Workpackage 1

Policy Scenarios: Supply of scientists and engineers

Deliverable 1.4a

2008

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C1S8-CT-2004-502529 KEI

The project is supported by European Commission by funding from the Sixth Framework Programme for Research.

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POLICY SCENARIOS
SUPPLY OF SCIENTISTS AND ENGINEERS

Executive Summary

A priority goal of the European Union (EU) is to encourage and promote the transition of the European economies to dynamic knowledge-based economies (KBE). A key aspect of a KBE is its stock of highly educated human resources, most importantly, its researchers and scientists and engineers.

The EU goal of increasing the average intensity of research and development from approximately 2% of GDP to 3% of GDP would require a large increase in the stock of European researchers, including science graduates with Bachelors or Masters degrees and PhDs and engineers. This scenario report examines how a large increase in the supply of researchers could be attained in the next ten years or so , and investigates the factors that influence the supply of researchers. The purpose of the exercise is to identify the relevant and most important indicators in terms of increasing this supply (see Table 1). These indicators can then assist the policy community in tracking progress towards the goal of increasing the supply of researchers[1]. Where relevant, simulations are used to estimate trends in supply and to help identify the key factors that need to be tracked over time. The authors also try to look for 'decision points' where a policy intervention could promote a substantial increase in the supply of scientists and engineers , and' bottlenecks' which could interfere with a process to reach the targets. Finally, the authors forecast possible outcomes, if certain actions, trends or other developments take place, or alternatively, if trends continue unchanged.

In 2004, there were about 1.8 million researchers and 9.5 million S&Es in the EU-25. According to estimates, the number of additional researchers required to reach the 3% R&D intensity goal is somewhere between 700,000 and 1,400,000[2]. This number can be translated into a requirement of an additional 3.5 to 10 million scientists and engineers, as compared to the current stock[3]. These figures are so high because only a small proportion of S&Es actually work in research. The current average 'researcher intensity' (ratio of researchers to S&Es) in the EU is 19%. However, the report also looks further into this ratio, as the countries performing at a higher R&D intensity level (at 2 to 4%)

[1] In addition to the nine key indicators, seven other indicators (all 16 are listed in Annex B, Table B-2) have been used in the simulations contained in this report, and in total 35 indicators have been included in the scenario (listed in Annex B, Table B-1). Additionally, a number of missing or underdeveloped indicators are listed in Table 9.1 in Section 9.

[2] The estimate of 700,000 has been made by the European Commission (see EC, 2003a), the higher estimate of 1,40,000 is made in this report.

[3] The estimate of 10 million comes from projections in this report. The size of the range is due to different methods of estimating future stocks.

tend to have more researchers among S&Es (at around 25%). The higher this intensity, the fewer S&Es are actually needed to reach the required number of researchers.

In conclusion, the number of S&Es would have increase to somewhere between 13 and 20 million to reach the desired R&D intensity. This range is large, but the report concentrates on reaching the more challenging end of the range.

Such numbers of additional S&Es are not likely to be obtainable under current trends and by EU domestic means alone as the estimates in Section 3 indicate, except for in cases where the reference is to the lowest estimates. Baseline simulations in Section 3 are conducted to investigate how EU member states could meet their targets of additional S&Es if current trends of new graduates and current retirement patterns (the main supply and loss channels) continued in the next ten years or so. A straightforward estimate, based on current trends, is that by 2015 there would be around 12 million S&Es in the EU-25[4] (i.e. 2.5 million more than currently). Therefore, the most modest target would be (nearly) attainable, but for the other targets there is likely to be a sizeable gap.

However, at a more detailed level, the shortages are not equally distributed. The report groups the 25 EU member states into five clusters to identify peer countries in the EU and to see differences between the clusters[5]. Based on the baseline simulations, countries belonging to Cluster 2 (Austria, Belgium, France, Germany, Ireland and Luxembourg) and Cluster 1 (Denmark, Finland, Netherlands, Sweden and the UK) should not have too much trouble. Even when using the highest estimate of additional S&Es, these countries should meet 85 to 95% of the requirements. Whereas, countries belonging to Cluster 3 (Estonia, Italy, Slovenia and Spain) and Cluster 4 (Czech Republic, Greece, Hungary, Lithuania, Poland, Portugal, Slovakia, and Latvia) would be, on the average, able to meet only 50% or less of their requirements. Malta and Cyprus (Cluster 5) come out at the bottom of this exercise. Overall, the worst performers in this case are Italy, Spain and Poland, all of which have the largest potential for future shortages of S&Es.

This scenario has some important limitations. Firstly, the report assumes that there is enough demand for researchers and therefore does not, for example, evaluate the likelihood of the business and public sectors increasing their R&D expenditures sufficiently to reach the 3% R&D intensity target. Secondly, this report does not look at the quality of S&Es. It may be, for example, that European researchers working in the US are on the average 'better' researchers than their EU counterparts[6], or that unemployed S&Es attracted back to work are not as 'good' as freshly trained S&Es. However, for the purposes of this scenario, all researchers and all S&Es are considered equal in terms of quality.

[4] This report only looks at the EU as it was up to the beginning of 2007, i.e. the two newest members Bulgaria and Romania are not included.

[5] The clustering is based on a wide range of areas, including economy, digital / ICT infrastructure, society, government and environment.

[6] See Saint-Paul (2004) for his concerns about 'European stars' – top 5% of PhDs - working in the US.

Possible influences on the flows and stocks of scientists and engineers include not only each EU member state's domestic policies, population trends, industry structure, employment rates etc., but also conditions within countries outside the EU, such as China, India or the United States. Many of these influences are not included in the current scenario so as to avoid too much complexity; however, the international mobility of both students and S&E personnel is included. Inflows of students and S&Es are an essential part of the picture, and must be considered to enable the EU to better reach its R&D targets in the near future.

Figure 1.1 in Section 1 shows the complexity of the situation by identifying factors influencing the supply of S&E personnel. In Sections 4 to 7, four separate 'modules' are considered within this larger picture: the domestic higher education system in the EU, international student mobility, the main supply channels to the stock of European S&Es and the main loss channels that decrease the number of S&Es in the EU. Within each module, the report first focuses on explaining the framework of the module and examining some of the related literature, available data and indicators. Subsequently, simple simulation exercises are performed with data from the 25 EU member states. In these simulations, the data are manipulated according to a number of fairly realistic assumptions of growth or reduction.

Section 8 brings all four modules together again and looks at the big picture. Figure 8.1 shows various quantified influences on the supply of S&Es on the way to reaching the goals of additional S&Es. After the manipulations performed in Sections 4 to 7, the stock of scientists and engineers in the EU could be expected to reach about 18 million by 2015. All the changes combined could therefore create a net impact of approximately 5.5 million extra S&Es by 2015. Such an increase would cover most of the estimated goals for S&Es in this report – except for the highest estimate of 20 million. Consequently, the overall goal of 3% R&D intensity could also be (at least nearly) reached in this manner, if the identified changes could be adequately encouraged.

One of the main goals of this report is to identify valuable indicators for tracking the success of the EU in reaching its R&D intensity goals. The most important indicators and the impacts of reasonable change in these indicators are shown in Table 1. It can be seen from this table that nearly 90% of the total impact in this exercise comes from the reasonable manipulation of just five indicators:

- Increasing average retirement age in the EU
- Increasing proportion of students choosing S&E studies
- Increasing proportion of S&E graduates obtaining S&E employment
- Bringing in more scientists and engineers from countries like China and India (or even the US)
- Increasing proportion of women studying S&E fields.

More than 50% of the impact comes from the top two indicators listed above. On the other hand, individual impacts from factors, including trying to retain non-EU students working in the EU after graduation, reducing unemployment in S&E fields, trying to retain EU scientists and engineers in the EU (as opposed to letting them migrate, for example, to the US) and getting more Chinese and Indian students to choose the EU for their studies, all remain small at somewhere between 1 and 4%.

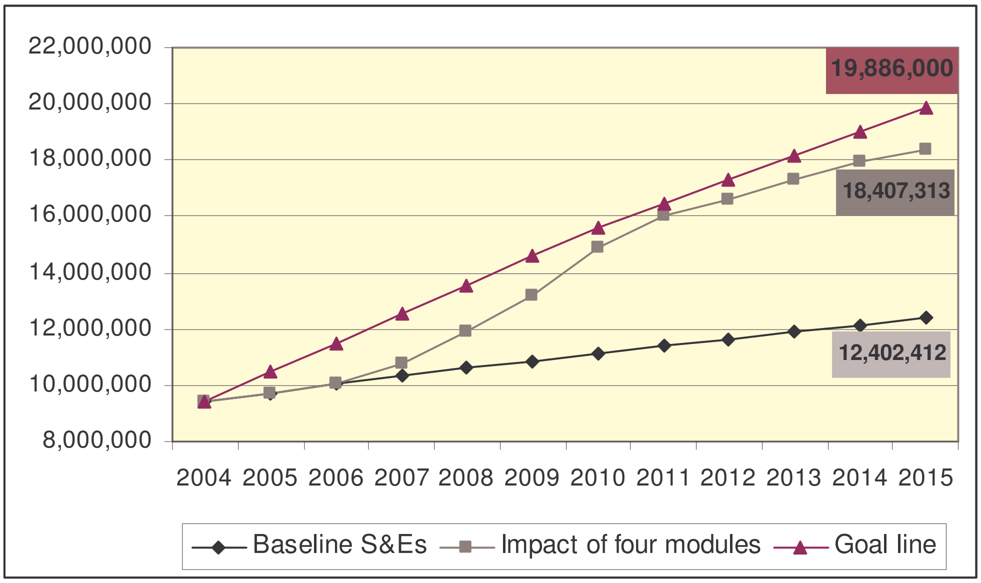
Table 1. Summary table of key indicators and the impacts of reasonable change.

Module	Indicator	Change	Extra S&E stocks by 2015 after changes implemented from 2007	Percentage contribution to total number of additional S&Es
Loss of S&Es	Average age of retirement	Increase average age of retirement in the EU to 65 years	2,000,000	36.0%
Domestic and Foreign Students	Students in S&E fields	Increase proportion of students choosing S&E fields instead of other fields by 2% per year	1,165,000	21.0%
Supply of S&Es	Employed S&E graduates	Increase proportion of graduates that opt to work in S&E fields from 65% to 75%	850,000	15.3%
Supply of S&Es	Engineers produced in the US, China and India	Bring 10% of this pool of engineers to work within EU borders	540,000	9.7%
Domestic and Foreign Students	Female enrolments in S&E studies	Increase participation of women studying S&E fields by 10% per year, by shifting from other fields	385,000	6.9%
Supply of S&Es	Foreign S&E graduates	Retain 50% of foreign EU S&E graduates (coming from outside the EU) and keep them working within EU borders	226,000	4.1%
Loss of S&Es	Unemployment of S&Es	Reduce unemployment rate in S&E fields by 10% per year as from 2007	185,000	3.3%
Loss of S&Es	Number of specialized temporary workers in the US	Retain all those S&Es who would otherwise migrate to work in the US	141,000	2.5%
Domestic and Foreign Students	Chinese and Indian tertiary students studying in the US	Increase participation of Chinese and Indian students at EU universities, by shifting 25% of the pool of potential S&E students from the United States into the EU.	63,000	1.1%
Total Impact			**5,555,000**	**100%**

The key indicators in Table 1 can also be considered in terms of two types of factors: bottlenecks – critical areas, which Europe or at least certain countries with the EU, have problems with - and policy decision points – currently debated or otherwise significant policy questions. These factors are closely related, as some of the bottlenecks (e.g. scientists and engineers retiring too early, science subjects not being popular enough at school, Chinese and Indian S&E students going to the US instead of the EU, or lack of women in S&E) can create opportunities for policy intervention.

Figure 1 shows the differences between the 'no change' trend line for S&Es, the highest estimate of required S&Es by 2015 , and the stocks of S&Es simulated in this report.

Figure 1. Stocks of S&Es – Baseline (no change) and simulated numbers compared with goals for 2015.



In addition to the identified key indicators and the overall indicators used in the report (listed in Annex B, Tables B-1 and B-2), certain other key indicators could be considered, but in many cases greater detail is required than what has been available, at least until recently. Also, a significant issue is associated with having enough consistency between countries, both in terms of what data are collected and how indicators are defined, these points being particularly important for mobility data. The conclusions in Section 9 discuss the most important missing or underdeveloped indicators.

1.0 INTRODUCTION

The European Union (EU) goal to increase the average research and development (R&D) intensity from approximately 2% of GDP[7] to 3% of GDP by 2010[8] would require a large increase in the stock of European researchers, including science graduates with Bachelors or Masters degrees and PhDs, engineers, and technicians[9]. The purpose of this scenario (see Box 1 for more on scenarios) is to identify the relevant and most important indicators in terms of increasing the supply of such human resources. These indicators can then assist the policy community in tracking progress towards the goal of increasing the supply of researchers in particular. Where relevant, simulations are used to estimate trends in and impacts on the supply of such personnel and to identify key factors that need to be tracked over time. These simulations examine how a large increase in the supply of researchers could be attained in the next ten years or so and to investigate the factors that influence supply.

In addition to the key indicators identified in this scenario, a total of 35 indicators have been used in this scenario, 16 of which have been included in the simulations (see Annex B, Tables B-1 and B-2 for a list of these indicators). Additionally, a number of 'missing' or underdeveloped indicators are included in Table 9.1.

Previous research by the European Commission (2003b) has identified factors that influence the development of careers in R&D, namely training, recruitment methods, employment conditions, evaluation mechanisms and career advancement. The EU has also made recommendations to improve the number of researchers in the European Union[10] as part of strategy to meet the objective of increasing European research spending to 3% of GDP in the EU. According to estimates from the European

Box 1. What is a scenario?

A scenario is usually a 'thought experiment' conducted to investigate how the future might look if certain events did or did not take place. Such a scenario does not necessarily include any forecasted or estimated data.

However, in addition to involving 'what if' ideas, a scenario can include projections or simple simulations based on numerical data. Although these simulations must usually be based on a number of broad assumptions and simplifications and cannot account for unforeseen events, they do provide an idea of trends and possible outcomes. For example, how well would the European Union do in the future in terms of its stock of researchers, if it *didn't* succeed in attracting more foreign researchers, or, if it *did* manage to get more women into science? Such scenarios enable us to look at the effect of changes in one or more variables, and also importantly, to find out which variables, or factors, have the most effect on the outcome, and which are less relevant.

[7] R&D investment was 1.93% of GDP in 2003, calculated for EU-25. If current investment trends would continue, R&D investment would reach 2.2% by 2010 (EC, 2005a).
[8] In this report, we set the goal for 2015, which is more manageable.
[9] Council of the EU (2005) notes that 'a determined effort must be made to increase the number and quality of researchers active in Europe, in particular by attracting more students into scientific, technical and engineering disciplines' (p 15).
[10] Council of the EU (2003): Resolution on the profession and the careers of researchers in the EU.

Commission (see EC, 2003a), this would require a net increase of approximately 700,000 additional researchers to the current stock, which also requires another 500,000 to replace those researchers that have been lost to retirement or from job changes. The highest estimate made in this report suggests that an additional 1,400,000 researchers might be required, providing a safety margin for possible errors in the estimations.

Estimating labour requirements for R&D is difficult, since there is a lack of data on the educational qualifications of researchers in many EU countries and on the share of science and engineering (S&E) graduates that go into S&E occupations (see Box 2 for definitions). According to Eurostat, there were 1.8 million researchers in the EU-25 in 2004 and 9.5 million employees in science and engineering occupations. If we make the assumption that all researchers have science and engineering occupations, then about 19% of these occupations were in research in the EU in 2004 (1.8/9.5*100). Based on the estimate that only 19% of S&E occupations are currently in research, production of 700,000 more researchers would require about 3.5 million more S&E employees. Using a rough estimate that about 65% of S&E graduates end up in S&E employment[11], this would mean that about 5.5 million additional S&E graduates would be required to fill 700,000 research positions if the additional supply were to be met only by increased higher education output. An estimate of 1.4 additional researchers would require about 9 million additional S&E graduates.[12]

These numbers of additional working S&Es or S&E graduates are not likely obtainable under current trends alone (see the discussion and baseline scenarios in Section 3). Consequently, in this scenario with respect to the supply of scientists and engineers, we investigate the various pathways and linkages that influence the stock of scientists and engineers in the European Union, whether the requirements could be met from within the EU alone or, whether the EU needs to look outside its borders. Rather than assess the likelihood of reaching the goal by 2010 or even by 2015, we try to identify a limited set of key indicators for tracking progress towards the goal, whenever it might be reached.

An important limitation of these scenarios is that we do not evaluate the likelihood of the business and public sectors increasing their R&D expenditures sufficiently to reach the 3% R&D target, which is the primary driver for an increase in demand for new researchers. We assume they will work towards that goal, i.e. that there will be sufficient demand for researchers. The scenarios concentrate on evaluation of supply conditions.

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[11] There is very little detailed data available on the careers of graduates. However, based on the fairly large European CHEERS graduate survey, Teichler (2002) notes that 'more than two-thirds of graduates from most fields of study are concentrated on one or two economic sectors which can be viewed as most closely linked to the respective fields' four years after graduation.

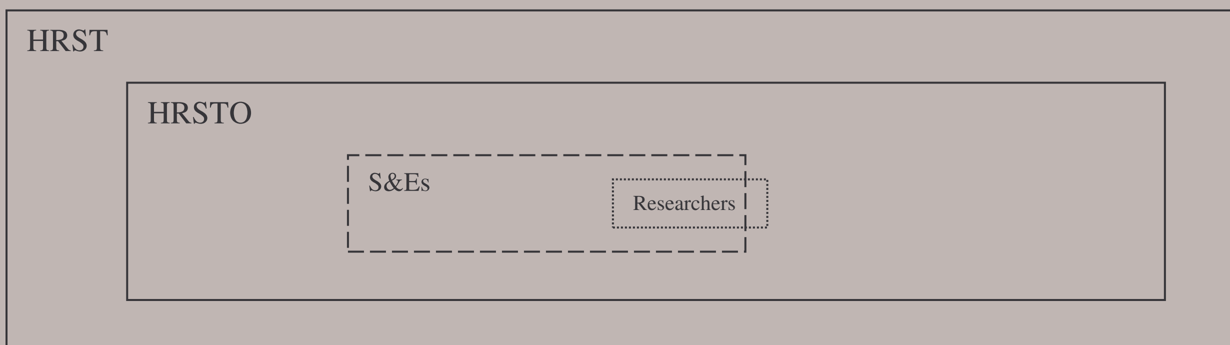
[12] Although the EU-25 average for the researcher/S&E ratio is around 19%, there is a lot of variation between countries, from around 7% to as much as 43%. These 'targets' will be further discussed in Section 3, where also a target of 25% 'research intensity' among S&Es is discussed. Currently, the countries with an R&D intensity between 2 and 4 % have about 25% of researchers in their stocks of S&Es, on average.

Box 2. Scientists and engineers vs. human resources in science and technology

The concepts of S&E and HRST can be somewhat confusing, as the 'science' in 'HRST' includes social sciences and humanities, in addition to natural sciences. In other words, people with degrees in, say, history are counted as HRST. It is easy to assume that the two groups of S&Es and HRST contain more or less the same number of people, whereas in reality, in 2004 only 17% of those with an HRST occupation were scientists and engineers (Eurostat).

In our report, we have chosen to limit ourselves to science and engineering, as most researchers can be found in this pool. In comparison, only 3% of people with an HRST occupation were researchers in 2004 (Eurostat).

This illustration hopefully further helps to put the various categories into perspective:



The following definitions for human resources in science and technology (HRST, HRSTE and HRSTO), science and technology (S&T) and scientists and engineers (S&E) are used by Eurostat, and are mostly based on the Canberra Manual:

HRST – people who have completed tertiary level education (ISCED 1997 levels 5a, 5b and 6) in a S&T field of study (HRSTE) or, people who are not formally qualified in this way, but are employed in a S&T occupation where tertiary qualifications are normally required (HRSTO).

S&T field of study – natural sciences, engineering and technology, medical sciences, agricultural sciences, social sciences, humanities and other fields.

S&Es – people who work in physical, mathematical and engineering occupations or in life science and health occupations.

Additionally, the Eurostat data for tertiary level science and engineering education is grouped as EF4 (science, mathematics and computing) and EF5 (engineering, manufacturing and construction).

1.1 Goals and timeframe

Since government policies are key factors influencing the supply of scientists and engineers (e.g. in terms of education, public awareness, or immigration), our first goal is to identify key indicators which policy makers can focus on, either by following trends, or by trying to influence the developments in these indicators in order to promote a more substantial increase in the supply of scientists and engineers. We also forecast possible outcomes if certain actions, trends or other developments take place, or alternatively, we forecast what the baseline scenario would be if there was no change.

Obviously, many factors other than an increase in the stock of scientists and engineers could increase R&D expenditures in the European Union[13], but the assumption that increased supply of S&Es is the primary means for this is made for the sake of the exercise. Certain other simplifications and assumptions have also been made to get a better idea of the big picture. For instance, we restrict the analysis to the total S&E stock, rather than look at different sectors, which may vary greatly in their R&D intensity. Similarly, country-specific R&D intensities also vary, not least because countries have different industrial structures[14]. The 3% Lisbon/Barcelona target is an average for the whole EU-25, and member countries have their own specific targets which were agreed upon in March 2006. The estimates of the required numbers of researchers for 2010 are based on the country specific targets, whereas estimates for 2015 use the EU-25 target of a 3% R&D intensity[15]. Reaching the country specific targets would result in the total EU (weighted average) R&D intensity of 2.6% by 2010. Section 3 also presents projections for 2010 and 2015 of numbers of S&Es (and corresponding numbers of researchers) based solely on previous trends in the number of S&Es or researchers in each EU member state[16] [17].

