,6%**
Slovenia	0,2%	0,1%	0,5%	0,0%	0,0%	0,0%	0,0%	0,0%	**0,2%**
Slovakia	2,6%	0,1%	0,4%	0,1%	0,0%	0,0%	0,1%	0,0%	**2,1%**
Finland	5,2%	2,5%	5,0%	0,5%	1,2%	0,3%	1,6%	0,3%	**4,4%**
Sweden	4,6%	5,4%	9,1%	1,1%	3,0%	0,9%	3,4%	43,0%	**4,6%**
United Kingdom	14,2%	40,4%	19,4%	15,2%	76,1%	12,3%	58,3%	41,6%	**18,8%**
TOTAL	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	**100,0%**

Source: IPTS with Eurostat data. How to read: 69.6% of doctoral candidates in the 21 EU countries reporting data from Africa are located in France.

Researchers by citizenship according to Eurostat data

Little information is available in Eurostat data. Only seven countries have some information on the citizenship of researchers. With this limited information it is impossible to do any EU extrapolation as these 7 countries represent only 7% of the total number of researchers in the EU27.

Table 13. Researchers (HC) by citizenship in Government and Higher education sector (2004 and 2005)

	Total	Nationals	European Union (15 countries)	Citizens of European countries not in EU	Africa	North America	Central and South America	Asia	Other
Higher Education									
Czech Republic	16781	16252	456	:	8	35	7	21	2
Estonia	3844	3791	45	:	:	4	1	3	:
Latvia	4452	4452		:	:	:	:	:	:
Hungary	19044	18706	286	:	:	:	:	:	52
Malta	648	641		:	:	:	:	:	5
Romania	11218	11218		:	:	:	:	:	:
Slovakia	12414	12289	99	:	:	:	:	:	:
Government									
Czech Republic	8361	7948	371	:	6	8	3	25	0
Estonia	636	631		:	:	:	:	:	:
Latvia	622	622		:	:	:	:	:	:
Hungary	5921	5841	68	:	:	:	:	:	12
Malta	24	4		:	:	:	:	:	:
Romania	6586	6582		:	2	:	:	:	2
Slovakia	2706	2683	15	:	:	:	:	:	:

Source: Eurostat. 2005 data for Czech Republic, 2004 for the other countries. For Slovakia, the sum does not correspond exactly to the total given.

Methodology

Doctoral candidates in the EU

Data are from Eurostat. They have been extracted on November 29th, 2006.

Calculations are based on 21 countries only as data on the remaining countries are not available. These 21 countries are: Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Spain, France, Italy, Cyprus, Lithuania, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, United Kingdom. The following are missing: Germany, Ireland, Greece, Latvia, Luxembourg and The Netherlands.

Here, “mobile”/”international” students are defined on the basis of their country of citizenship. The data collected on mobile/international students has changed in the Unesco-OECD-Eurostat data collection in 2005.[55] However, the changes are not fully implemented yet and can not be used here as it is still in a pilot phase. This change has been motivated by the fact that the data collected previously to the 2005 UOE data collection are not appropriate for measuring all mobile/international students. Observations based on this criterion are affected by the differences in legislation governing the acquisition of nationality. Certain foreign students may thus have lived in their host countries for many years and completed some or all of their prior education in the same country, and, therefore, they may have never been “mobile”. Citizenship alone is not a sufficient variable to measure in-coming and out-going students. New concepts are introduced in the 2005 UOE data collection to better capture student mobility across countries: country of citizenship, country of permanent residence and country of prior education.

Data on foreign students refer here to citizenship. Students are non-citizens students if they do not have the citizenship of the country for which the data are collected. Normally citizenship corresponds to the nationality of the passport which the student holds or would hold. Countries unable to provide data or estimates for non-citizens on the basis of the passport held should fill other parts of the data collection on mobile/international students depending on the concept available in their data sources (country of permanent or usual residence, country of prior education).

Researchers by citizenship

Data are from Eurostat and were extracted on November 21st, 2007.

[55] Cf. Unesco-OECD-Eurostat, *UOE data collection on education systems, Manual: Concepts, definitions and classifications*, Volume1, (Montreal, Paris, Luxembourg: 2005).

WP 2: Indicators on researchers' mobility
Indicator 8: Circulation of researchers between public and private sector

As it was emphasized in the EC communication "A mobility strategy for the European Research Area"[56], "Mobility, a well-known and effective way of training skilled workers and disseminating knowledge, is a core element in research development, which has not yet been fully exploited in Europe. […] [Mobility] permits the creation and operation of multi-national teams and networks of researchers, which enhance Europe's competitiveness and prospective exploitation of results. Increased physical mobility of researchers, whether transnational (movement between countries) interregional or intersectorial (movement between academia and industry is therefore essential in order to take a maximum advantage of available resources."

Unfortunately, there is no systematic collection of information on the flows of researchers from public/academic sector to the private sector (and respectively from the private to the public/academic sector). The stocks of researchers in the different sectors are compiled in Eurostat data but flows cannot be derived as such from the stocks. In addition, very few specific studies or surveys address this question, and their results are not directly comparable and can not give consistent information across Europe.