1.2 Overall description of the scenarios

In general, as noted above, the primary driver for the supply of scientists and engineers is demand at a given price (reflected through salaries). The demand for scientists and engineers in the public sector is influenced by policy on R&D investment, whereas demand in the private sector partly depends on the industrial distribution, due to large differences by sector in the expected profitability of investing in R&D. As mentioned earlier, this report will only be looking at the supply side, and it is therefore assumed that there is enough demand for S&Es.

Figure 1.1 shows the complexity of the situation by identifying the number of factors that influence the supply of S&E personnel. Possible influences on the flows and stocks of scientists and engineers include not only each EU member state's domestic policies, population trends, industry structure, employment rates etc., but also conditions within countries outside the EU, such as China, India or the United States. The international mobility of both students and S&E personnel is an essential part of the picture and must

[13] Other ways of increasing R&D investment would be, for example, paying researchers higher salaries, or purchasing more R&D equipment.
[14] In terms of S&E personnel, the relative proportions also vary between countries: for example, in Ireland, 39% of HRST in manufacturing and 31% of HRST in services were scientists and engineers in 2004, whereas in Austria only 8% of HRST in manufacturing and 11% of HRST in services were S&Es. In some countries, the differences between manufacturing and services also vary significantly (Wilen, 2006).
[15] Except for Finland and Sweden, which both have a higher target of 4%.
[16] In other words, these forecasted numbers do not take into account changes in the outflow to retirement or changes in the inflow due to demographics.
[17] The scenario for 2015 gives a more realistic time frame for the large increase in S&E personnel that would be needed to meet the 3% R&D intensity target, given the time to educate new scientists, or attract them from abroad.

therefore be considered. However, including international mobility greatly increases the complexity of the exercise and the number of indicators to be considered[18].

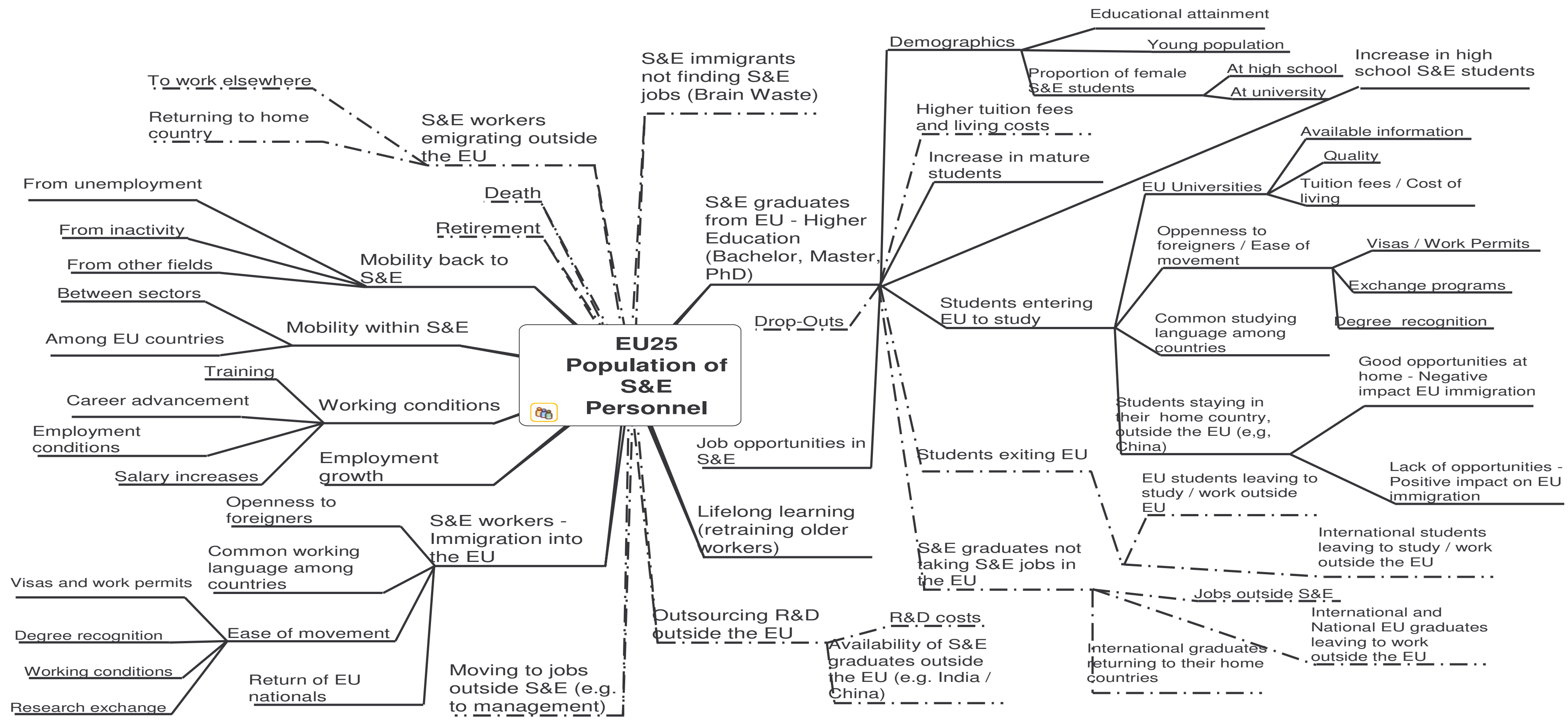
The factors identified in Figure 1.1 are divided into four main components (or modules), discussed later in Sections 4 to 7 and also shown in Figure 8.1 in Section 8 (with some quantified influences and potential pathways for reaching the EU goals):

- *The domestic higher education system of each EU country*, for which the main subcomponents to consider are: potential tertiary S&E students (number of young people below age 19), students graduating from secondary school, mature students entering university studies, drop-out rates from universities, popularity of science as a subject at secondary schools and universities, general attitudes in society towards science and scientific advances, as well as the image of working scientists and engineers, role of girls and women in science, and finally, general living costs, tuition fee policies and spending on (higher) education.
- *International student mobility from within or outside the EU-25*, which is partly influenced by similar factors as above, e.g. tuition fees and general living costs, but other components include: reputation of the universities, the image of the openness of the country in question, the language of study, ease of movement, the amount of information available on specific universities or countries, lack of opportunities in the students' home countries, and the popularity in the home countries of international education. Finally, there is also outward international student mobility from the EU caused by students returning to their home countries before or after graduation, and by EU citizens going abroad before or after graduation.
- *Supply of science and engineering personnel,* for which the main subcomponents are: new 'domestic' science and engineering graduates, people moving from jobs outside S&E to S&E employment, graduates from outside S&E fields active in research, inactive or unemployed people going into S&E, and last but not least, immigrant S&E workers (including workers returning from a temporary stay abroad). Many of the factors influencing international mobility of workers are the same as for international students and include ease of movement, working conditions, common working language , and conditions in the home countries of the potential immigrants. Factors affecting the within country flows include general economic outlook, working conditions , and policies on public R&D expenditures, the retirement age and the unemployment rates for S&Es.
- *Loss of science and engineering personnel* – The main outflow channels from the stock of scientists and engineers are: retirement, leaving S&E for jobs in other fields or emigrating to outside the EU-25 , and firms shifting R&D to countries outside the EU-25. Lack of career opportunities in the EU is an obvious reason

[18] Although external influences are included in the simulations in this report, we do not look into factors that might alter these influences.

for emigration or for missing the potential pool of international S&E workers in the EU. Similarly, there are other groups of potential S&E workers who for one reason or another do not end up in the S&E pool, e.g. graduates choosing other jobs or S&E immigrants not finding S&E jobs. Relevant policies include those mentioned above plus immigration policies.

Figure 1.1. Various influences on the supply of scientists and engineers.



Note: Dashed lines indicate a negative effect

2.0 METHODOLOGY

Our scenarios focus on both the theoretical framework of how the supply side of the stock of scientists and engineers can be expected to function, as well as simple simulation exercises with data from the 25 EU member states[19] and from outside the EU where relevant. Following is an overview of the methods used.

Initially, the functioning of each module is explained in some detail. Subsequently, certain linkages between subcomponents in the module are explored and the relevant literature is discussed.

Secondly, the above 'theory' is used to identify the most relevant indicators for each module. This is done by scaling down the number of potential indicators.

Thirdly, clustering is used to identify peer countries in the EU. This is useful to see how the relevant indicators differ between clusters.

Fourthly, baseline simulations are run to determine the basic trends that the data for EU-25 and the clusters would indicate for the near future. These baseline simulations are meant to explore whether the EU and – specifically, which member states – would or would not meet the targets without any changes in policy, instead just based on past demographic, educational output, retirement and S&E stock data.

Fifthly, we proceed to modify some of the variables that might have a significant impact on the supply of S&Es and see what changes would help the EU best to meet its targets.

Finally, recommendations are given for the key indicators that can be used to both follow the developments in the supply of scientists and engineers , and to try to influence the trends in the most efficient manner.

2.1 Indicators

In total, we used 35 indicators of relevance for this scenario, each of which was assigned to one of the four modules. These indicators are listed in Annex B, Table B-1, which gives the source of each indicator and data availability. Of these indicators, 16 were used (and manipulated) in the simulations performed for this scenario. These 16 indicators are listed in Annex B, Table B-2.

Many key indicators are available, but in some cases greater detail would be required than what has been available, at least until recently. Data on the educational fields of human resources in science and technology (HRST), which enables us to separate between scientists and engineers and the rest of HRST, have only been collected by Eurostat since 2003[20]. This also means that other breakdowns for European scientists and engineers – for example, by gender or by age - are only available from 2003. Such breakdowns are important. For example, an estimate for the probability of augmenting the supply of S&E personnel by drawing from the pool of older personnel that have left

[19] Bulgaria and Romania, members from January 2007 were not included in this report.
[20] The average share of HRST educated in S&E fields was 27% in 2005 (Eurostat, 2006).

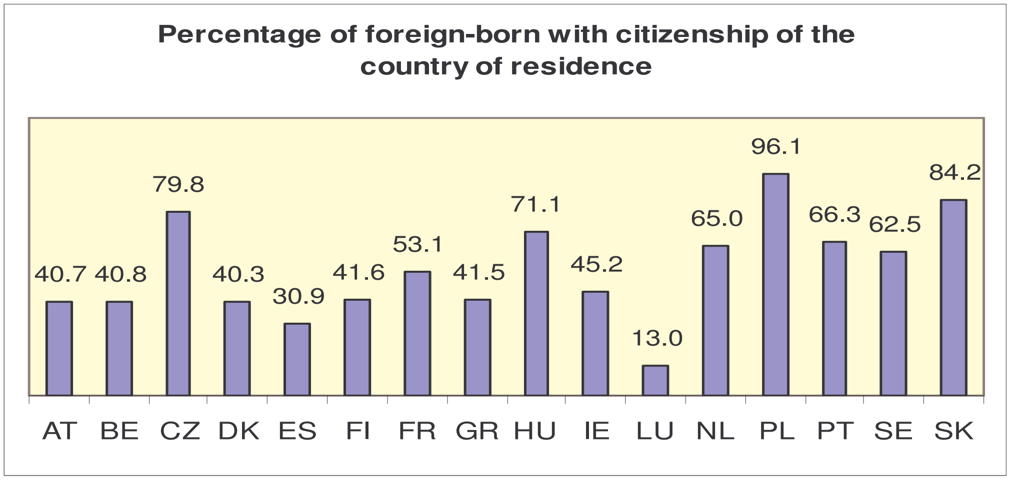
S&E positions or retired S&E personnel, requires data that has been broken down by age cohorts. Currently, Eurostat provides data for S&E personnel in most of the 25 EU member states in a rather approximate manner with the age cohorts from 45 to 64 being lumped together.

A major challenge for measuring the international mobility of S&E students and employed personnel is that relevant data are either unavailable or not comparable. There are several issues involved[21]:

- Migration policies and policies for the acquisition of citizenship vary among countries. Figure 2.1 shows some of the variation among EU member states in the foreign-born acquiring the citizenship of the country of residence;
- Ways of counting and defining immigrants vary among countries (in some countries 'temporary immigrants' are not counted as immigrants; on the other hand, national statistical offices often do not take the accepted definitions of long-term or short-term migrants into account);
- All foreigners (non-citizens) in higher education are often counted as international students, although they might have lived in the country for years prior to their studies, or may have even been born there[22];
- Data is rarely collected on immigrant qualifications;
- Education systems and qualifications vary among countries making data more difficult to compare;
- Collecting data on departures or emigration is not systematic in many countries;
- Flows of migrants are not usually measured in the most reliable sources (population censuses and labour force surveys) instead, only stocks are.

[21] This paragraph is mostly from Auriol (2006).
[22] It has been estimated that non-mobile students with a foreign citizenship make up between 18% and 50% of all students with foreign citizenship (Lanzendorf and Teichler, 2003).

Figure 2.1. Acquisition of citizenship in some receiving EU countries.



Source: OECD (2005).

Furthermore, the Eurodata study by Kelo, Teichler and Wächter (2006) found that up to half of all temporarily mobile (e.g. Erasmus) students are not included in the official student mobility statistics, and that in fact, most EU countries do not even collect data on genuine student mobility[23] [24].

However, there have been recent efforts to rectify some of these problems. For example, the OECD, together with Eurostat and UNESCO launched a project in 2004 to measure careers and international mobility of earned doctorates (PhDs). The OECD has also worked on improving the databases on education and migration (Auriol, 2006). Some of the newly available data is discussed further in Sections 4 to 7.

Other data have only become available very recently. For example, the educational background of HRST in the EU has only been available through Eurostat from 2006, with the data going back to 2003 (Eurostat, 2006). For such data, trend analysis is not yet appropriate.

Many potentially valuable indicators are simply not available or only available for a few countries. A number of key 'missing' indicators are identified in the conclusions.

2.2 Country clusters

The EU 25 is formed by a group of countries that present dramatic differences among each other, differences that are even more accentuated when we consider the new member countries.

[23] In other words, students moving across country borders for the purpose of study.

[24] The study by Kelo, Teichler and Wächter (2006) found that three European countries (Finland, Germany and the UK) as destination countries provide fairly complete data on student mobility, e.g. making a distinction between mobile and foreign students.

Such differences are based on many aspects, ranging from their economies, environment, population and social conditions, reflecting distinctive stages of development when it comes to the Knowledge Based Economy. Clustering countries into distinctive groups helps to understand their strengths and weaknesses and will serve as a starting point for our analysis in this and other scenarios.

Consequently, in this scenario, we can expect that the EU25 countries will differ from each other in terms of their stocks of S&Es and their ability to supply their needs either by producing' enough S&Es or attracting them from other sources.

The EU-25 countries were clustered into five groups taking into consideration characteristics in a wide range of areas which included the economy, digital / ICT infrastructure, society, government and environment. Those areas are interlinked and together form a broad background that allow us to group the EU-25 countries that are similar to each other into clusters of high internal homogeneity and high external heterogeneity, facilitating the understanding of specific clusters' weaknesses and strengths in terms of the Knowledge Based Economy. The stage of a country development in the KBE depends on several factors, such as its economy (relative importance of the tertiary sector); ICT infrastructure, which creates the condition for knowledge to be created and diffused; society, in terms of tertiary education, workforce, retirement age, GDP per capita, opportunities for research; government and its institutions, rule of law (protection of inventions) level of corruption, that reflects in a country's propensity to either attract or repel foreign capital as well as environment, which is one of the KBE main concerns for the near future.

Clusters differ in all the above factors, and consequently countries belonging to different clusters ask for different measures, policies and priorities in terms of forming a pool of S&E personnel necessary to achieve the Lisbon goals in terms of Research and Development, which is analyzed in this scenario. Clustering the EU25 is the first stage to understand the EU25 countries, their current position and their current needs to achieve the 3% goal of R&D in relation to GDP by 2015.

2.3 Clustering method

In order to group the EU25 countries into five clusters, we used a group of indexes developed by well-known institutes which covered all aspects listed in Table 2.1.[25]

[25] For clustering, we used SPSS software, hierarchical - agglomerative procedure with average linkage. We opted for Euclidean distance – squared to measure the similarity of magnitudes in the values.

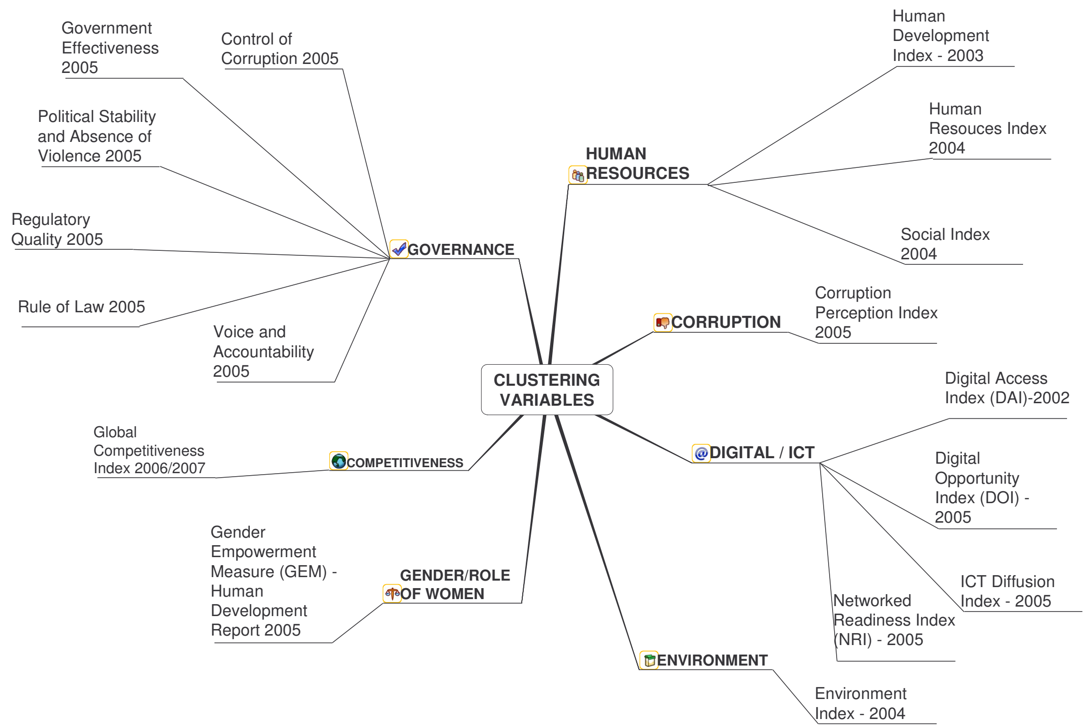
Table 2.1. Indexes used for clustering.

Factor	Notes for inclusion	Indexes	Source
Competitiveness	If a country is competitive, then it offers an environment in which there is a solid infrastructure allowing institutions to perform in an efficient and profitable manner. We can expect that for such countries it will be easier to attract more investments and human resources in S&E.	Global Competitive Index 2006/2007	World Economic Forum
Corruption	A country that is perceived to be corrupted is likely to find more difficulties in attracting and retaining S&E resources and actually receiving investments for innovation.	Corruption Perception Index - 2005	Transparency International
Digital / ICT	Digital access and ICT represent technology infrastructure, access to information, affordability, utilization and quality of ICT, the base on which innovation takes place.	Digital Access Index – 2002	International Communication Union – Market, Economics and Finance Unit
		Digital Opportunity Index – 2005	International Telecommunications Union
		ICT Diffusion Index – 2005	United Nations
		Network Readiness Index – 2005	World Economic Forum
Environment	The environment is vital to future economic sustainability. Given its increasing importance, environment is part of the innovation agenda for many countries and should be included in any related study.	Environmental Index 2004	World Travel & Tourism Council
Gender / Role of Women	Women's participation in innovation is fundamental for the EU-25 countries to achieve the numbers of S&E necessary to meet their Lisbon goals. Participation of women in S&E is linked to the role of women in society and the acceptance of females in an area that has been historically male dominated. In an ideal society, with equal empowerment of genders, women and men should have the same share (50% each).	Gender Empowerment Measure - 2005	United Nations Development Programme
Governance	Innovation is linked with talent, creativity, tolerance, knowledge, quality of human resources (education), which can only take place in an environment of freedom of expression, with a sound rule of law to protect innovation output.		World Bank
Human Resources	Innovation can not take place without its main engine, human resources, both in numbers and in quality. Qualified Human Resources depend on education as well as on access to information and knowledge.	Human Resources Index - 2004	World Travel & Tourism Council
		Social Index - 2004	World Travel & Tourism Council
		Human Development Index - 2003	United Nations Development Report 2005

Within each of the above seven areas covered, the selection of specific indexes was based first, on the index being representative of the aspect it was expected to represent and second, if the index was available for the 25 countries involved.[26]

Figure 2.2 illustrates the seven factors used to group the EU25 into clusters, as well as indexes and sub-indexes that were included under each factor.

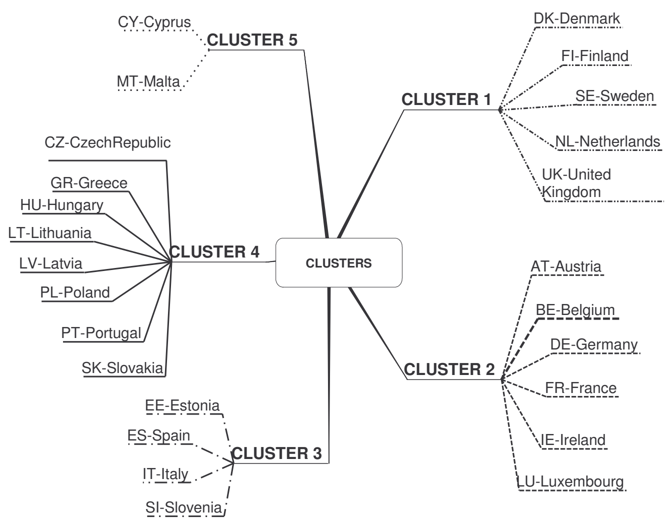
Figure 2.2. Factors used for clustering.



The clustering exercise resulted in five clusters which are represented in Figure 2.3. Clusters ranged from only two countries (Cluster 5) up to eight countries (Cluster 4).

[26] Gender Empowerment Measure was not available for France and Luxembourg.

Figure 2.3. Country clusters.



Annex A gives a full description of each index included in the clustering.

3.0 S&Es AND RESERCHERS – RELATIONSHIPS AND PROJECTIONS

There is not much detailed data describing the stock of researchers in the European Union. We do know that only a small proportion of scientists and engineers are researchers, but on the other hand, most researchers are found in the S&E stock. Therefore, our starting point to discuss the scenarios considers the S&E stock, of which more data are available.

By establishing links between the two stocks, S&Es and researchers, we are able to bridge the gap of information and project both numbers into the future.

In this section, we first establish the relationships between S&Es and researchers and then we look into where countries actually are in terms of both stocks, the number of S&Es and researchers they will need to achieve the 3% Lisbon goal and finally, by projecting both stocks into 2010 and 2015 we are able to calculate potential shortages or excesses in the numbers of S&Es and researchers.

3.1 Relationships between S&Es and researchers

Relationships between S&Es and researchers may differ depending on the level of R&D intensity that a country is in. Because the EU25 countries are in different stages of development in terms of KBE, as was demonstrated in the clustering exercise where we grouped the EU 25 members into five distinctive clusters, we should again look at the links between the two stocks, S&Es and researchers, considering where countries are in terms of R&D intensity.

3.1.1 Relationship between S&Es and S&E personnel in research by R&D intensity

On average, 18.9% of S&E personnel in the EU25[27] are in research (researchers), although it is not clear if this average holds across all levels of R&D intensity. Considering that the goal for all EU25 countries is to reach the 3% R&D intensity in relation to GDP, it is important to understand if the ratio of 18.9% holds at that level.

By splitting the EU25 into three tiers of R&D intensity in relation to GDP (below 1%, between 1 and 2% and between 2 and 4%) we grouped the 25 European countries according to their present R&D intensities so that we had a better understanding of the requirements in terms of S&Es and researchers, as countries R&D intensities increase to reach the 3% Lisbon goal.

<u>S&E personnel in research at different levels of R&D intensity</u>

For countries in the group 'less than 1% of R&D in relation to GDP', there is a strong relationship between numbers of researchers in relation to the number of S&Es as R&D intensity is still low in relation to GDP, with the exception of Cyprus. As a country's R&D intensity increases, the relationship becomes weaker, except for two outliers which

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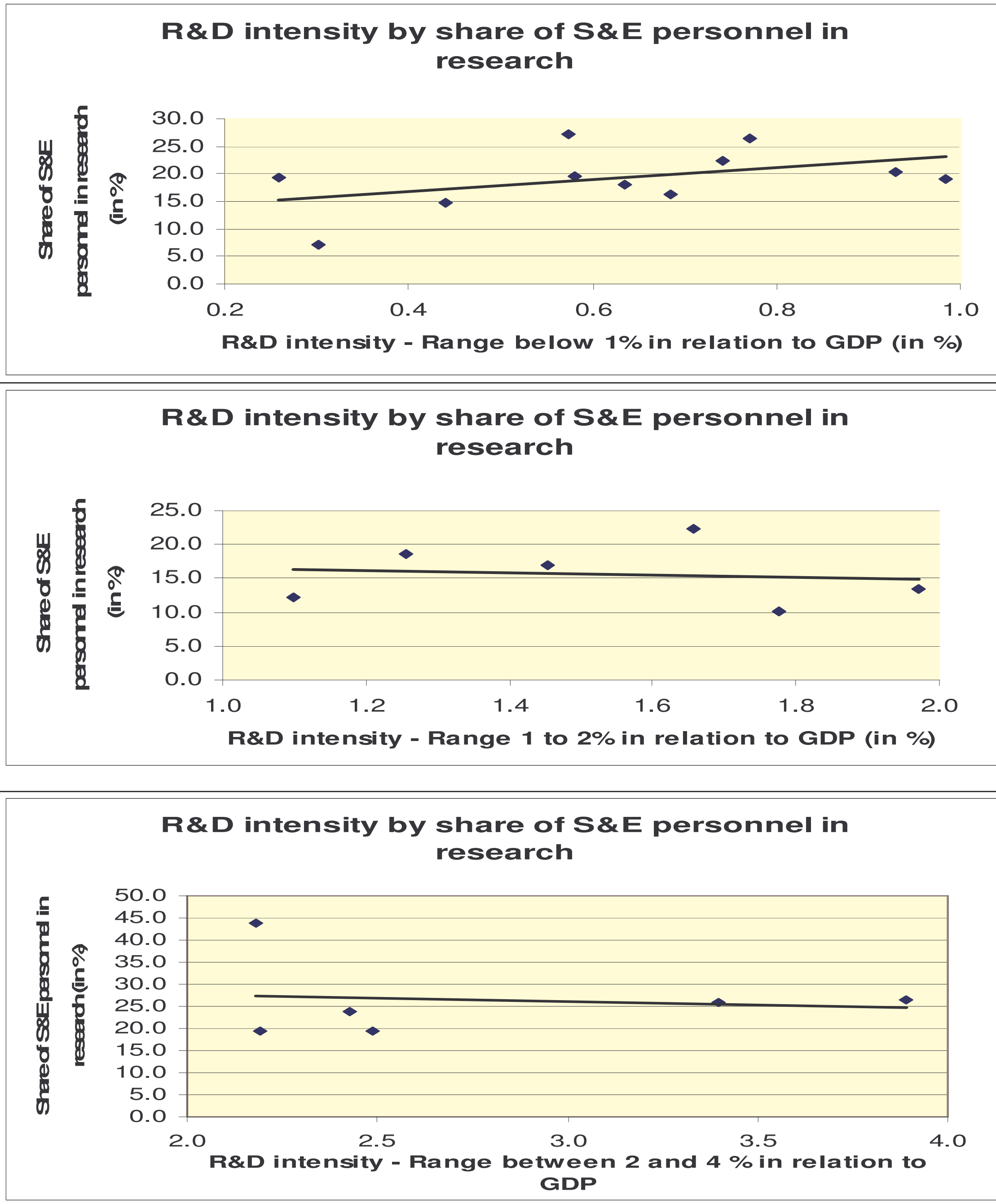
[27] Average between 2000 and 2005 – Eurostat.

include Luxembourg in the group between 1 and 2% R&D intensity and, Austria in the group between 2 and 4% intensity.

Figure 3.1 illustrates the relationships for the three levels of R&D intensities. Based on these relationships, we can observe that **the relationship between the number of researchers in relation to S&Es is stronger when R&D intensity is still low** (less than 1% of GDP).

Figure 3.1. S&E and Researchers relationships at different R&D intensities.

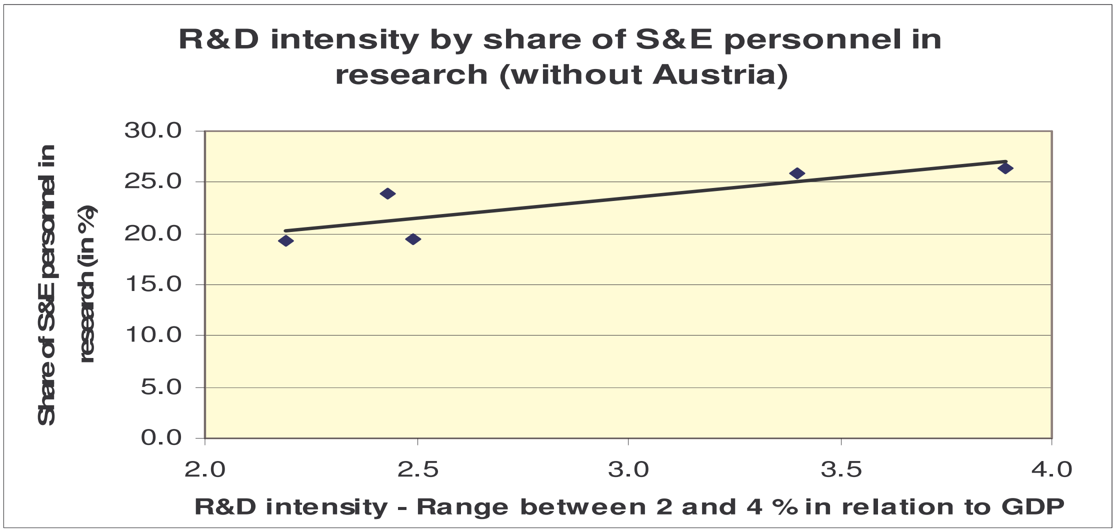


Obs: Point at intersection of 2.15% R&D intensity with 43.8% ratio of researches in relation to S&Es represents Austria, an outlier.

When we repeat the same exercise at R&D intensity level between 2 and 4% and exclude the outlier Austria, the results change dramatically: there is a strong relationship between the number of researchers and number of S&Es, indicating that increasing levels of R&D

intensity translate into a stronger relationship among the number of researchers in relation to numbers of S&Es. Figure 3.2 illustrates this relationship.

Figure 3.2. Relationship between researchers and S&Es at higher R&D intensity levels



3.1.2 Relationships for EU countries which percentages of R&D in relation to GDP were between 2 and 4% between years 2000 to 2005

Considering the Lisbon goal of 3% of R&D in relation to GDP, it is important to better understand the relationships among total number of researchers and total numbers of S&Es at that level of intensity. In order to study these relationships at this level of intensity, we took the sample of European countries whose percentages of R&D expenses in relation to GDP were between 2 to 4% during the period of time ranging from 2000 to 2004. Austria, Denmark, Finland, France, Germany, and Sweden were the six European countries whose numbers of R&D in relation to GDP satisfied the set condition. Since these countries have higher investments in R&D compared to the remaining European countries, they can be considered the most representative ones for understanding the needs for S&Es and researchers for all other European countries that are still behind in terms of investments in R&D.

Table 3.1 provides detailed information on absolute numbers for this group of countries, showing the average numbers for the above mentioned period.

Table 3.1. Relationships among S&Es and researchers at 2 to 4% R&D intensity.

	EU25	AT	DK	FI	FR	DE	SE	Average *
R&D/GDP	1.88%	2.18%	2.43%	3.40%	2.19%	2.49%	3.89%	**2.76%**
S&Es	9,142	95	149	183	1,188	2,036	264	
Researchers	1,727	41	36	46	229	397	70	
Researchers / S&Es	18.9%	43.8%	23.9%	25.9%	19.3%	19.5%	26.4%	**26.5%**

Source: Eurostat and own calculations.
Numbers in thousands.
* Considering the six listed countries: Austria, Denmark, Finland, France, Germany and Sweden.

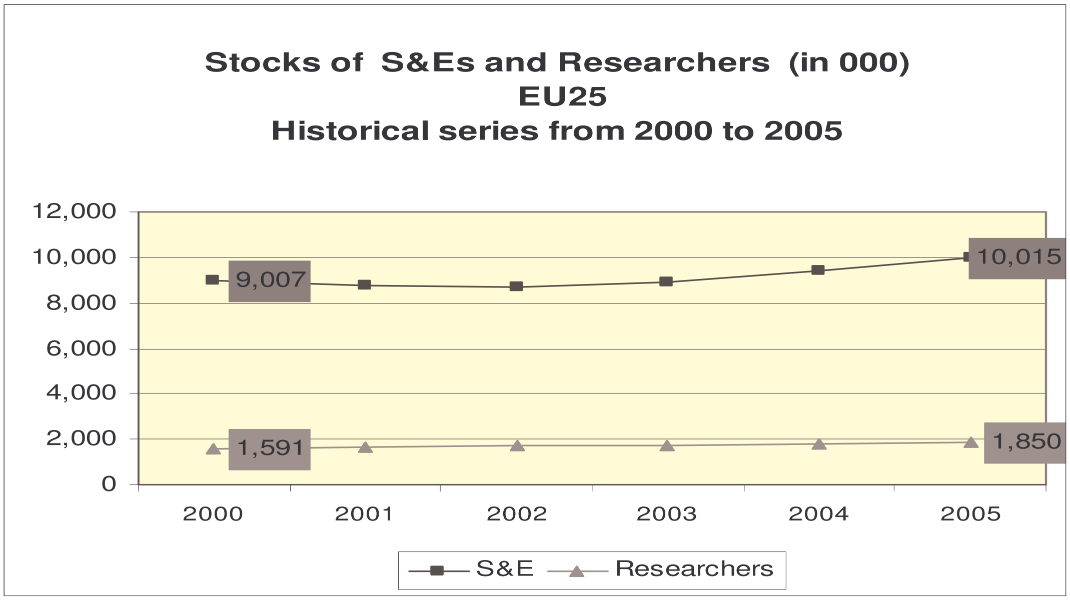
Austria is clearly an outlier (please also refer to Figure 3.2), with a ratio of researchers in relation to S&Es of 43.8%, it is far above the other countries in the group of high intensity R&D countries. Even if we remove Austria from this group, the average ratio would just decrease from 26.5 to 23.0%.

While the average R&D intensity for the EU25 was 1.88% in 2004, with a ratio of 18.9% researchers in relation to S&Es, the group of countries with higher R&D intensity within the EU25 had an average R&D intensity of 2.76% and a ratio between 23 and 26.5% (depending if Austria was included or not). In summary, the higher the R&D intensity level, the higher the ratio of researchers in relation to S&Es.

If we consider that the goal for all EU25 countries is to reach 3% of R&D in relation to GDP by 2015, then the proportion of 26.46% (or 23% without Austria) of researchers in relation to S&Es is a more reliable indicator as it reflects actual proportions when considering countries already in the range between 2 and 4% R&D in relation to GDP. For this exercise, we rounded this ratio to 25%. This proportion of 25% will be used to calculate more accurate numbers of researchers for 2015.

Figure 3.3 depicts actual numbers for S&Es and Researchers for all EU25 countries during the period 2000 to 2005.

Figure 3.3. Comparisons between S&Es and researchers.



Source: Eurostat

3.2 Calculating required and forecasted numbers of S&Es for 2010 and 2015

When calculating the **required number of S&Es** for 2010 and 2015 (Table 3.2), we used the percentage of actual R&D expenses in relation to GDP (year 2004) and the number of S&Es in that same year and then extrapolated to countries' targets for 2010 and 2015.

For example, referring to the Austria case, if in 2004 Austria had an R&D intensity of 2.23% and its numbers of S&Es were 116 000, then in 2010, when it is expected to reach the 3% R&D intensity, it would require 156 000 S&Es.[28] The same line of thinking was applied when calculating the number of S&Es for year 2015 (and considering the 2015 R&D target).

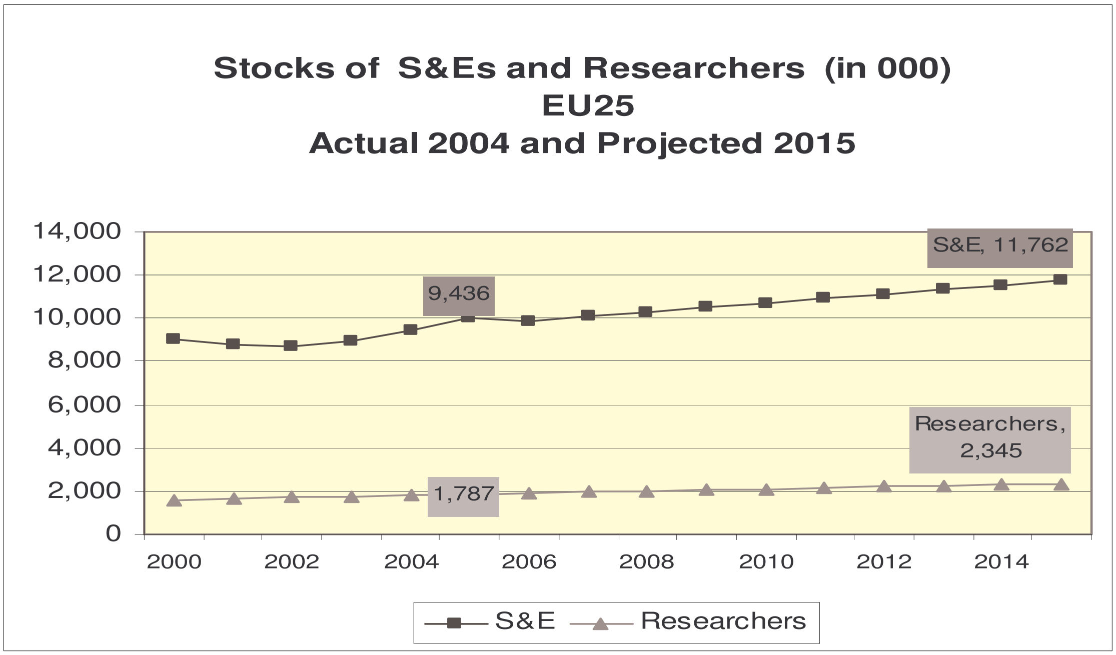
Note that EU25 countries have different targets for 2010. Nevertheless, all of them, with the exception of Finland and Sweden that would have already reached 4% R&D intensity, have the same target of 3% R&D intensity for 2015. [29]

The **projected number of S&Es** for 2010 and 2015 were based on forecasted numbers considering an historical time series.

Figure 3.4 illustrates stocks of S&Es and researchers for EU25, including actual numbers for 2004 and forecasted numbers for 2015 using historical time series.

[28] Calculated as simple cross multiplication
[29] Considering Lisbon target of 3% R&D in relation to GDP for all countries

Figure 3.4. Comparisons between S&Es and researchers – Actual and projected.



Source: Eurostat
Projections: Historical times series

Table 3.2 summarizes the actual, required and projected numbers of S&Es for all EU25 countries for both 2010 and 2015, using the same calculations as explained for Austria's case. Note that differences between the first and last row for the total EU25 (15.2 vs. 19.9 million) were due to the fact that the percentage of R&D in relation to GDP for the EU25 in 2004 in the amount of 1.86% was calculated using weighted average, while total EU25 (last row) represented an unweighted sum of all EU25 countries. Consequently, the last row takes into account individual countries when calculating for the whole EU25.

Based on calculations of required and projected numbers of S&Es, we then calculated the excess or shortage of S&Es in 2010 and 2015, by simply subtracting required numbers of S&Es from projected numbers of S&Es in a given year (2010 and 2015). The column 'Shortage /Excess' reflects the surpluses or deficits in numbers of S&Es that will need to be fulfilled if the country is to reach its goals for that year.

Table 3.2 Required and projected numbers of S&Es for 2010 and 2015.

	R&D as % GDP	Number of S&Es (000)	R&D as % GDP - Target	N. S&E required (000)***	N. S&E Projected (000) ****	Shortage / Excess (000)	R&D as % GDP - Target	N. S&E required (000) ***	N. S&E Projected (000) ****	Shortage / Excess (000)
	2004	**2004**	**2010**	**2010**	**2010**	**2010**	**2015**	**2015**	**2015**	**2015**
EU25	1.86*	9,437	2.60	13,192	10,714	2,478	3.00	15,221	11,762	3,459
Austria	2.23	116	3.00	156	157	(1)	3.00	156	199	(43)
Belgium	1.89	333	3.00	529	380	149	3.00	529	411	117
Cyprus	0.37	15	1.00	41	16	25	3.00	122	17	105
Czech Rep.	1.26	160	2.06	262	177	85	3.00	381	185	196
Denmark	2.48	151	3.00	183	199	(16)	3.00	183	232	(50)
Estonia	0.88	19	1.90	41	27	14	3.00	65	32	33
Finland	3.46	173	4.00	200	179	21	4.00	200	190	10
France	2.14	1,251	3.00	1,754	1,503	251	3.00	1,754	1,713	41
Germany	2.50	2,063	3.00	2,476	2,295	180	3.00	2,476	2,468	8
Greece	0.63	183	1.50	436	223	213	3.00	871	265	606
Hungary	0.88	170	1.80	348	202	146	3.00	580	240	340
Ireland	1.21	141	2.5**	291	185	107	3.00	350	221	128
Italy	1.10	795	2.50	1,807	974	833	3.00	2,168	1,166	1,002
Latvia	0.42	38	1.50	136	51	84	3.00	271	61	210
Lithuania	0.76	72	2.00	189	88	101	3.00	284	105	179
Luxembourg	1.66	10	3.00	18	12	6	3.00	18	14	4
Malta	0.63	4	0.75	5	4	1	3.00	19	4	15
Netherlands	1.78	494	3.00	833	558	275	3.00	833	624	208
Poland	0.56	455	1.65**	1,341	879	461	3.00	2,438	1,150	1,287
Portugal	0.77	156	1.80	365	193	172	3.00	608	234	374
Slovakia	0.51	61	1.80	215	70	145	3.00	359	78	281
Slovenia	1.45	42	3.00	87	65	22	3.00	87	83	4
Spain	1.06	900	2.00	1,698	1,216	482	3.00	2,547	1,486	1,061
Sweden	3.91	270	4.00	276	344	(68)	4.00	276	398	(122)
UK	1.77	1,365	2.5**	1,928	1,466	462	3.00	2,314	1,532	782
Total EU25 (SUM)		9,437		15,612	11,463	4,149		19,886	13,109	6,777

* R&D as % of GDP – Weighted average. Includes R&D both in the Business and Public sectors

** Other targets: Ireland 2.5% of GNP in 2013; Poland 1.65% of GDP in 2008 and the United Kingdom 2.5% of GDP in 2014

*** Calculated based on R&D as a % of GDP

**** Projections based on historical time series

Source: Eurostat, OECD, Council of the EU (2006) and own calculations.