Crespi, Geuna and Nesta (2005) summed up the situation in writing: "Mainly qualitative case based evidence has been gathered on mobility between academia and business; the only paper, to our knowledge, that develops theoretical and econometric analyses of the mobility of researchers between universities and firms is Zucker et al.'s (2002) study on the [U.S.] biotechnology industry. However, little is known about academics' mobility in the European context".

The pilot ad-hoc surveys currently undertaken are likely to provide additional information.

Some qualitative results from the UK

Morano-Foadi (2005), based on the MOBISC project, expresses qualitative judgements but it is difficult to judge to what extent they are founded. She wrote that:

- "In general, the phenomenon of moving out from the academic sector is not perceived by scientists as a positive one, even if it is a move toward industrial research. In some part this may be because respondents interviewed within the MOBISC project have predominately been academic researchers […]
- Most of the researchers who leave academia to work for an industry are frustrated, and sometimes the only incentives are better salaries and working conditions. Retention in industry is based on money and stability.
- As an empirical study conducted in the United Kingdom reported, external mobility and flexibility could have negative consequences to a career in research. (Tomlinson and Miles, 1999). On the contrary, internal mobility and scientific partnership and collaboration, also at an interdisciplinary level, present positive elements. Once a decision to move from academia has been made, it is really difficult to go back, unless an academic profile in terms of research publications is maintained."

Preliminary results from Germany

The proceedings of a workshop (ProTon Europe Expert Workshop 2006) mentioned the preliminary results from a Fraunhofer study on "Brain exchange-brain circulation: intersectoral mobility of scientists":

- The degree of intersectoral mobility is rather low in Germany.
- While the study focuses on the scientific field of biomedicine / biotechnology, one might conclude that mobility is probably not much higher in other sectors in Germany, since the field biomedicine/biotechnology had been selected for its reputedly high degree of dynamic and interaction across sectors.

[56] Communication from the Commission to the Council and the European Parliament, COM(2001) 331 final, 20.06.2001.

- One main argument for university researchers to remain within academia is that intersectoral mobility does not seem to be beneficial to a university career.
- Scientists from non-university research institutes appear a little more likely to switch to the industrial sector than university researchers, maybe because they are more familiar with both “worlds”.
- Main barriers in Germany seem to be career incentives and inflexible structures.
- It was discussed if these are specific German problems. This is difficult to judge since also in other European countries there is few data available on mobility of individual researchers between the sectors. And the fact that science and education systems are not the same across Europe, makes it sometimes difficult to compare results from different countries.

References

Communication from the Commission to the Council and the European Parliament, “A mobility strategy for the European Research Area”, COM(2001) 331 final, 20.06.2001.

Crespi A., Geuna A. and Nesta L. (2006), “Labour Mobility of Academic Inventors: Career Decision and Knowledge Transfer”, EUI Working Paper RSCAS 2006/06.

Morano-Foadi Sonia (2005), « Scientific Mobility, Career Progression, and Excellence in the European Research Area », International Migration 43(5).

ProTon Europe Expert Workshop “Pathways between academia and industry: benefits and barieers of intersectoral mobility” (Brussels, October 2006).

WP 3: Qualitative indicators on researchers' motivation and satisfaction
Indicator 9 & 10: Motivations for R&D careers and satisfaction of researchers with their jobs and careers

To our knowledge, these qualitative issues have not been addressed for researchers at the European level. Therefore, collection of new data is needed. Individual data have to be collected to be able to construct these qualitative indicators as the job holders themselves have to answer to a questionnaire specifically designed to that purpose. As the collection of such data is very costly in time and money, it was chosen to carry out a survey on a specific population of researchers in a limited number of EU countries. The methodology of this survey is going to be presented here.

A pilot ad-hoc survey

A survey was carried out on experienced life scientists in the public and private sectors in 9 EU countries and Norway.[57] The goal of the survey is to develop and test a new methodology to collect information on personal and educational characteristics, career characteristics and qualitative characteristics.

The field of life sciences was chosen as a follow up of the NetReAct survey but the target population was not the doctoral candidates and postdoctorates as it was necessary to cover a broader population of researchers.

A sample frame of life scientists in nine EU countries (Czech Republic, France, Germany, Hungary, Italy, Portugal, Spain, Sweden and the UK) and Norway was compiled based on experienced life scientists listed in citation and patent databases. Experience was determined by a set of parameters developed for the citation and patent information sources and according to criteria such as number of citations and number of patents according to national representativeness. A survey instrument was created and piloted and carried out online.

The life sciences included are based on the classification of ISCED '97. In order to locate the individuals, the citation and patent databases were used to provide as much information as possible (existing e-mail references; research affiliations) to obtain the email address of the researchers. An electronic survey designed for this study was sent to individual researchers. The sample frames were to be produced from two key databases for obtaining contact names for 'experienced' researchers in the life sciences as measured by number of publications (Thomson citation database) and by number of patents (European patent database).