The same exercise was completed for a number of researchers in 2010 and 2015. Table 3.3 reflects the same calculations but this time for numbers of researchers. When calculating the **required number of researchers** for 2010 and 2015, we used the intensity of R&D expenses in relation to GDP for year 2004 and the number of researchers in that same year. We then extrapolated to countries' targets for 2010 and 2015. Considering the example of Austria, if in 2004 the country had an R&D intensity of 2.23% and its numbers of researchers were around 44 000, then in 2010, when it is expected to reach the 3% R&D intensity, it would require approximately 59 000 researchers.[30] The same line of thinking was applied when calculating the number of researchers for year 2015 (and considering 2015 R&D target).

The **projected number of researchers** for 2010 and 2015 were based on forecasted numbers considering historical time series (Please refer to Figure 3.4 for projections of S&Es and researchers). Differences between the first and last row in Table 3.3 for the total EU25 (2.9 vs. 3.7 million) were due to the fact that the percentage of R&D in relation to GDP for the EU25 in 2004 in the amount of 1.86% was calculated using weighted average, while total EU25 (last row) represented an unweighted sum of all EU25 countries.

Table 3.3 summarizes required and projected numbers of researchers for 2010 and 2015.

[30] Calculated as simple cross multiplication.

Table 3.3. Required and Projected numbers of Researchers for 2010 and 2015.

	R&D as % of GDP	N. Researchers	R&D as % of GDP - Target	N. Researchers Required***	N. Researchers Projected ****	Shortage / Excess	R&D as % of GDP - Target	N. Researchers Required ***	2015-2004	N. Researchers Projected ****	Shortage / Excess
	2004	2004	2010	2010	2010	2010	2015	2015		2015	2015
EU25	1.86*	1,786,971	2.6	2,497,916	2,097,718	400,198	3.00	2,882,211	1,095,240	2,345,400	536,811
Austria	2.23	43,634	3	58,700	55,863	2,837	3.00	58,700	15,066	66,054	(7,354)
Belgium	1.89	44,867	3	71,217	47,069	24,148	3.00	71,217	26,350	48,904	22,313
Cyprus	0.37	1,209	1	3,268	1,850	1,418	3.00	9,803	8,594	2,384	7,419
Czech Rep.	1.26	34,152	2.06	55,836	39,544	16,292	3.00	81,314	47,162	44,729	36,585
Denmark	2.48	39,533	3	47,822	47,048	774	3.00	81,314	41,781	54,658	26,656
Estonia	0.88	5,482	1.9	11,836	6,620	5,216	3.00	18,689	13,207	7,569	11,120
Finland	3.46	51,219	4	59,213	60,877	(1,664)	4.00	59,213	7,994	70,727	(11,514)
France	2.14	233,615	3	327,498	264,771	62,727	3.00	327,498	93,883	290,735	36,763
Germany	2.5	408,914	3	490,697	458,899	31,798	3.00	490,697	81,783	500,553	(9,856)
Greece	0.63	31,293	1.5	74,507	39,147	35,360	3.00	149,014	117,721	45,692	103,322
Hungary	0.88	30,420	1.8	62,223	37,693	24,530	3.00	103,705	73,285	43,051	60,654
Ireland	1.21	16,321	2.5**	33,721	18,432	15,289	3.00	40,465	24,144	20,257	20,208
Italy	1.1	108,559	2.5	246,725	118,484	128,241	3.00	296,070	187,511	126,754	169,316
Latvia	0.42	5,625	1.5	20,089	7,547	12,542	3.00	40,179	34,554	8,809	31,370
Lithuania	0.76	10,181	2	26,792	10,126	16,666	3.00	40,188	30,007	10,079	30,109
Luxembourg	1.66	2,128	3	3,846	2,746	1,100	3.00	3,846	1,718	3,262	584
Malta	0.63	893	0.75	1,063	2,015	(952)	3.00	4,252	3,359	2,950	1,302
Netherlands	1.78	56,399	3	95,054	68,105	26,949	3.00	95,055	38,656	77,860	17,195
Poland	0.56	96,531	1.65**	284,422	109,962	174,460	3.00	517,130	420,599	120,856	396,274
Portugal	0.77	37,851	1.8	88,483	50,395	38,088	3.00	147,471	109,620	60,848	86,623
Slovakia	0.51	17,354	1.8	61,249	16,423	44,826	3.00	102,082	84,728	16,557	85,525
Slovenia	1.45	5,842	3	12,087	6,365	5,722	3.00	12,087	6,245	6,405	5,682
Spain	1.06	169,971	2	320,700	219,494	101,206	3.00	481,050	311,079	263,443	217,607
Sweden	3.91	75,318	4	77,052	92,472	(15,420)	4.00	77,052	1,734	106,767	(29,715)
UK	1.77	257,759	2.5**	364,066	288,622	75,444	3.00	436,880	179,121	314,340	122,540
Total EU25 (SUM)		1,785,070		2,898,166	2,070,569	827,597		3,744,970	1,959,900	2,314,243	1,430,727

* R&D as % of GDP – Weighted average. Includes R&D both in the business and public sectors
** Other targets: Ireland 2.5% of GNP in 2013; Poland 1.65% of GDP in 2008 and the United Kingdom 2.5% of GDP in 2014
*** Calculated based on R&D as a % of GDP
**** Projections based on historical times series
Source: OECD, Council of the EU (2006) and own calculations.

3.3 Baseline - Projecting numbers of S&Es for 2010 and 2015

So far, we have simply projected numbers of S&Es and Researchers into 2010 and 2015 using historical time series. These simple projections do not take into account any variable that could be influencing these numbers, and consequently cannot be considered accurate. Consequently, our next step is to calculate a baseline projection that goes beyond simple projections, and takes into account two main variables that impact numbers of S&Es: numbers of S&Es originated from graduates in S&Es (from the supply side) as well as losses on S&E stocks due to retirement.

As mentioned before, there are more data available for S&Es than there is for researchers. The baseline calculation considered supply and loss variables, which were only available for S&Es. Due to this lack of information when it comes to researchers, we opted to look into the numbers of S&Es and then extrapolate to numbers of researchers.

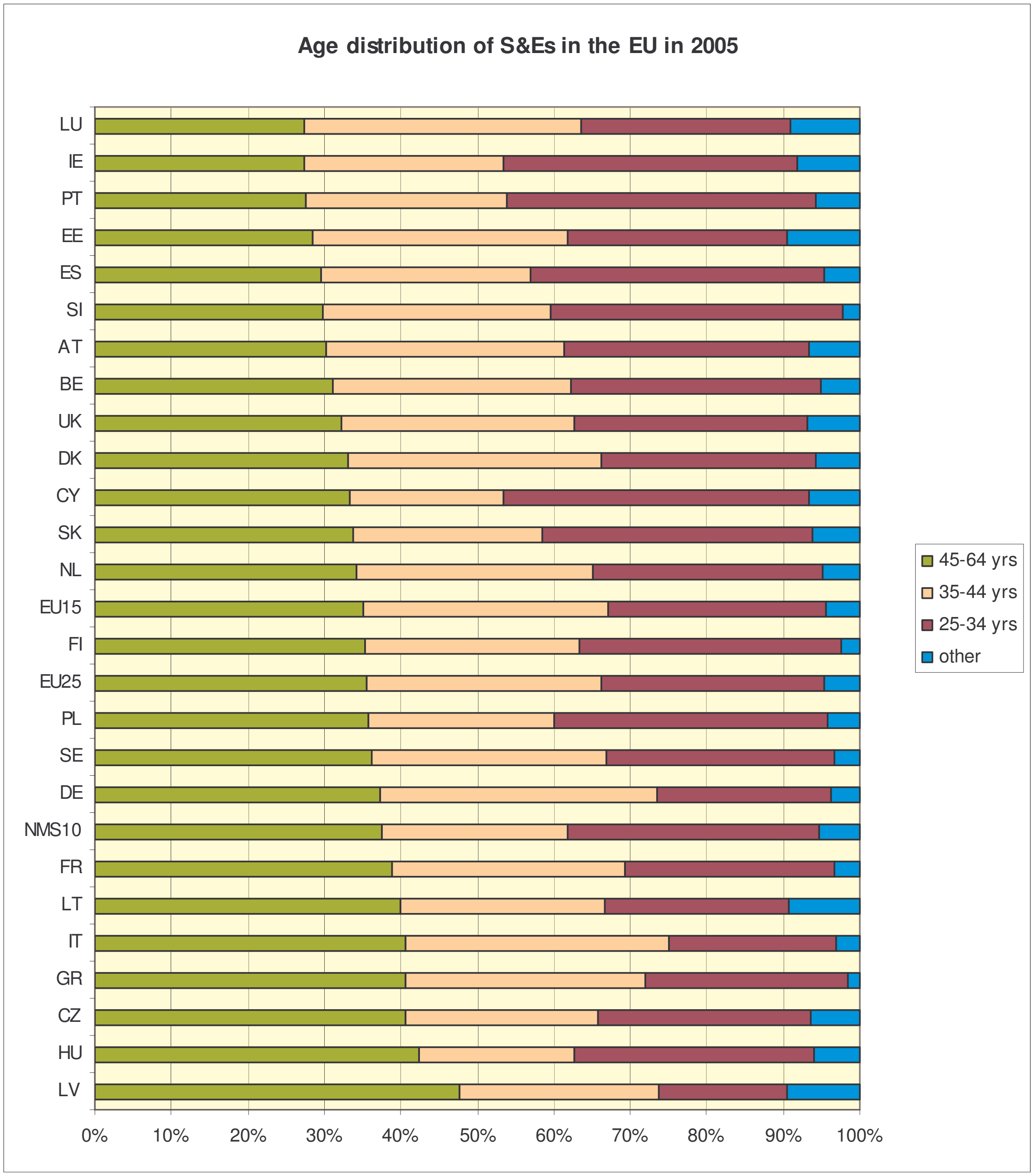
3.3.1 Demographic baseline estimates

We have done a 'baseline simulation' for the 25 EU member states, to see what the number of S&E personnel would be in 2010 and 2015, assuming current trends for the **domestic** supply of new S&E personnel and losses of S&E personnel to retirement.

The indicators included in the baseline simulations were:

- *The annual number of S&E graduates*: For the baseline simulations we use the proportion of graduates between 20-29 years. Some students of course graduate after the age of 29, but such data is not currently available by field of study. Data on the size of age cohorts from 14 to 24 years provide an indicator for the number of potential tertiary students, and later, potential S&E graduates.
- *Average retirement age*: These data are available per country and are used for the baseline simulations to measure the outflow from the stock of S&Es. We use the country totals of working scientists and engineers as well as data by age cohort to see the impact of retiring personnel (Figure 3.5 shows the current age distribution of scientists and engineers in the EU). The numbers of employees in the medium to high age brackets. i.e., from 45 to 64 years, give an indication of the 'natural' outflow of employees through retirement in the next 10 years or so.

Figure 3.5. Age distribution of scientists and engineers.



Note: Data for Malta are not available, NMS = new member states.
Source: Eurostat.

When calculating the baseline, differences in S&Es numbers using number of people retiring based on data broken-down into group ages between Y45_54 and Y55_64 instead of total group age Y45_64 were insignificant. Furthermore, a breakdown in the data for age groups Y25_54 and Y55_64 was just available for 9 countries out of the 25 European countries and for different years, which would result in unreliable data comparison. Due to these reasons, we opted to use data on population within group age Y45_64 to calculate cohorts retiring each year.

A summary of the baseline calculations considering the above described variables and grouped by clusters is found in table 3.4. Based on this more accurate calculation of S&Es numbers (baseline calculations), we can recalculate shortages and/or excesses in S&Es stocks by 2010 and 2015. Furthermore, the last column of Table 3.4 indicates the percentage of the required numbers of S&Es that is expected to be covered by a country's own internal resources.

Table 3.4. Number of S&Es in years 2010 and 2015 – Baseline projections.					
	Baseline 2010 (E)	**Baseline 2015 (E)**	**Required 2015 ****	**Shortage/ Excess**	**Internal coverage - %**
Cluster 1					
Denmark	159.835	167.980	183.000	15.020	91.8
Finland	195.842	213.342	200.000	(13.342)	106.7
Netherlands	490.566	488.281	833.000	344.719	58.6
Sweden	299.420	329.412	276.000	(53.412)	119.4
UK	1.747.698	2.078.773	2.314.000	235.227	89.8
Sub-total	2.893.361	3.277.787	3.806.000	**528.213**	**86.1**
Cluster 2					
Austria	134.620	148.589	156.000	7.411	95.3
Belgium	350.225	362.894	529.000	166.106	68.6
France	1.736.394	2.140.263	1.754.000	(386.263)	122.0
Germany	2.103.100	2.132.332	2.476.000	343.668	86.1
Ireland	188.761	223.111	350.000	126.889	63.8
Luxembourg	8.517	7.284	18.000	10.716	40.5
Sub-total	4,521,617	5,014,474	5,283,000	**268,526**	**94.9**
Cluster 3					
Estonia	23.588	27.731	65.000	37.269	42.7
Italy	922.478	1.006.195	2.168.000	1.161.805	46.4
Slovenia	44.959	46.296	87.000	40.704	53.2
Spain	1.098.077	1.208.839	2.547.000	1.338.161	47.5
Sub-total	2.089.102	2.289.061	4.867.000	**2.577.939**	**47.0**
Cluster 4					
Czech	177.728	188.936	381.000	192.064	49.6
Greece	206.406	217.391	871.000	653.609	25.0
Hungary	170.971	169.479	580.000	410.521	29.2
Lithuania	96.789	119.930	284.000	164.070	42.2
Poland	616.187	731.964	2.438.000	1.706.036	30.0
Portugal	204.057	234.325	608.000	373.675	38.5
Slovakia	83.424	99.845	359.000	259.155	27.8
Latvia	43.921	49.588	271.000	221.412	18.3
Sub-total	1.599.483	1.811.457	5.792.000	**3.980.543**	**31.3**
Cluster 5					
Cyprus	15.244	15.372	122.000	106.628	12.6
Malta	4.149	4.176	19.000	14.824	22.0
Sub-total	19.393	19.548	141.000	**121.452**	**13.9**
Total(SUM)	11.122.956	12.412.327	19.889.000	**7.476.673**	**62.4**
EU25*	**11.134.205**	**12.402.412**	**19.889.000**	**7.486.588**	**62.4**

* Calculated as EU25 as a whole.
** From table 3.2 – Column 8 – N. of S&E required (000)
(E) - Estimated

Source: Eurostat, OECD and own calculations.

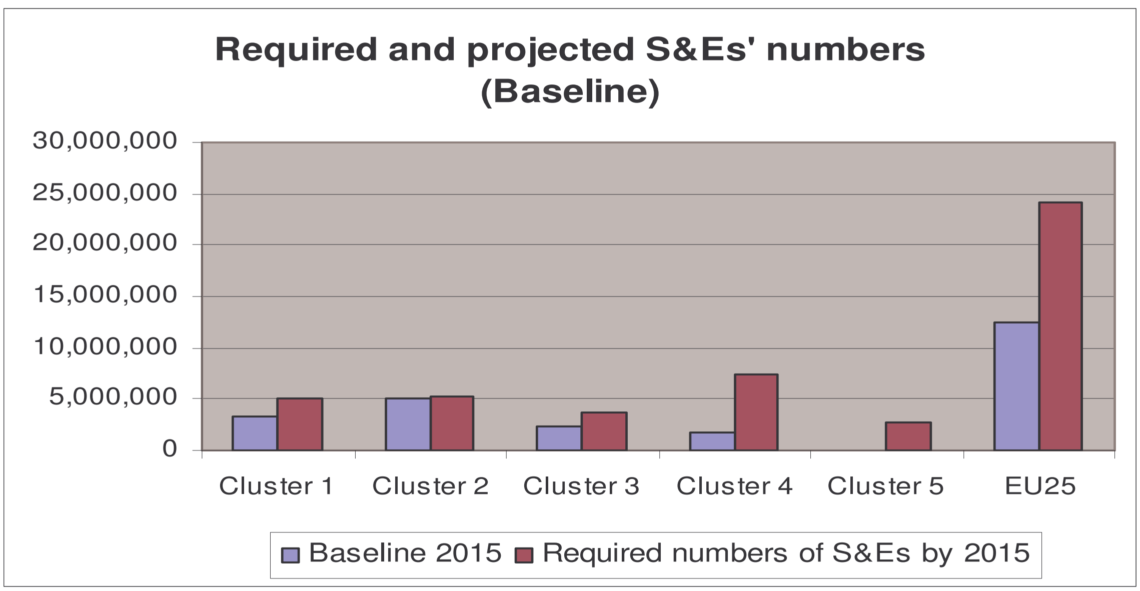
The results of this exercise lead to some interesting points: when considering the sum of the EU25, there will be a shortage of approximately 7.5 million S&Es by 2015. This means that the EU25 countries will be able to 'produce' only about 62% of their needs of

S&Es to meet the 3% R&D goal. The balance will have to come either from outside the EU25 or from changes within the EU25 borders.

Although the EU25 can only cover around 62% of its needs of S&Es, this shortage is not equally distributed among the 5 previously defined clusters. Cluster 2 (Austria, Belgium, France, Germany, Ireland and Luxembourg) will be able to cover 95% of its requirements, followed by Cluster 1 (Denmark, Finland, Netherlands, Sweden and the UK) with approximately 86%. Cluster 3 (Estonia, Italy, Slovenia and Spain) will be able to account for around 47% of its needs, while Cluster 4 (Czech Republic, Greece, Hungary, Lithuania, Poland, Portugal, Slovakia, and Latvia) will cover around 31% of its requirements. Cluster 5 (Cyprus and Malta) will only be able to produce around 15% of its required numbers.

Figure 3.6 illustrates projected and required numbers of S&Es based on Baseline calculations for 2015.

Figure 3.6. Baseline - Required and projected numbers of S&Es.



Source: Our own calculations

Within clusters, a few countries will not have to be concerned about meeting their requirements of S&Es by 2015 in order to achieve the goal of 3% of R&D in relation to GDP. The countries that will be producing in excess of their needs are France, Finland, and Sweden. Table 3.5 shows a more detailed projection of required numbers of researchers, calculated as approximately 25% of stocks of S&Es[31] in 2010 and 2015 as well as projected numbers according to the Baseline forecast, which considers only the current domestic trends in supply and losses.

[31] Calculated using relationships among S&Es and researchers between 2 and 4% R&D intensity. Please refer to Table 3.1.

According to these projections, by 2010 all EU 25 countries with the exception of Sweden, will have a shortage of S&Es considering current trends in supply and losses for retirement. By 2015, Sweden will continue to generate enough S&Es for its own requirements, as well as Finland and France. All other countries, for both years 2010 and 2015 will have a shortage, when considering current trends. On the other hand, considering the EU25 countries as a whole, there will be an improvement in numbers of S&Es from 2010 to 2015, as countries approach their 3% R&D targets.

Considering that countries that have an intensity level of R&D between 2 and 4% of GDP have approximately 25% of its S&Es going to research[32], we extrapolated numbers obtained through the baseline for S&Es into numbers of researchers. By doing this simple exercise, the shortage of researchers throughout the EU25 can be assessed at that level of R&D intensity. By 2010, Belgium, France, Germany, Ireland, the Netherlands and the UK will generate enough researchers if present trends continue and if in fact 25% of S&Es end up in research. By 2015, the same countries plus Sweden, will have enough numbers of researches for their needs. All other countries will be behind in their required quotas.

Table 3.5 summarizes Baseline calculations as well as required numbers of researchers considering R&D intensity between 2 and 4%.

[32] As per Table 3.1 calculations.

Table 3.5. Number of researchers in years 2010 and 2015 – Baseline projections.

	N. Researchers required	N. Researchers projected - Baseline*	Shortage/ Excess	N. Researchers required	N. Researchers projected - Baseline*	Shortage/ Excess
	2010	2010	2010	2015	2015	2015
Austria	58,700	33,655	25,045	58,700	37,147	21,553
Belgium	71,217	87,556	(6,339)	71,217	90,724	(19,507)
Cyprus	3,268	3,811	(543)	9,803	3,843	5,960
Czech Rep.	55,836	44,432	11,404	81,314	47,234	34,080
Denmark	47,822	39,959	7,863	81,314	41,995	39,319
Estonia	11,836	5,897	5,939	18,689	6,933	11,756
Finland	59,213	48,961	10,253	59,213	53,336	5,878
France	327,498	434,099	(106,601)	327,498	535,066	(207,568)
Germany	490,697	525,775	(35,078)	490,697	533,083	(42,386)
Greece	74,507	51,602	22,906	149,014	54,348	94,666
Hungary	62,223	42,743	19,480	103,705	42,370	61,335
Ireland	33,721	47,190	(13,469)	40,465	58,278	(17,813)
Italy	246,725	230,620	16,106	296,070	251,549	44,521
Latvia	20,089	10,980	9,109	40,179	12,397	27,782
Lithuania	26,792	24,197	2,595	40,188	29,983	10,206
Luxembourg	3,846	2,129	1,717	3,846	1,821	2,025
Malta	1,063	1,037	26	4,252	1,044	3,208
Netherlands	95,054	122,642	(27,588)	95,055	122,070	(27,015)
Poland	284,422	154,047	130,375	517,130	182,991	334,139
Portugal	88,483	51,014	37,469	147,471	58,581	88,890
Slovakia	61,249	20,856	40,393	102,082	24,961	77,121
Slovenia	12,087	11,240	847	12,087	11,574	513
Spain	320,700	274,519	46,181	481,050	302,210	178,840
Sweden	77,052	74,855	2,197	77,052	82,353	(5,301)
UK	364,066	436,925	(72,859)	436,880	519,693	(82,813)
Total EU25 (SUM)	2,898,166	2,780,739	117,427	3,744,971	3,105,582	639,389
EU25**	**2,898,166**	**2,783,551**	**114,615**	**3,744,971**	**3,100,603**	**644,368**

* Calculated as 25% of numbers of S&Es
**Calculated for EU25 as a whole

In terms of numbers of researchers required by 2010 and 2015 and considering the relation of 25% between numbers of S&Es and numbers of researchers when countries are between 2 and 4% of R&D in relation to GDP, there will be a shortage of approximately 117 000 researchers by 2010 and 640 000 by 2015 for the whole EU25. Nevertheless, countries such as Belgium, France, Germany, Ireland, Netherlands and the UK will have more researchers than their requirements. When considering the year 2015, the same countries will again present an excess of researchers in relation to their needs.

This picture is only valid if in fact 25% on average of all S&Es end up in research. If this proportion is not maintained, then these prognostics may change dramatically.

In summary, after recalculating numbers of S&Es projected for 2010 and 2015 and taking into account the relationship between numbers of researchers and numbers of S&Es at R&D intensity between 2 and 4%, there will be a gap of 7.5 million S&Es by 2015. Consequently, the EU25 as a whole, and individual countries will need to assess this difference and the possible alternatives at hand to close this gap.

Important indicators for controlling stocks of S&Es:
In this section, when calculating the baseline projection for numbers of S&Es and researchers, three main indicators were considered: S&Es graduates, demographic age cohorts and retirement age.

4.0 MODULE ON DOMESTIC HIGHER EDUCATION

One of the principal ways to increase the pool of S&E workers is to increase the supply of national graduates in S&E disciplines[33]. In order to increase the supply, more students must be attracted to the S&E programmes at the tertiary level, which would include drawing them away from other programme areas to S&E[34]. Enrolment into S&E programmes might be increased by making S&E careers more attractive by increasing salaries and/or by increasing awareness of the benefits of S&E for society as a whole and for an individual's pursuit of an interesting and successful career.

This module examines the factors that influence the supply of national citizens who graduate with a tertiary degree in an S&E field. Within each EU country (see Figure 4.1), the domestic higher education system is mostly fed by recent graduates from domestic secondary schools. There are also an increasing number of mature students entering tertiary education. Increases or decreases in the number of S&E students are influenced not only by demographics (i.e., the number of young people within specific age cohorts), but also by the popularity of science as a subject at secondary schools and tertiary institutes which is influenced by general social attitudes towards science.

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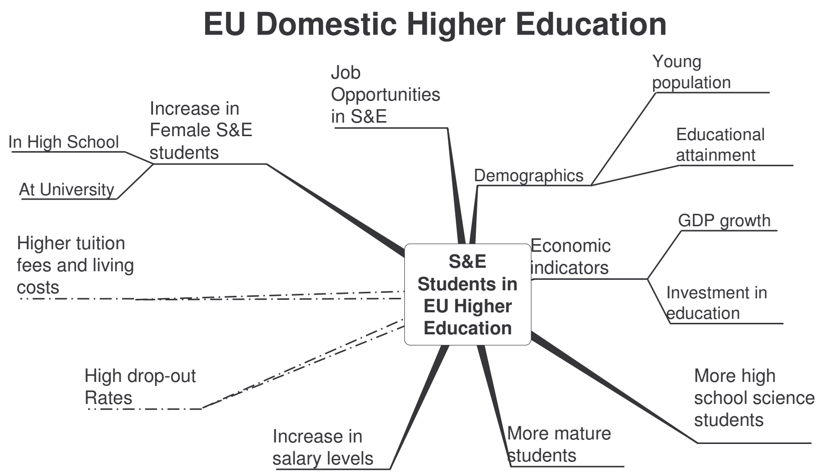
[33] Paradoxically, the European Union produces more science and engineering graduates than the United States, but has fewer researchers in the labour market (EC, 2005b). For example, according to the National Science Foundation (NSF), in 1998 the share of 24-year-olds with S&E degrees was about 40% higher in the UK than in the US (NSF, 2000).

[34] However, this is a challenge, as a recent study (Sjoberg, 2002) examining how 13-year-old pupils perceive science and scientists indicated: children in developed countries are very choosy about their interests, and boys and girls likes and dislikes differ considerably. Another recent study (as part of ROSE, an international project supported by the Norwegian government and the University of Oslo, see http://www.ils.uio.no/english/rose/) covering a range of European and non-European countries found that most 15-year-olds think science is important, but many children from developed countries have negative experiences with science at school, and they do not want to become scientists. Conversely, in many developing countries science is popular at school and as a future career option, also among girls.

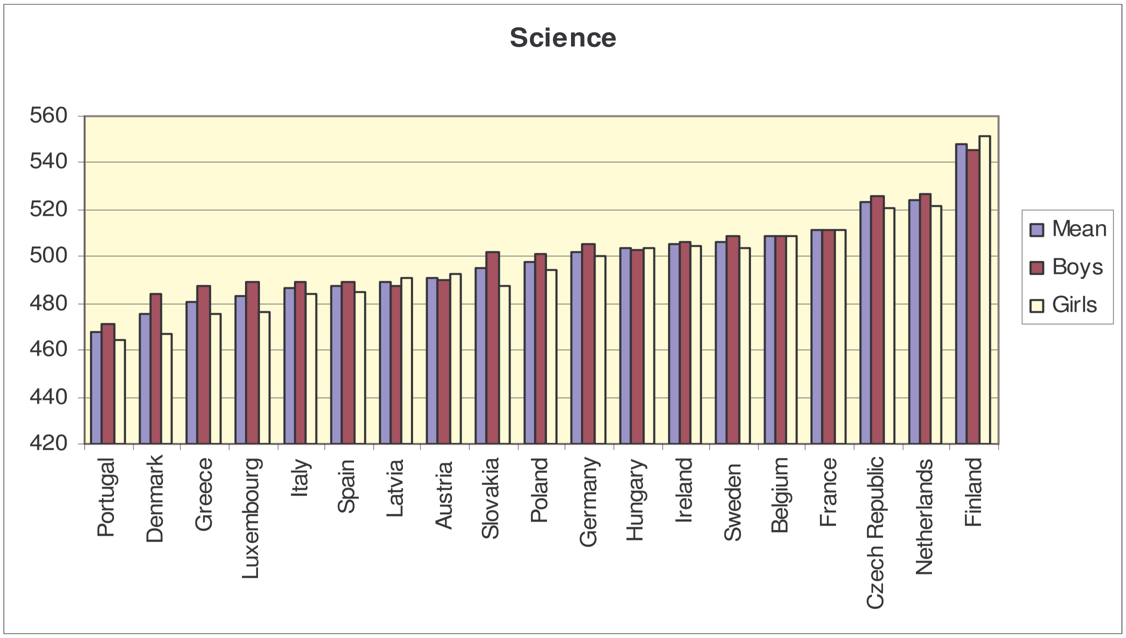
Figure 4.1. Module 1 – Domestic higher education.

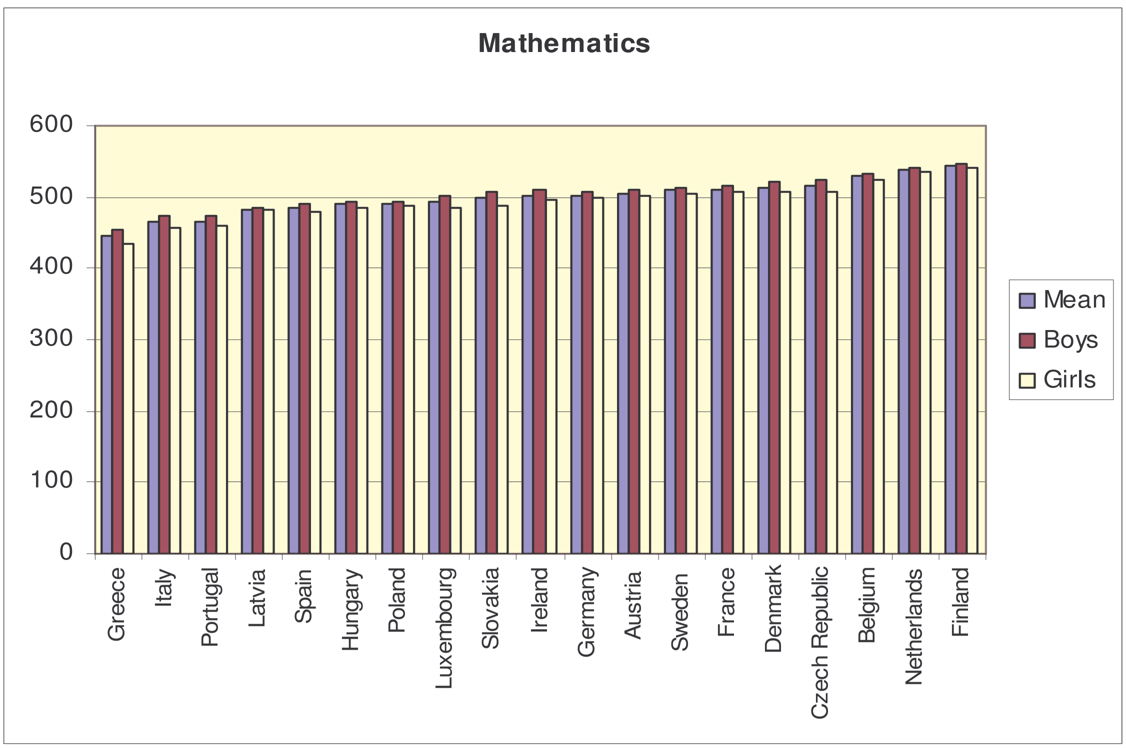


Note: Dashed line indicates a negative effect.

Figure 4.2 shows the most recent OECD Programme for International Student Assessment (PISA) results of the academic performance of 15-year-old boys and girls in the study of science and mathematics. An increase in the science aptitude of children at an early age can stimulate the future supply of scientists and engineers. As can be seen from the results, in most countries boys do a little bit better than girls in this test. Also note that the results indicate that the range for science aptitude is wider than the range for math skills.

Figure 4.2. Performance of 15-year-olds in science and mathematics (PISA 2003).

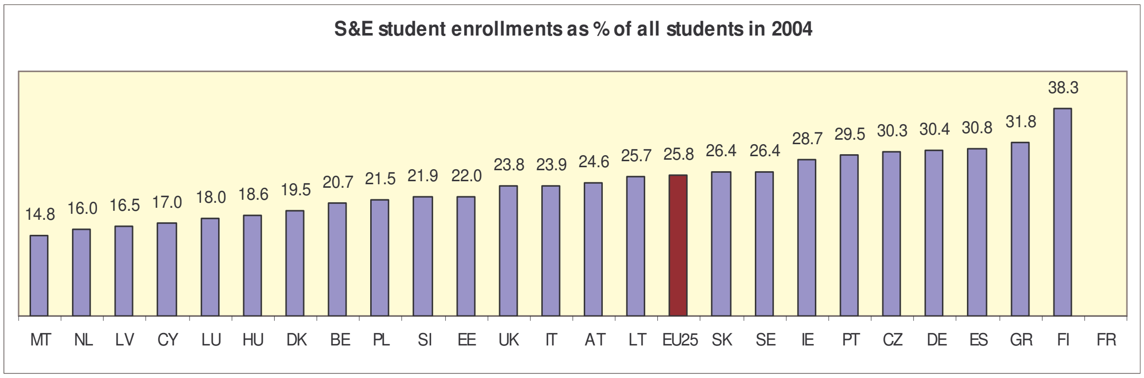




Source: OECD PISA website (http://www.pisa.oecd.org).

The share of tertiary students enrolling in S&E over the last decade has remained relatively constant.[35] Figure 4.3 depicts the situation for 2004, where on average, a quarter (25.8%) of all EU students studied science or engineering. The range was quite wide, from approximately 15% in Malta to more than 35% in Finland. In 2003, S&E graduates took 24.2% of all degrees awarded in the EU (EC, 2005a)[36].

Figure 4.3. Science and engineering student enrolments in higher education in the EU in 2004.



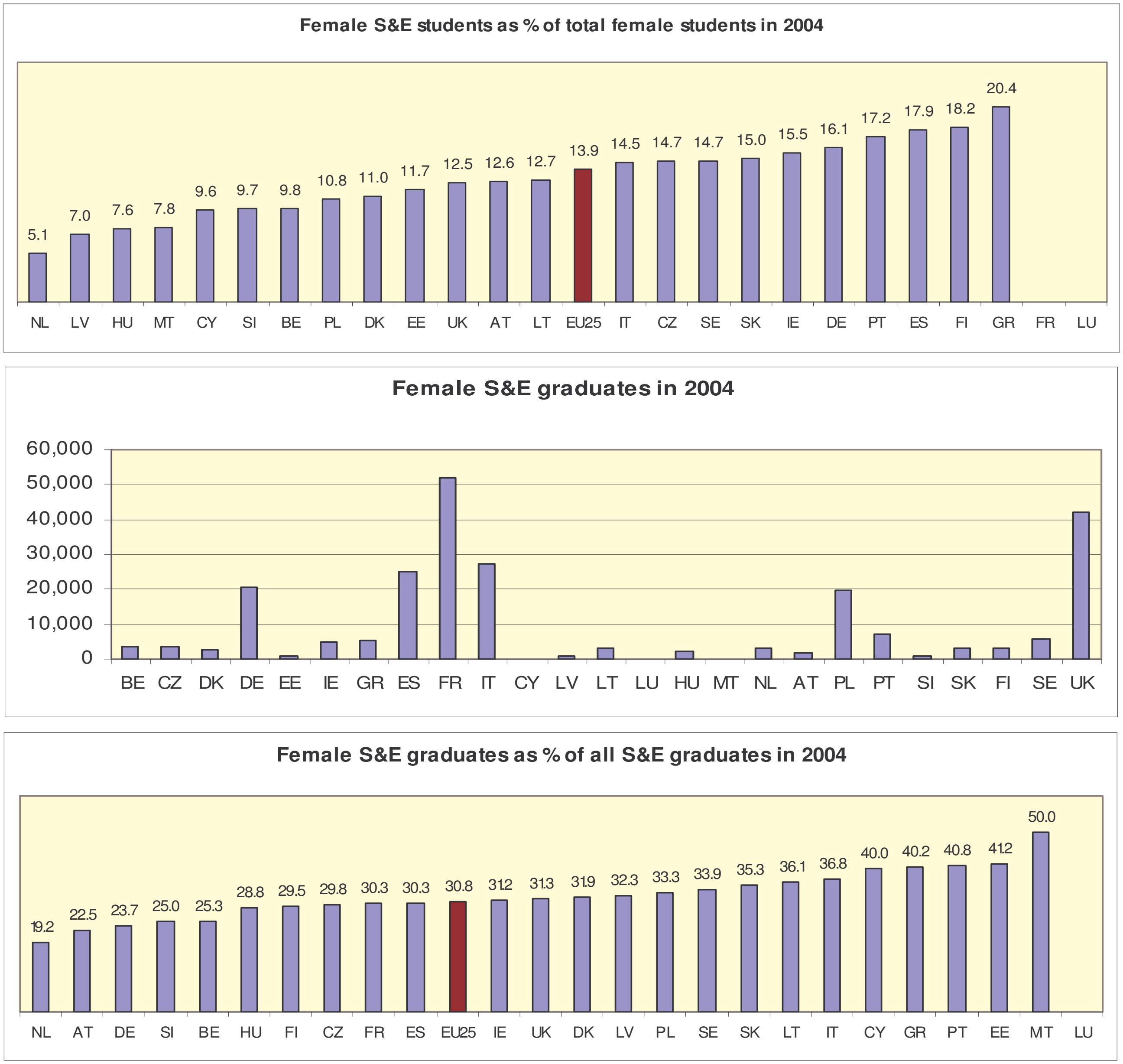
Note: Data for France is missing; data for Luxembourg are for 2002.
Source: Eurostat

An increasingly important method that should be used to increase the supply of S&E personnel is the increase and promotion of the number of girls and women studying science subjects. Although women outnumber men in tertiary education[37], Eurostat data shows that the proportion of female graduates in S&E fields remains fairly low (see Figure 4.4 for data on female S&E enrolments and graduates in 2004). However, between 1998 and 2004 there was a small increase in the number of EU-25 female S&E graduates, with 29% of all S&E graduates being women in 1998 and 31% in 2004. Portugal had the highest proportion of female S&E graduates in 2004 at 41% and the Netherlands had the lowest at 20%.[38] Figure 4.4 also shows that the proportion of women studying S&E subjects varies greatly between the EU countries. For example, in 2004, it only varied from approximately 5% in the Netherlands to approximately 20% in Greece. However, if one looks into the near future, it can be estimated that by 2015 the number of young people of secondary school age (aged 10-14) will decrease in most EU countries (decreasing by 12% in the EU-25), especially within the new member states (Eurydice,

[35] The overall proportion of EU population with tertiary education (23%) is considerably less than in the US (38%) or in Japan (37%) (Hollanders and Arundel, 2007 figures are for 2005), although it has been growing at a higher rate, annually by 3.1% on average between 1997 and 2002, when corresponding figure for the US is 2.2% and 0.1% for Japan (EC, 2005b).
[36] However, the corresponding figure for the US is only 18.5%, and 23.1% for Japan (EC, 2005a).
[37] In 2002, all EU-25 countries for which data were available had more new female graduates than male graduates (Eurydice, 2005). In the whole EU in 2001, there were 136 women graduating for every 100 men.
[38] The absolute numbers of female S&E graduates also show an increase (Eurostat).

2005). Because of this bottleneck, it is even more important to the survival of the S&E fields that as many young women as possible choose science and engineering, both for their education and as a career.

Figure 4.4. Female science and engineering students and graduates in 2004.

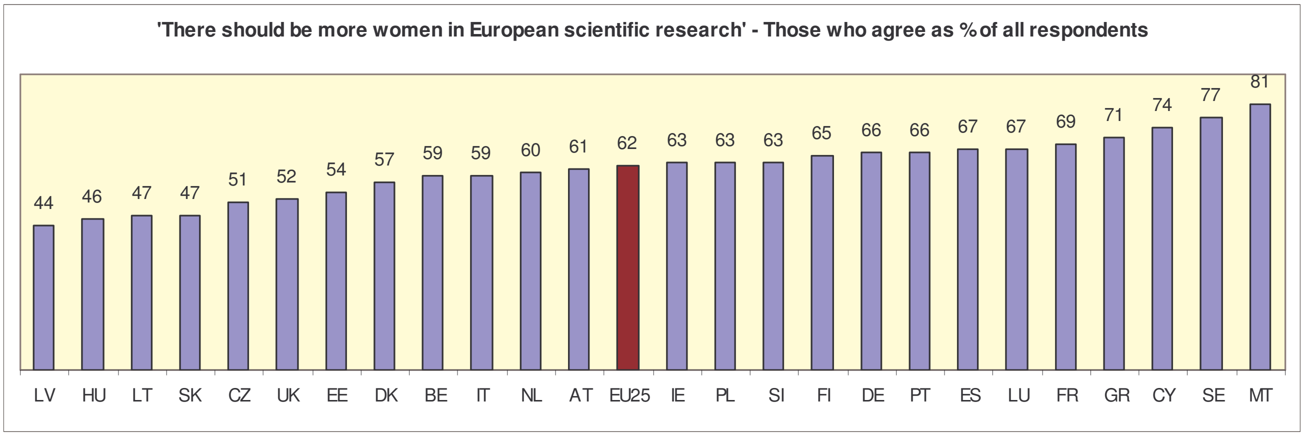


Notes: First graph: for France and Luxembourg the data are missing.
Second and third graphs: for Luxembourg the data are missing, for Finland, France and Malta the data are for 2003.
Source: Eurostat.

Figure 4.5 shows Europeans' attitudes towards increasing the number of women in scientific research. Clearly, there is potential to do so given that the majority of the EU-

25 would like to see more women in science. However, it is interesting to note that there is a wide range of support from an approximate rate as low as 45% in Latvia and as high as 80% in Malta.

Figure 4.5. Attitudes towards women in science.



Source: Special Eurobarometer 224 (Europeans, Science and Technology), June 2005.

Other factors that can influence the supply of S&E graduates include domestic policies on tuition fees, general living costs, spending on higher education , and the image (true or false) associated with scientists and engineers (i.e., earnings, rate of success in their career). Potential increases to the number of S&E graduates might be realized by decreasing the relatively high drop out rate in European higher education[39] and as such should also be taken into account. Drop out rates at EU universities and within degree programs vary from just under 20% to more than 60% (Teichler, 2000). Finally, the unified BA/MA/PhD model under the Bologna process might also be a method to increase both enrolment and graduation rates, as more students view Bachelor programs as a viable option (EC, 2005b).