Methodology

The methodology was developed based on the need to collect new and timely information on researchers in the life sciences in 10 countries and in particular on senior researchers in consideration of providing a link to previous studies (e.g. NetReAct).

The survey questionnaire

A questionnaire-based survey was designed and conducted as an e-survey with direct mailout to individual researchers. The questionnaire was designed to collect information on researchers in the public and private sectors.

The questionnaire addressed three main areas of interest including:

- Personal and education statistics: gender, age, civil status, country of birth, country of citizenship, education;

[57] Final report work package 3 for the specific contract: Collection and analysis of existing data on researchers careers and Implementation of new data collection activities, Framework Service Contract Nr -150176-2005-F1SC-BE, Submitted to the IPTS by the ERAWATCH NETWORK ASBL, Prepared by: MERIT with CNR, GEM-CITE, IKU, SPRU, ZEW, 07 September 2007.

- Career characteristics: country of current employment, sector of current employment, time use in research and other activities, sector mobility, factors that influenced the mobility;
- Qualitative characteristics: rating of job conditions and expectations, rating of adequacy of degree training, rating of suggestions on how to increase the attractiveness of a career in science.

There were a total of eighteen core questions but in the areas of career and qualitative characteristics, there were a series of questions attached depending on the answer. The questionnaire was presented in English only. This approach was taken with the bias towards English in scientific literature and international research and given the time and resource constraints, it was agreed that one language (English) would not limit the outcome of the pilot survey.

Universe and sample

Defining the life sciences

A list of fields of life sciences was developed using guidelines of ISCED '97 and the Eurostat's Fields of Education and Training Manual (December 1999). This meant including Group 422 environmental science. The list of disciplines includes:

- Group 421 Biology and biochemistry: Biochemistry, Biology, Biometrics, Biphysics, Botany, Entomology, Genetics, Limnology, Microbiology, Molecular biology, Ornithology, Parasitology, Pharmacology, Toxicology, Virology, Zoology;
- Group 422 Environmental science: Ecology, Environmental science.

Identification of the researchers' email addresses

The challenge was to build a representative database of valid e-mail addresses of experienced researchers in the life sciences to invite them to participate in an e-survey. Two key sources for information on experienced researchers and of particular relevance to researchers in life sciences are records of their research activities as measured by outputs with citations and patents. Researchers in the public and private sectors can be identified from citation and patent data analysis. The databases of ISI-Thomson (citations) and EPO (patents) were therefore the starting points for research for e-mail addresses.

Citations database. Names of academic researchers were drawn from top searches in the Web of Science database. The publication data RANGE = 1/1/2004 to present which brought the database to three full years plus approximately the first two months of 2007. The timeliness of the database enhanced the possibility of identifying and locating researchers' details to obtain an e-mail address for the survey invitation. The life sciences were categorized according to Web of Science Field of Science Codes. A search was carried out for each of the ten targeted countries by searching for the country name in the affiliation field within the database.

Patents database. A stepwise approach was followed. The first step was to identify the relevant technology domains that pertain to biomedical research. This was done using the Science-Technology concordance table developed by Incentim-CWTS. This S-T concordance table relates fields of science to technology domains by using non patent references: a more outspoken relationship between a scientific field and a technology domain is assumed if relatively more citations within a technology domain refer to the scientific field. Only patents applied for after 2000 have been considered to ensure high levels of accuracy and relevancy when contacting identified inventors within latter steps of the process. After selecting all relevant patents within these technology domains, the ten countries under study were selected (based on nationality of applicants).

Preparation of data

With the citation data, the first step was to isolate those individuals who are most likely from local institutions in the target country (removing collaborators from foreign institutions, visiting professors, etc.). After this filtering process reduced the pool of authors, the set was further reduced by requiring that each author have at least a specified number of papers published during the time period covered by the set. Requiring a minimum number of papers increased the chances that researcher would be either mid-career or above.

Like the citation data, the patent data also needed preparation. The first step was to remove duplicate names that appeared in both patents and citations. This step reduced the effort required to contact survey participants by lowering the possibility that the same individual would be contacted twice. Prior to name matching, the inventor names required cleaning using a fuzzy matching algorithm with cross-field matching to correct for name variations inherent in the data. After de-duplication, applying a filter that required that an inventor have a specified number of patents within a specified time frame further reduced the data set. As with citations, this cutting process increased the likelihood that researcher would be at least mid-career or above.

Identification of the individuals and emails

A mail-out list of e-mail addresses was assembled based on starting points/references provided by the citations and patents files and then researched on the Internet. In some cases, a number of e-mail addresses were provided and research was carried out to determine the most likely current e-mail address. A second scenario was the provision of a name with affiliation but no e-mail address provided. In this case, the available information (e.g. name + affiliation reference) was used to identify the researcher through web searches. The results of the Internet searches were collected and a database of email addresses (by country) was assembled.