Currently, 15% of young people (of 18-24 years) in Europe are early school leavers (i.e., for EU-25 in 2005, according to EC, 2006c). The EU has made a commitment to get a third of these people to stay in education[40].

[39] Survival rates are calculated as the number of graduates/number of new entrants at the typical age of entrance. In 2000, the rate was 66% for 13 EU countries for which data existed, compared to an OECD average of 70% and a rate of 94% for Japan (EC, 2005b). The proportions varied greatly among EU countries.

[40] If this was achieved by 2015 (the original goal is 2010, but 2015 is perhaps more realistic), there would be another 2 million students in the EU higher education system, and some of these students would have chosen to study science and engineering.

Mature students[41] are an increasing source of graduates in many countries. For example, there has been a rapid increase in the number of mature students in the last 20 years in the UK, due partly to policies intended to expand the higher education system to a larger population. However, Purcell et al. (2003) and others have found that mature students often have difficulties in securing their initial graduate jobs and when they do, they receive a smaller financial benefit for their degrees.[42] On the other hand, it seems that over time the differences between 'traditional' student graduates and mature student graduates converge at least to some extent. Additionally, mature students tend to be more loyal to their employees than the 'traditional' graduates (Purcell et al., 2003). In any case, the greater the number of mature student graduates, the larger the pool of potential scientists and engineers.

The introduction of tuition fees is one of the more controversial issues in Europe. Increasing fees could potentially reduce enrolment. In the UK, the increase in tuition fees from 1,200 to 3,000 pounds (£) led to a decrease in enrolments by 3.7% between 2005 and 2006.[43] [44] On the other hand, there is recent evidence from the US that a gradual increase in tuition fees does not affect enrolments over the long term and might in fact increase the prestige of the universities in question. Furthermore, and in line with what has been happening in the United States, while higher fees may have deterred students from attending university last in the UK last year, they may not have a long lasting impact, given that the latest figures show a 6.4% rise in applications for the next academic year. The increase in applications was particularly important for the science and math subjects which were previously struggling. The latest increase in applications might be related to the fact that the wealthy, middle-class students continue to dominate admissions, particularly at elite institutions.[45] The increase in fees in the UK has been justified as necessary to meet the challenges of university expansion and to maintain its position and the quality of its education. The UK experience, as the US experience, seems to indicate that increasing tuition fees does not affect numbers of enrolments over the long term.

4.1 Indicators

Indicators on the potential supply of S&E personnel from the domestic educational system include both demographic and educational indicators.

[41] There is no universal definition for the term 'mature student', but generally, the term refers to someone commencing his/her university studies several years after completing secondary school. In the study by Purcell et al (2003), 'young mature graduates' referred to those graduating between ages 24 and 30, and 'older mature graduates' referred to those getting their first degrees after the age of 30.

[42] Although they are also apparently less likely to highlight the importance of an attractive salary (Purcell et al, 2003).

[43] The Guardian, 19 October 2006.

[44] Increasing tuition fees, would of course also increase the 'private investment' in EU higher education, which is so far from the levels in the US, where tuition fees are much higher (in fact, they were around 3,800 euros in public universities in 2004 according to EC, 2005b (quoting the Guardian newspaper on p. 22).

[45] Guardian Unlimited, February 14th 2007 'Top-up fees - the year after'

The first two sets of data were used for the baseline simulation to estimate the potential supply of scientists and engineers in the near future:

- *S&E graduates*: These data are also available broken down by gender and level (ISCED97 5a, 5b and 6)[46]. Level 5a provides graduates with the level of education required for professions with high skills requirements so that they can enter into advanced research programmes (level 6). Although level 5b is also considered tertiary education, the 5b category is shorter in duration than 5a and it focuses on occupationally specific skills (mainly practical skills) for entry into the labour market. If the 5b graduate wants to pursue advanced research programmes or acquire high skills, he / she would have to complete 5a programmes.

- *Demographic age cohorts*: Data on the size of age cohorts between 15 and 49 years of age provide information on the number of potential tertiary students. These data are available for different age brackets from Eurostat.

This following set of indicators can be used to measure the potential effect of policy intervention:

- *Secondary school science students*: The higher the numbers of students studying science in secondary school, the higher the potential input for tertiary science and engineering studies. Furthermore, changing attitudes towards a girl who chooses science at this level can provide some indication of the number of women who chose to study science at the tertiary level. Currently, these data are only available at an overall ISCED97 level 3 (upper secondary). A breakdown of the data to levels 3a (high school), 3b and 3c[47] is required to assess the impact of changing attitudes on tertiary science and engineering students. Therefore, these data were not used for our current simulations.
- *Participation rates in tertiary S&E programmes*: Participation rates can be used to develop more dynamic indicators such as the participation of men compared to women and the way in which these indicators have changed over time. These data are available from Eurostat.
- *Math, science and technology related fields of study as a proportion of tertiary education*: the share of maths, sciences and technology related

[46] There are some problems with counting PhD students (ISCED97 level 6) though. Kelo, Teichler and Wächter (2006) note that there is a lot of variety among European countries with some countries counting almost all doctoral students and others counting only those on taught courses, or those not being employed at the same time. In some countries it is mostly up to the students themselves whether to register as doctoral students before getting their degrees.
[47] ISCED97 level 3a generally leads to level 5a, 3b to 5b and 3c to ISCED level 4 or other level 3 programs.

programmes in relation to total fields at tertiary level. These data are available from Eurostat.

- *Number of mature tertiary students:* This data is currently available from Eurostat defined either by age groups or by field of study, but not combined as both age and field of study.
- *Survival rates:* Share of students entering tertiary S&E fields that complete an S&E degree. This indicator is available from the OECD, but is not currently available by field of study.
- *Youth and mature education attainment:* Percentage of a population cohort that have at a minimum, completed upper secondary education. These data are available from Eurostat.

The actual supply of S&E graduates will also depend on a set of indicators based on the attractiveness of science (including image and potential salary rates) , and the influence of tuition fees, salary increases for graduates and other factors based on the decision to pursue a tertiary education. This data is generally only available as point data, i.e. for one year.

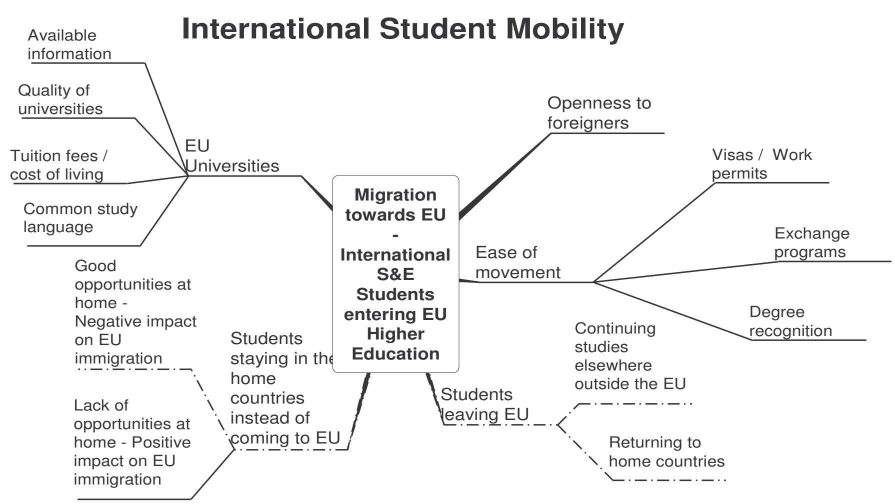
Simulations concerning domestic and international students were conducted together, as part of the data available was aggregated (i.e., not broken down by student's country of citizenship). When data was not aggregated, their impact on the numbers of S&E graduates was considered separately. Simulations on domestic and international students are included in Section 5.2.

5.0 MODULE ON INTERNATIONAL STUDENT MOBILITY

The United States has benefited from the number of international S&E students studying in the United States, as they become a source of employees for the S&E sector upon their successful graduation. The EU could take a similar approach and increase its supply of S&E personnel by encouraging more non-EU students to study within the EU[48] and by making it easier for them to work in the EU after graduation[49].

International student mobility from within or outside the EU-25 (see Figure 5.1), is partly influenced by similar factors experienced by domestic students, such as tuition fees and general living costs, but is mostly influenced by a variety of different factors. A study by the OECD (2001) indicates that the driving forces of outward student mobility in Europe and elsewhere are related to the size of the country (i.e., the smaller the country size the greater the influence) and the institutional and geographical proximity, whereas the situation is much more diverse with respect to inward student mobility.

Figure 5.1. Module 2 – International student mobility.



Note: Dashed line indicates a negative effect.

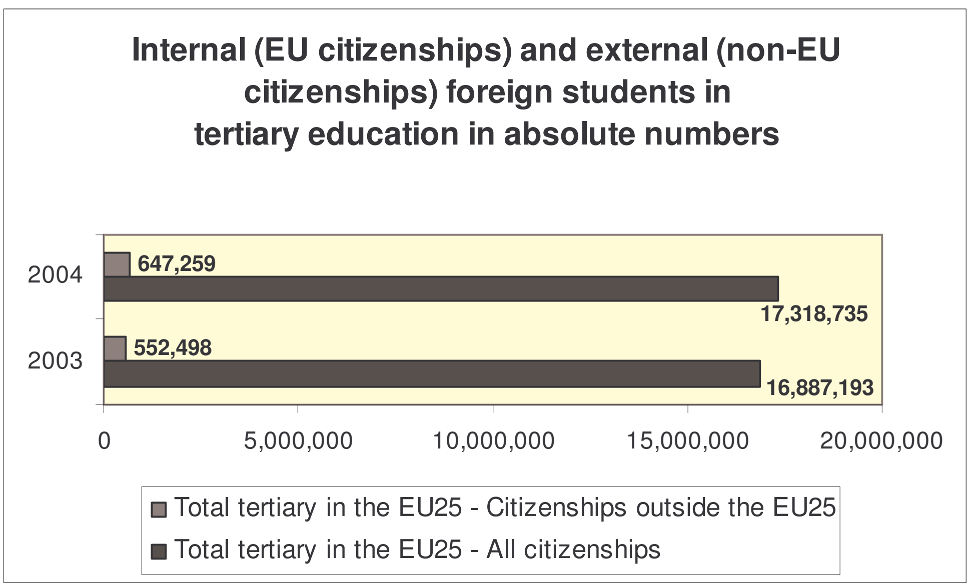
International students choose their host universities or host countries by their reputation, the image they have of the openness of the country in question, the language of

[48] Around 50% of international students in Europe are mobile EU students, i.e. originate from another EU country (Vlk, 2006). Such mobility is also beneficial, and the EU has a target according to which 10% of the student population should be mobile one way or another (EC, 2006c). Although ‘internal’ EU student mobility may increase the total number of S&E graduates in the block, as discussed in the text, we concentrate more on foreign students coming from outside the EU.
[49] Additionally, some of these students (PhD students) also contribute to R&D activities in their host countries.

instruction, the ease of movement (i.e., problems/excessive paperwork with visas, recognition of final degrees, existence of exchange programs), and finally, the amount of information they can find about certain universities or countries. Most of the EU25 tertiary education is populated with students whose citizenships is also from within the EU25 pool. Although there is mobility of students at tertiary level within the EU25, the majority of this mobility comes from within the EU25 pool of students. Figure 5.2 illustrates the participation of students with EU25 citizenships and students with non-EU25 citizenships in tertiary education in the EU25 countries.

Several factors in the home country will influence the decision to study abroad and to remain in the foreign country after graduation. These include a lack of opportunities to study at home (i.e., in terms of programs or places offered) and post-study options for employment. Internal EU student mobility is relevant here, given that the future possibility for an S&E career within certain countries may be bleaker than in others. Sufficient mobility helps to ensure that students look for the best opportunities for themselves, and should therefore increase the total number of graduates in the EU. Finally, there is also outward international student mobility (exiting the EU) caused by students returning to their home countries before or after graduation , and by EU citizens leaving the EU to pursue studies or work abroad.

Figure 5.2. Internal (EU citizenships) and external (non-EU citizenships) foreign tertiary students in the EU.

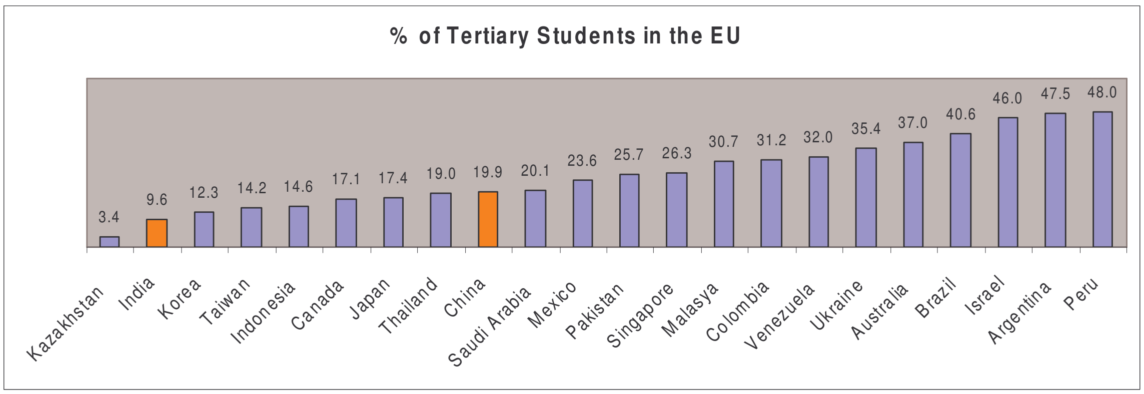


Note: Most foreign students at tertiary level in the EU25 are also EU25 citizens. There is a minority of non-EU25 students in the EU25 tertiary education: In 2003, 3.3% of all foreign tertiary students in the EU25 had a non-EU25 citizenship, up to 3.7% in 2004.
Source: Eurostat and own calculations.

In cases where within the pool of foreign tertiary students in the EU25 students that do not have an EU25 citizenship, a few of the student's countries tend to send a substantial part of their tertiary abroad to the EU instead of other destinations. For example, of all tertiary students that Peru sent abroad in 2003, 48% of them chose to go to the EU, while just 19.9% of all Chinese students sent abroad to attend tertiary education in 2003 opted to go to the EU.

Figure 5.3 indicates the percentage of students in tertiary education abroad that choose to study in the EU instead of other destination alternatives.

Figure 5.3. Non EU25 tertiary students going abroad – EU as a destination (%).



Source: Atlas of Student Mobility - 2003

Although countries such as Argentina and Peru have high percentages of their tertiary students sent abroad to study in the EU, when the absolute numbers are considered, they do not constitute as being the main suppliers of tertiary students in the EU25 countries. Table 5.1 shows in absolute numbers the main suppliers of tertiary students from outside the EU25. In this case, Chinese students come out at the top.

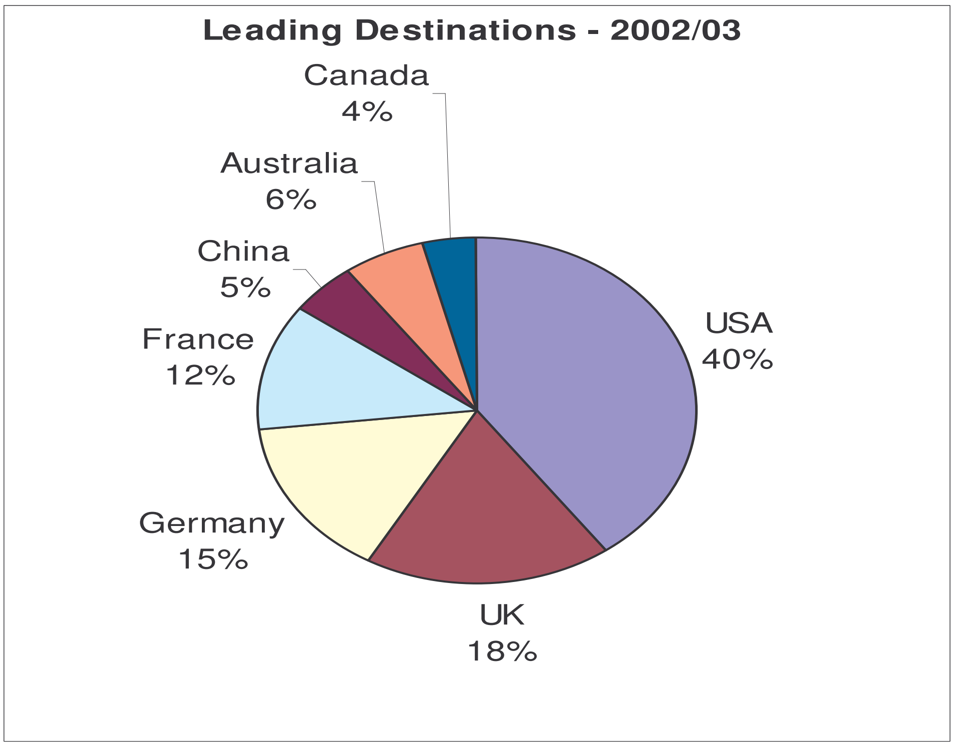
Table 5.1. Sources of tertiary students

Main sources of tertiary students from outside the EU25 in the EU25 - 2004	
Country of origin	**Absolute numbers in the EU**
China	96,077
United States	26,183
India	22,277
Japan	12,689
Korea	12,170
Hong Kong	10,625
Norway	10,012
Brazil	9,405

Source: Eurostat.

When considering a study abroad, students seem to have a clear preference for studying in English speaking countries. Furthermore, the same countries that offer education in English are those that have the largest numbers of universities that rank among the Top 500 (i.e., ranking of the 500 best universities around the world).[50] The United States takes the first place with its 167 universities, followed by the UK with its 43 universities and Canada with its 22 universities. According to data from the Atlas of Student Mobility for 2002/2003 (see Figure 5.4), 68% of mobile students (students outside their countries of citizenship) chose an English-speaking country as their destination[51].

Figure 5.4. Leading destinations for students going abroad.



Source: Atlas Student Mobility

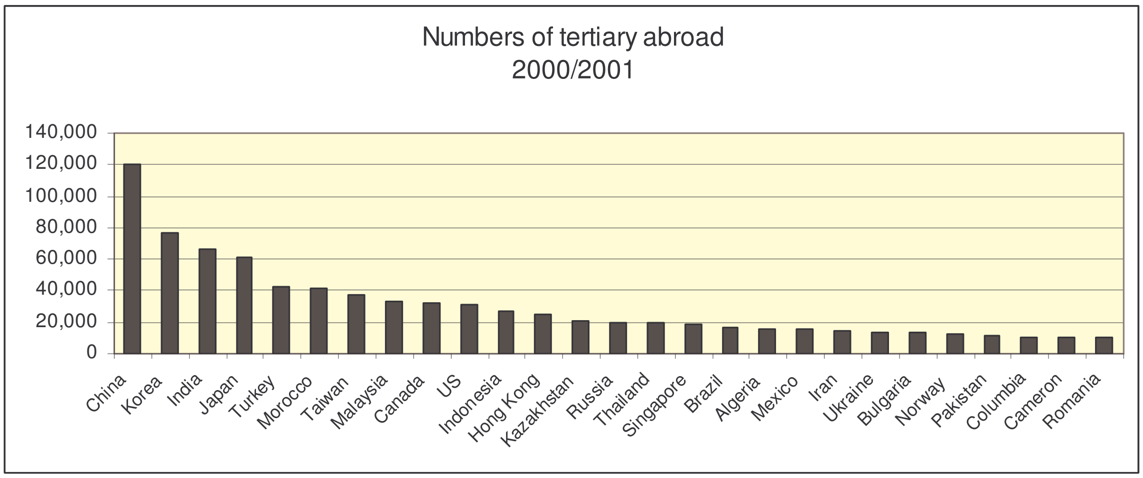
International student mobility has doubled in the last 20 years (Vlk, 2006) with the OECD countries. The global demand for international higher education is projected to continue rising at a rapid pace, with a four-fold increase in the estimated number of international students (from 1.8 million to 7.2 million)[52] between 2000 and 2025, 70% of which are estimated to come from Asia (Böhm et al., 2002).

[50] 'Top 500 World Universities' – 2005 – Institute of Higher Education, Shangai Jiao Tong University.
[51] Böhm et al., 2002 estimate the share of the major English-speaking destination countries (the US, the UK, Australia, Canada and New Zealand) to be considerably lower, at 46.8% in 2003. They forecast that it will decrease to 44.3% by 2025.
[52] The estimated number of international students in 2015 is over 4 million.

Discussions in a recent study conducted for the European Commission coupled with the perceptions of EU higher education in Asia, Latin America and Russia (Muche et al., 2006)[53] suggest that there is unrealised potential in getting students to come to the European Union. Although a net recipient of tertiary students similar to the US[54], the EU still lags behind the US in attracting foreign students, especially students from Asia[55].

Although in absolute numbers China and India are the main sources of tertiary students abroad, the EU has a limited participation when it comes to attracting these students to its member's states.

Figure 5.5. Tertiary students abroad – Potential sources for the EU.



Source: Atlas of Student Mobility

The United States continues to be the main destination for tertiary students. The majority of tertiary students from Asia, as discussed, opt to study in the US and consider it their main destination. Figure 5.6 illustrates the percentages of students per country of origin that chose to pursue an education in the US. Eighty two percent of the total number of

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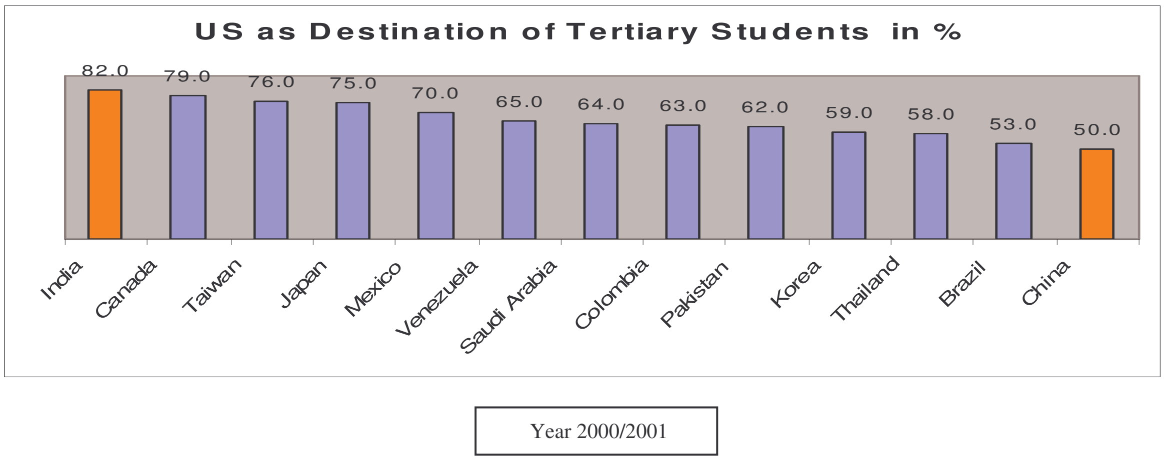
53 The target group for the study included students wanting to or already studying abroad, university staff and school teachers.

54 In the 1980s, the number of European students studying in the United States was larger than the number of US students studying in Europe (Haug and Tauch, 2001), but such brain drain seems to have levelled off to some extent, as more recent figures show the numbers of student entering the EU and the US to be more or less equal. Recent data put the flows at just under 400,000 (EC, 2003c). However, Moguerou (2006) finds that this is not the case for PhD student flows between Europe and the US, to the advantage of the latter.

55 Other data show that the EU is also behind the US as a destination for studies in S&E. For example, 55.8% of doctoral engineering degrees in the US were earned by foreign students in 2001, as compared to 10.7% in Germany or 22.0% in France (in 1999). The UK had a similar proportion (51.2%) to the US (Moguerou, 2006).

Indians going abroad for their tertiary education opted to study in the US. For Chinese students, this proportion was 50% in 2000.[56]

Figure 5.6. US as a study destination.



Source: Atlas of Student Mobility

Moreover, foreign students in Europe are concentrated in just a few countries, mainly the UK, Germany and France.[57] The study by Muche et al. (2006) found overall, that information on Europe and its higher education system is missing or hard to access. The above three countries were practically the only EU-25 countries for which students in the potential supply countries were able to access good information on higher education. There was not enough information about studying in the new EU member states[58], nor was there adequate information about English-taught programs in non-English speaking EU countries[59].

According to the above study, when Russian and Latin American students considered the potential supply regions for foreign students, they generally placed Europe at the top of their study destinations, whereas Asian students preferred the US, considering European cultural and language diversity a ‘problem’. Other general factors that hampered study in Europe were related to finances and immigration policies[60]. The most important overall criteria for choosing study destinations was the quality of education, reputation of degrees

[56] Atlas of Student Mobility.
[57] Europe is still seen more as a range of different countries (in terms of quality or education, costs and student support) than as a block with similar attributes when it comes to deciding where to go to study.
[58] Not surprisingly, there was also little interest in studying in these countries.
[59] Cai (2005) also argues that lack of information in China about European study programs significantly affects the flows of Chinese students to Europe.
[60] Especially after the events of 9/11, the immigration policies of many countries, most notably the US, have tightened.

, and the prestige of the university, whereas the world region played an insignificant role.[61]

The obvious source countries for potential new international students in the EU are China and India. These two countries, together with South Korea, have been the largest suppliers of international students for the OECD countries (OECD, 2004)[62]. However, as estimated by Khadria (2004), in 2001, almost 80% of the Indian students enrolling in tertiary education in the OECD countries went to the US. Additionally, the rapid growth of universities in Asian countries is challenging Europe and the US in terms of attracting doctoral candidates in S&E[63]. This may be partly due to the fact that the numbers of Chinese students in the UK have levelled out after a strong increase in recent years. On the other hYao (2004) argues that as the competition for study places in Chinese universities gets tighter, some of the left-over students may be heading overseas, therefore lowering the overall quality of Chinese students studying outside of China. On a similar note, Cai (2005) predicts that China's growing middle class might shift the source of Chinese overseas students from those that are more academically inclined to those from wealthy families.

The participants in the EC commissioned study (Muche et al., 2006) recommended three essential measures to increase Europe's attractiveness as a study destination: an information portal about EU study programs, EU-wide rankings of universities , and financial support for non-EU students. The study itself further recommended that a European higher education 'brand' be created, immigration and visa policies made more flexible , and the number of English-taught programs increased. Finally, the EU should look to its strengths in terms of academic study areas and invest in those. For the purposes of increasing the supply of scientists and engineers, it would therefore be important to look to European universities that are strong in the S&E fields.

Finally, as mentioned earlier, openness of a society to ideas or people from other countries can be a significant pull factor for both international students and highly skilled workers (a topic in Section 6). Brandi (2002) concludes from her study of foreign researchers in Italy that skilled migration is considerably influenced not only by the attitudes of the immediate surroundings, but of the whole host society. Oftentimes, feeling welcome within a society can make up for other problems encountered, e.g. to do with bureaucracy. Hooper (2001)[64] argues further that Germany's initial failure to attract

[61] The study participants recommended three essential measures to increase Europe's attractiveness as a study destination: an information portal about EU study programs, EU-wide rankings of universities, and financial support for non-EU students. The study itself recommended further that a European higher education 'brand' should be created, immigration and visa policies made more flexible and number of English-taught programs increased.

[62] South Korea, although not the largest supply country in absolute terms, sent out the highest number of its national students – 18 - for each foreign student received (OECD, 2004).

[63] International graduate admissions survey, US Council of Graduate Schools, Dec 2005.

[64] An article titled 'Germany to offer permanent future to skilled migrants' in the Guardian newspaper on 5 July 2001.

Indian IT specialists was largely caused by and/or due to the image that Indians had of Germany as being an unwelcoming society.

5.1 Indicators

Ideally, the share of foreign students earning EU degrees and remaining in the EU (e.g. number of foreign EU degree recipients that remain in the EU versus the number that leaves the EU upon graduation), should be estimated. Such data are not available EU-wide, but if available, are important for measuring the impact of foreign students on supply. As mentioned, there are data for the US that show that, in the long term, approximately 50% of doctoral degree recipients stay in the US (see Finn, 1997).

Some of the most important indicators for international student mobility are:

- *Proportion of students from outside the EU in European S&E programmes:* data on non-EU students is important for developing dynamic indicators on the popularity of the EU-25 as a destination for S&E studies. These data are available from Eurostat, but are not available by field. Therefore, we have only been able to look at foreign students in all fields of study.
- *Student mobility data*: this data is important for assessing the inward (brain gain) and outward (brain drain) flows between the EU and other countries. As explained in Section 2.1, such data have not been particularly reliable. However, a change in the potential supply of S&E students can also be proxied by, 1) the number of new PhDs in supply countries (increasing opportunities to study at home could reduce the number of students seeking PhDs in the EU), 2) economic growth rates in supply countries (the higher the rate, the more likely it is that graduates in supply countries will find employment opportunities at home, reducing interest in emigrating) , and3) the number of European nationals that opt to acquire their PhDs in the United States. We have used option (3) in our simulations.
- *Data on factors influencing flows of international students*: these data sets are potentially important predictors for incoming student flows and include data on the quality of universities within the EU-25, data on lack of opportunities to study in the students' home countries outside the EU, data on openness of countries towards foreigners in general within the EU, and finally, data on availability of information on European universities. Some of these data can be found, but it is mostly point data, i.e. available only for one year. Data on quality of universities was used in our current simulations.

Other potential influences on inward student flows include common languages between home and host countries. However, students may not actually follow the assumption that common language draws more interest, i.e. they may choose their study country based on a *different* language, which they want to learn. On the other hand, the OECD (2001) notes that science and engineering students may not follow this behaviour, as languages are not an essential part of S&E studies, and these students may in fact prefer common languages.

5.2 Simulations

In order to achieve the necessary numbers of S&Es by 2015, we manipulated a few variables within certain parameters. All manipulations considered variations that are not far from actual parameters given that any drastic change in the variables under study would not be realistic.

Consequently, we first manipulate a group of variables and describe their impact in the final numbers of S&Es and researchers and then we summarize the ones that have the most significant impact on these numbers.

While module 1 looked at domestic education's contribution of the formation of S&Es, module 2 looks into the role of international students in the field. The sum of both modules represents the total numbers of students in the EU25 entering, participating and graduating in tertiary education and more specifically, in the sciences and engineering fields.

We opted to simulate for both modules together, since we are studying the EU25 and not individual countries. Even when considering individual countries within the EU25 group, international students for a certain country includes other EU25 students studying outside his/ her home country. Furthermore, literature on the subject, points out that most international students within the EU come from other EU countries, followed by students from previous European colonies, Asian countries, the United States, Canada and Latin America (except when the destination is the United Kingdom). In short, international students studying in EU countries are mostly Europeans.

As far as education is concerned, the formation of S&Es assumes that this population should have at least a tertiary education. Due to data availability and data classification, we opted to include in our simulations, numbers related to tertiary education classified as 5a and 6 according with ISCED classification.[65] Please refer to our previous discussion on tertiary education classification in section 4.1 – Domestic Higher Education Indicators.

Forecasting numbers of S&E graduates at levels ISCED_5a and 6

The numbers of graduates in any given field are first dependent on population numbers. We start by looking at the total population for the EU25 countries and forecast the present population up to 2015 based on an historical time series since year 1998.

Entrants at level 5a necessarily have upper secondary education and are mostly in the age bracket between 15 to 24 years old (around 80% of total entrants in a given year). The difference in the number of entrants per year is assumed to come from mature students (25 to 49 years old).

[65] ISCED 1997 – International Standard Classification of Education

We start by looking at the three main groups of entrants considering three distinctive cohorts (ages 15 to 19; 20 to 25 and mature students) and then forecast numbers of entrants based on the historical time series projected to 2015.

The youngest cohort entering tertiary education relates to the population age 15 to 19 years old. Any improvements in the share of this population entering tertiary education would create a positive impact in the numbers of entrants from this cohort into tertiary education.

The second cohort entering tertiary education is between 20 and 24 years old. If we consider the indicator Youth Education attainment, which measures the percentage of youth aged 20 to 24 that have completed upper secondary education, then we can also calculate the share of this cohort 'lost for tertiary education'. Any improvements in terms of reducing the number of people in the age cohort of 20 to 24 years old that have not acquired at least upper secondary education would create a positive impact in the numbers of people from this cohort entering ISCED 5a level of education.

The same reasoning can be applied to mature students, our third and last cohort entering tertiary education, classified as entrants in tertiary education between 25 and 49 years old. We opted to cut off the upper level of this cohort at 49 years old, as we assume that students stay, on average, 5 years in tertiary education. By the time a 49 year old would finish tertiary education, he/she would be 54 years old when reintegrated to the labour market and would have less than 10 years by today's average retirement age (61 years old in 2007 - estimated)[66] to be productive before retiring. Data for education attainment for mature students is available for population cohort 25 to 64 years old. We are assuming that the same level of attainment (at least upper secondary education) applies for our chosen age bracket for mature students (between 25 and 49). Any improvements in the levels of educational attainment for the mature cohort would increase the share of this cohort being able to join tertiary education.

Absolute numbers of new entrants in tertiary education – level 5a represent on average, 20% of the total enrolments (in absolute numbers) in a given year. This proportion is considered accurate, since participants in the EU25 take on average 4.8 years to complete tertiary education. Based on projections of students entering tertiary education, we can project enrolments.

Furthermore, the number of foreign students the EU can attract into its borders affects enrolments. The numbers of foreign students in the EU25 have been increasing at an approximate rate of 9.1% per year. Foreign students are attracted to reputable universities. Considering the number of universities the EU25 has within the Top 500 universities according to the Shangai University report[67], we can assume that the more universities the EU would have within this selective group, the more foreign students the EU would be able to attract. Consequently, upgrading the education system, to increase

[66] Projected as per time historical time series – Eurostat database
[67] 'Top 500 World Universities' – 2005 - Institute of Higher Education, Shangai Jiao Tong University.

the number of universities recognized among the Top 500, should increase the numbers of foreign students in the EU25.

Women already represent more than 50% of total enrolments at level 5a. In 2006, projected numbers for women's participation was 55% of total enrolment, a proportion that has been increasing by 0.7% per year.

Graduates for tertiary 5a represent on average 18% of numbers enrolled, which again is compatible with the average stay of around 4.8 years for this type of education.

Drop out rates remained steady at 2% of total enrolments.

Looking at Sciences and Engineering fields[68] as a proportion of total fields in tertiary level 5a, the S&E fields represent on average 24.4 % of total enrolment, a proportion that has been declining on average 1.0 % per year since 1998.

Any change in the proportion of students in the fields of S&E in relation to total fields would have a positive impact in the number of graduates in this field.

Women's participation in tertiary education changes dramatically when we specifically consider their participation in the fields of science and engineering.[69] Women represent on average about 30% of total enrolment in S&E related fields. Furthermore, the participation of women in S&E fields has been declining when compared to their participation in other fields of tertiary 5a education.

Any change in the proportion of women in S&E fields would create a positive impact in the number of graduates in S&E related fields. As women already account for more than 50% of enrolment in total tertiary education at level 5a, it would not be a question of whether to increase women's participation in tertiary education as a whole, but of increasing the proportion of females that opt to go into sciences and engineering courses. In other words, a shift from other fields into S&E related fields.

As for ISCED 6 – Second stage of tertiary education leading to advanced research qualification, enrolments have been increasing on average 1.9 % per year since 1998. Women's participation in ISCED 6 has been on average 44% of total enrolments in 6.

Although lower than the proportion for level 5a, the numbers of females in relation to total enrolment at level 6 have been increasing at the rate of 1.0% per year on average, for the period of 1998 to 2004. If this increase continues at the same rate, the EU25 countries should have 50% of its total level 6 enrolments represented by females by 2011.

In summary, if we considered levels ISCED 5a and 6 total fields of education, women's participation is already at least 50% of total enrolments and if not, it will reach that mark by 2011 (level 6). The only exception is Germany, where the average participation of

[68] According to Eurostat classification: Science, Mathematics and Computing (ef4) as well as Engineering, Manufacturing and Construction (ef5).
[69] According to ISCED (International Standard Classification of Education) 1997, Sciences, Mathematics and Computing, as well as Engineering, Manufacturing and Construction

women at level 5a is still below the EU25 average, representing around 47% of total enrolments at level 5a.

As for participation of S&E related courses in relation to total fields at level 6, sciences and technology fields have been increasing in relation to total fields since 1998, and are expected to represent 42% of total enrolments by 2015. Women's participation in S&E at level 6 has also increased and should represent 43% of total enrolments in S&E level 6 by 2015.

If absolute numbers and female's relative participation in S&E fields at level 6 have been increasing, the only other way to increase participation at level 6 is to create incentives for foreign students to come to the EU for their tertiary level 6 education. Again, the number of universities among the Top 500 according to the Shangai Report 2005 is an important variable when it comes to attracting more foreign students to any educational level.

We assume that around 25% of students enrolled in ISCED 6 will graduate in a certain year, which is compatible with an average of 4 years to complete this level of education.

We also consider in the scenario, the number of PhDs acquired in the USA every year (a loss for EU education) instead of acquiring the same degree qualification within EU borders.

Moreover, a recent increase of around 100% in tuition fees in the United Kingdom has had a negative impact of 3.7% in total enrolments. Any change in tuition fees is bound to negatively impact the numbers of students at all levels.

With these assumptions and variables subject to manipulations, we can forecast numbers of S&E graduates at both levels 5a and 6 until 2015.

Manipulated variables:

1. Increase in shares of new entrants' age 15 to 19 years old in relation to total population in this age bracket. Students entering tertiary education from this age bracket represented approximately 4.1% of this age cohort in 2006 (estimation based on previous years). This proportion has been increasing by a rate of 2.2 % per year. The percentage rate of students in this age cohort that enter tertiary education is low given that very few students between 15 and 17 years old would have had the opportunity to complete secondary education. Normally, a student would be at least 18 by the time he/she finished secondary education.

   In order to increase absolute numbers of entrants coming from this cohort, we changed the average rate of a 2.2% increase per year to 3%. The impact of this change is very limited in terms of absolute numbers of students in this age cohort entering tertiary education. Because of this change, instead of the forecasted number of 10,219,000 new entrants in the period of 2007 to 2015 (if the increase rate would continue at 2.2 %), we would have 10,271,000 new entrants in the same period, an increase of only 52,000 new students in that period.

Increase in percentage of students age 15 to 19 in relation to same age population entering tertiary education by introducing new measures that would reflect an annual increase of 3% per year in this share, against present rate of increase of 2.2% per year.

2. Youth education attainment level - total - Percentage of the population age 20 to 24 having completed at least upper secondary education

Youth Education attainment has been improving at an average rate of 0.51% per year since 1998. This rate can be improved further so that more students could complete their upper secondary education and be eligible to enter tertiary education. If the increase is changed from the actual 0.51% per year to 1 % per year, then more students in this age cohort could join tertiary education.

The impact of this change is more significant in terms of absolute numbers of students in this age cohort entering tertiary education. Because of this change, instead of the forecasted number of 15,145,000 new entrants in the period of 2007 to 2015 (if the increase rate would continue at 0.51%), we would have 15,464,000 new entrants in the same period, an increase of 319,000 new students in that period. Although the impact is important, one has to remember that it takes on average 5 years for a new entrant to graduate. Consequently, any changes in 2007 will only reflect on the final numbers of S&Es by 2012. In conclusion, this measure although important, has a lag effect of 5 years to bring about results.

Improvement in Youth education attainment rates by doubling today's 0.51% yearly increase to 1% per year as from 2007.

3. Mature education attainment level – Percentage of the population age 25 to 64 having completed at least upper secondary education.

Mature education attainment has been improving at an average rate of 1.58% per year since 1998. Again, this rate can be improved further so that a more mature population can acquire the necessary upper secondary education, to be eligible to enter tertiary education.

The impact of this change is less significant in terms of absolute numbers of students in this age cohort entering tertiary education, when compared to the previous pool of new entrants (cohort 20_24). Because of this change, instead of the forecasted number of 6,926,000 new entrants in the period of 2007 to 2015 (if the increase rate would continue at 1.58%), we would have 6,979,000 new entrants in the same period, an increase of 153,000 new students in that period. Again, it will take on average 5 years for these new entrants to graduate.

Improvement in Mature education attainment rates from 1.58 % average increase per year to 2 % as from 2007.

By introducing the above modifications in the three age cohorts that represent the majority of new entrants in tertiary education, there will be a positive impact in the number of new entrants, as demonstrated in figure 5.7 below.

4. Foreign students participation – Increase in the number of universities within EU25 classified in the Top 500 according with the Shangai report - 2005

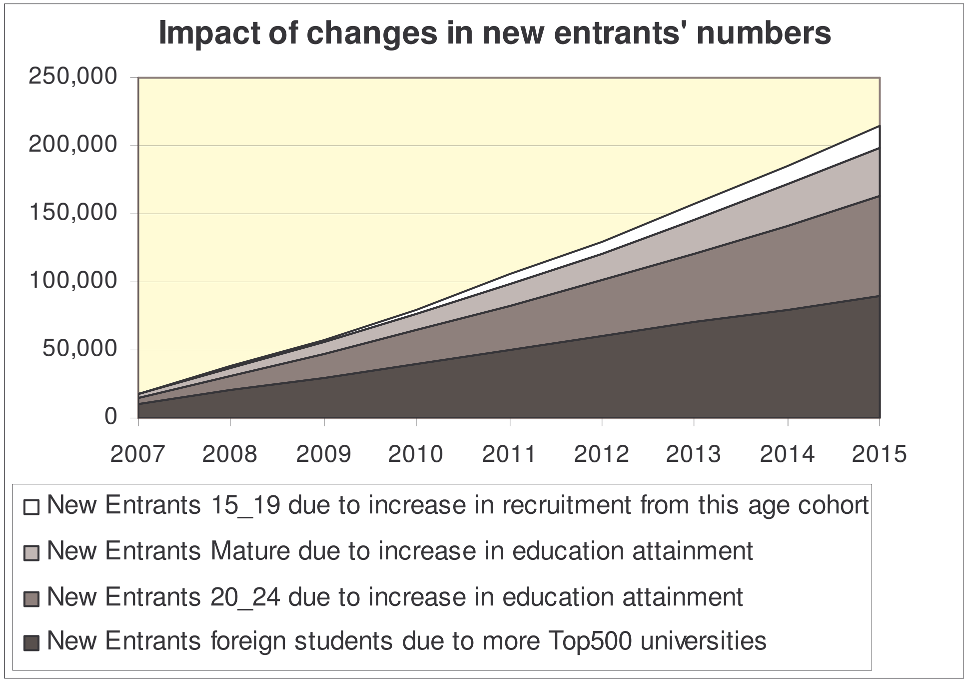
Although foreign students' participation in the EU25 has been increasing on average 9% per year, this increase can be even higher if more universities are classified within the Top 500.

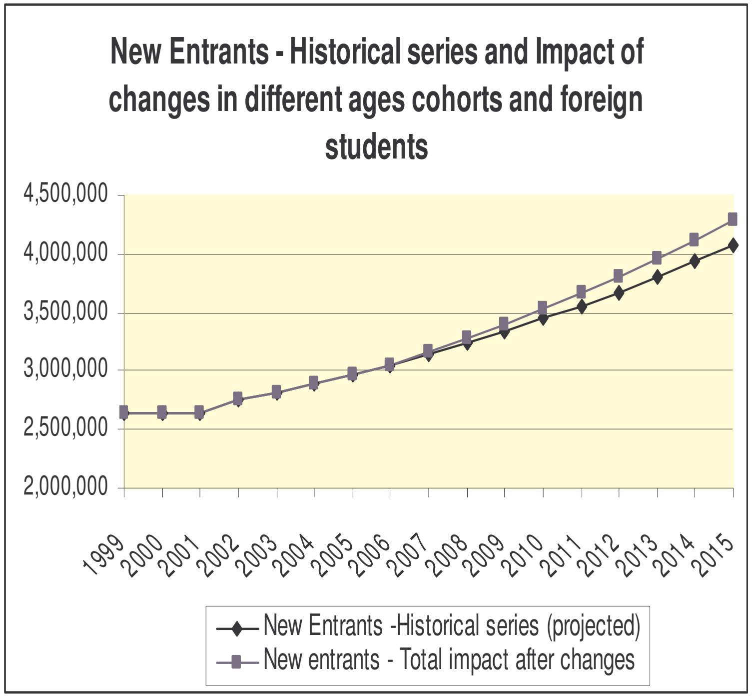
Increase in the number of EU25 universities within the Top 500 by 1% per year as from 2007. – The impact of one new university classified within the Top 500 per year would be equivalent of 5.000[70] new foreign students per year at level ISCED 5A.

Figure 5.7 illustrates the impact of different cohorts in total numbers of entrants, after proposed changes.

[70] According to Eurostat, in 2006 there were approximately 963,000 foreign students in the EU25. In 2005 the EU25 had 193 universities among the Top 500. If we assume that the foreign students were equally distributed among the 193 universities, then there were approximately 5,000 foreign students at each European university among the Top 500.

Figure 5.7. Impact of new entrants.





5. Sciences and Engineering related fields as a proportion of all fields at tertiary 5a – Increase in the participation of these fields in relation to total fields.

The proportion of graduates in Sciences and Engineering represents on average 24.4% of all graduates (all programmes) in tertiary education level 5a, a proportion that has been decreasing by approximately 1.02% per year since 1998.

Increase enrolment in Math, Sciences and Technology fields by 2 % per year as from 2007.

6. Women enrolled in 5a in the fields of S&E in relation to total fields – has been declining by approximately 1.84% per year in relative terms. It is important not just revert this negative growth in participation of women in S&E related fields, but also to increase women's participation in this field by shifting females from other areas of study into sciences and engineering.

Increase women's participation in S&E related fields by 1% per year as from 2007, by shifting women from other areas into S&E fields.

7. Number of foreign students enrolled at level ISCED 6 can be increased by increasing the number of universities in the EU25 among the Top 500.

Increase in the number of EU25 universities within the Top 500 by 1% per year as from 2007. – Impact of each new university classified within the Top 500 would be equivalent to 580 new foreign students per year at level ISCED 6.[71]

8. Bring more Chinese and Indian students that would go to the US otherwise to attend tertiary education (all fields) into the EU25. On average, 25% of all tertiary students end up in S&E fields.

   The majority of Chinese and Indian students go to the United States when opting to study abroad. It is anticipated that in 2007, the numbers of Chinese and Indian students attending tertiary education (all fields) in the US will be approximately 224,000 students.[72] If part of this pool of students would opt to go to the EU25 instead and 25% end up in S&E related fields, they could contribute to future numbers of graduates in S&Es.

   Bring about 25% of Chinese and Indian students to study within the EU25 borders instead of attending tertiary education in the United States.

9. Number of PhD students that conclude their studies in the United States instead of staying in the EU.

[71] According to Eurostat, in 2006 there were approximately 109,000 foreign students at tertiary ISCED 6 in the EU25. In 2005 the EU25 had 193 universities among the Top 500. If we assume that the foreign students were equally distributed among the 193 universities, then there were approximately 565 foreign students at tertiary level ISCED 6 at each European university among the Top 500.
[72] Based on Eurostat data, available from 1998 until 2003, and forecasted for 2007.

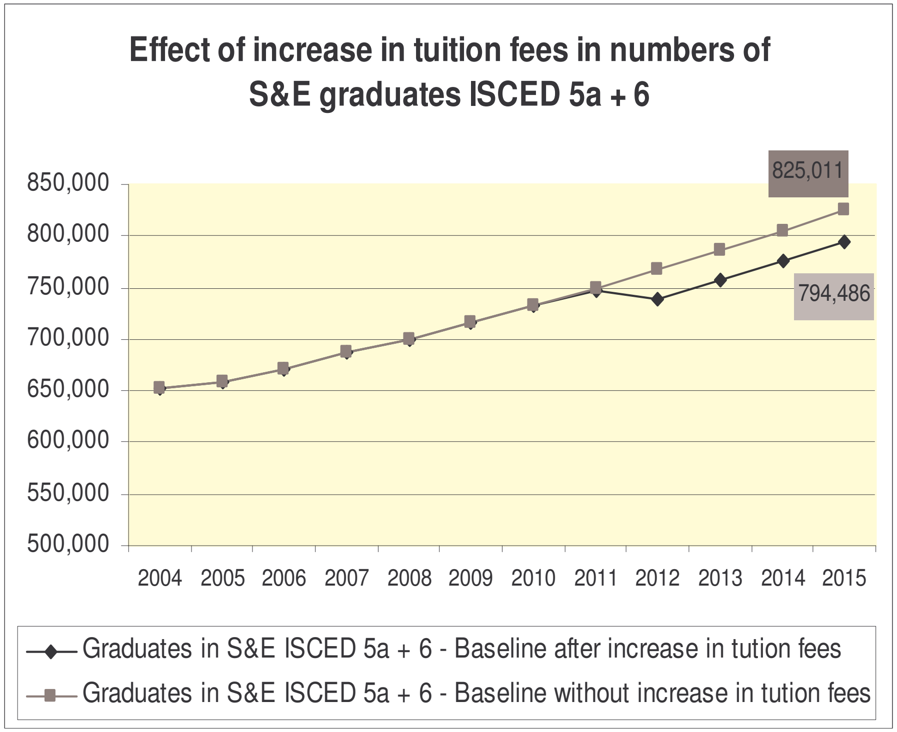
Reduce by 15% the number of students receiving PhDs in the US per year, by shifting these students back to the European educational system as from 2007.

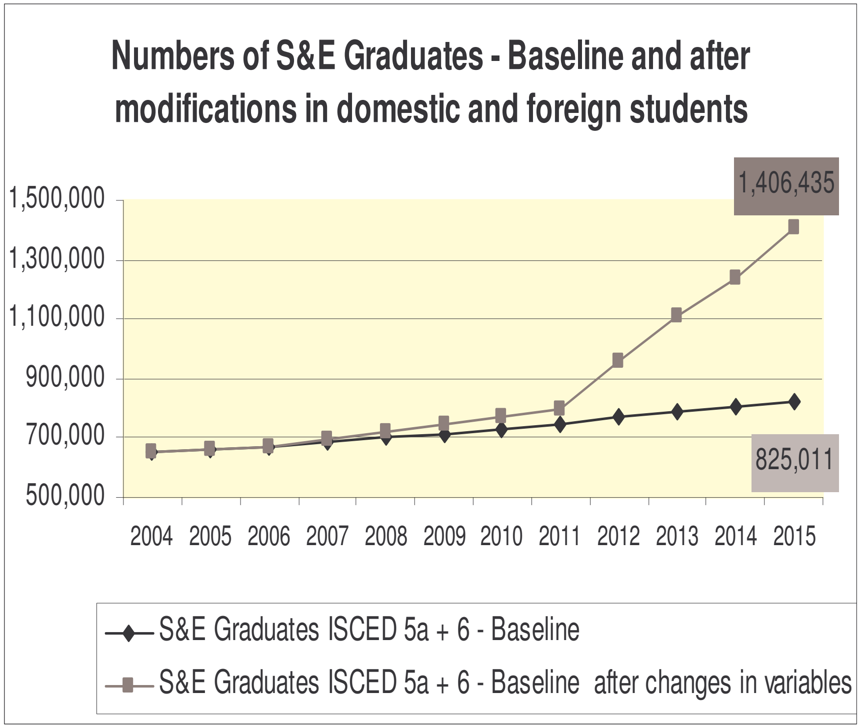
10. Tuition fees can create a negative impact in the number of enrolments. Considering that students level 5 take around 5 years to complete their studies and students at level 6 around 4 years on average and considering absolute numbers for both levels, we introduce an increase of 100% in tuition fees in 2007 which will impact enrolments that year and graduates with a time lag of 5 years on average.

    Increase tuition fee by 100% in 2007, causing a negative impact of 3.7% in enrolments and a decrease of 3.7% in number of graduates in 5 years time (graduates as from 2011).

Figure 5.8 illustrates projections for graduates in S&E related fields at both ISCED 5a and 6, considering maintenance of present variables that influence such output and their manipulations as described. We also projected such numbers, considering the negative impact of increasing tuition fees.

Figure 5.8. Impact of tuition fees and changes in domestic and foreign students.





By introducing the above-mentioned changes in education at levels ISCED 5a and 6, it is possible to increase the pool of S&Es. An important point to consider is that changes in terms of entrants at level 5a plus changes in terms of increasing numbers of students opting for S&E fields at level 5a, shifting females to S&E fields at level ISCED 5a and bringing more Indians and Chinese students to attend tertiary education in the EU25 will only have an impact on the number of graduates in S&Es at ISCED 6 after 9 years. Considering that it takes on average 5 years to conclude tertiary education at level 5a and 4 years at level 6, any changes introduced by 2007 at level ISCED 5a will only have a positive impact at ISCED 6 by 2016, while already influencing ISCED 5a by 2012. The exceptions considering the variables that we included in this exercise are in the number of foreign students entering tertiary education directly at level 6 by increasing the number of universities within the Top 500 as well as increasing the relative numbers of women that opt to enrol at S&E fields at level ISCED 6. Attracting foreign students directly to ISCED 6 as well as women in science related fields will affect the numbers of S&Es after 4 years from the time that such measures have been adopted.

Table 5.2. Impact of changes in domestic and foreign students

			Extra S&E graduates by 2015[73], after changes implemented in 2007[74]	
			S&Es	**Researchers[75]**
ISCED 5A				
Entrants				
	Age cohort 15_19	Increase entrants from this group by 3.0% per year	1,300	300
	Age cohort 20_24	Increase entrants from this group by improving Youth education attainment by 1.0% per year	14,700	3,700
	Age cohort - Mature	Increase entrants from this group by improving Mature education attainment by 2.0% per year	7,000	1,800
Total Impact of New Entrants			**23,000**	**5,800**
Foreign students		Increase number of universities in the Top 500 by 1.0% per year	25,000	6,300
Maths. Sciences and Technology fields		Increase proportion of students choosing this field in relation to total fields by 2.0% per year	1,165,000	290,000
Women's enrolments in S&E		Increase participation by 1.0% per year, by shifting from other fields	385,000	96,000
Chinese and Indian tertiary students		Increase participation of Chinese and Indian students at tertiary level, by shifting 25% of this pool of potential students from the United States into the EU	63,000	16,000

[73] Cumulative effect, as from 2007 when changes were proposed and implemented, until 2015 (9 years), although sometimes changes implemented in 2007 would only reflect on numbers of graduates in S&E in 2011 or 2012, since it takes on average 4 years to complete tertiary ISCED level 6 and 5 years for ISCED level 5a.

[74] Effects of each change were considered isolated. Impact of changes displayed in this table did not considered multiplicative effects of changes. For example, impact of shifting more students from other fields to S&E was considered on its own and did not include any effects from increases in the numbers of entrants.

[75] At R&D intensity level between 2 and 4% of GDP, the proportion of researchers in relation to S&E is approximately 25%.

ISCED 6				
Foreign students		Increase number of universities in the Top 500 by 1.0% per year	6,800	1,700
Women's enrolments in S&E		Increase participation by 1.0% per year, by shifting from other fields	3,000	800
EU PhD graduates		Reduce the numbers of EU PhD graduates in the USA by 15.0%	2,300	600
Total impact in domestic education and foreign students (Accumulated from 2007 to 2015)			**1,673,100**	**411,400**

By manipulating the above variables, the EU25 would be able to graduate around 1.7 million more S&Es, representing around 400 thousand more researchers by 2015.

From this exercise, we can conclude that simply increasing the numbers of entrants in the three age cohorts will not create much impact in the final numbers of S&Es by 2015. Entrants will take 5 years to graduate and of those graduates, around 25% will be in S&Es fields. A more feasible way to increase the numbers of graduates by increasing the numbers of students would be to bring in more foreign students, both at tertiary ISCED 5a and ISCED 6. Furthermore, increasing the numbers of Chinese and Indians students that would otherwise go to the United States for their tertiary education would also create a positive impact on the numbers of S&Es graduates at a later stage.

Foreign students, including in this case, Chinese and Indians students, can enter directly at level ISCED 6 and consequently within 4 years the EU25, could have positive results in terms of increasing numbers of S&Es.

Moreover, the number of Europeans pursuing a PhD in the US is not as relevant in terms of influencing the final numbers of S&Es. More important than keeping those students in the EU for their studies, is to bring them back once they conclude their studies abroad.

A variable with a stronger impact in the numbers of graduates in S&Es fields is the percentage of women that opt to study in the area. On average only 30% of all female enrolments are in S&Es fields, although women are responsible for more than 50% of all enrolments at the tertiary level, a proportion that has been steadily increasing over the years. If it would be possible to increase even further and faster the percentage of women that opt for S&Es fields, by shifting female students from other fields into sciences and engineering fields, then the numbers of graduates would increase even more quickly.

Furthermore, the variable percentage of students that opt to study in Sciences and Engineering is around 25% in relation to enrolments at tertiary level ISCED 5a. The greatest impact in the number of graduates would be to increase further and faster the numbers of students opting to study these fields, by shifting students from other areas into S&Es fields.

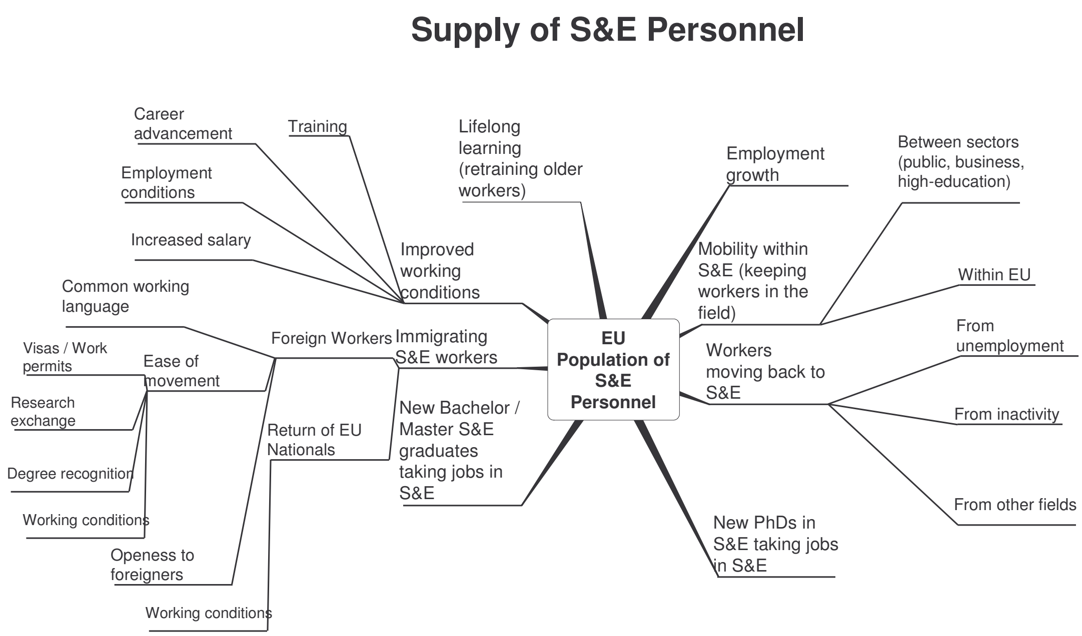
In summary, it is not by bringing more domestic students into tertiary education that the EU25 will reach their requirements of S&Es and researchers by 2015, but by shifting students in general and females in particular to the S&E fields, as well as recruiting more students from outside the EU, specifically Chinese and Indians that today prefer to go to the US for their tertiary education.

Important indicators for controlling numbers of graduates in S&E fields:
Main important indicators in this module were the proportion of students in Science and Engineering fields as opposed to other fields, the proportion of women in study enrolments in Science and Engineering fields, and the number of Chinese and Indian students.

6.0 MODULE ON SUPPLY OF S&E PERSONNEL

The next two modules (supply and loss of employed scientists and engineers) are closely linked, as a positive change in a loss factor turns this factor into a supply factor, and vice versa. Some of the related issues will however, be discussed in this section and some in the next section.

Figure 6.1. Module 3 – Supply of science and engineering personnel.



As shown in Figure 6.1, the most obvious input to the pool of S&E personnel are new 'domestic' S&E graduates (at all three levels: Bachelor's, Master's and PhD). However, many S&E graduates choose or, are forced to choose, occupations outside S&E. On the other hand, there are other supply channels, such as, people moving from jobs outside S&E back to S&E positions, graduates from outside S&E fields, inactive or unemployed people going into S&E, retraining of older workers (often referred to as lifelong learning), and immigration of S&E workers (including workers returning from a temporary stay abroad).

Many of the factors influencing the international mobility of S&E personnel are the same as for international S&E students. Generally, mobility between sectors or countries is considered to have positive economic effects in addition to keeping workers happier provided their experiences are positive. Factors affecting the within country flows include general economic outlook (employment growth), working conditions (salary levels, career advancement and training opportunities), policies on public R&D expenditures , and the retirement age (e.g. increasing retirement age or attempting to keep people working longer).

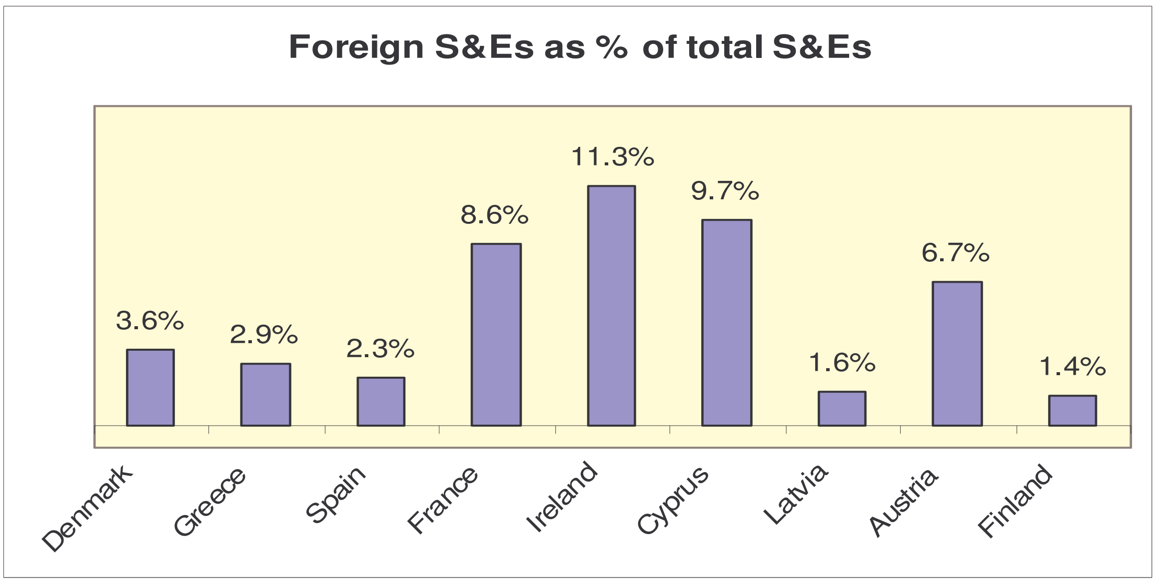
As mentioned earlier, one important way to increase the number of working scientists and engineers is to attract more women into S&E fields. As discussed in Section 4, there is a slight positive trend in the EU-25 in the ratio of female S&E graduates to all S&E graduates[76]. However, the decreasing young population in the EU means that there will be fewer graduates overall to supply the pool of S&Es in the future. Therefore, it is even more important that as many young women as possible choose science and engineering, both in their education and in their career path. Currently, the growth rate of women working in S&E is lower than that for men. If such a trend continued, the proportion of women in S&E (29% in 2004) would decline even further[77].

Another way to increase the supply of people working as scientists and engineers in the EU is through the 'import' of trained scientists and engineers as both temporary workers and immigrants. With respect to this, an example of a pull effect is suggested by Solimano and Pollack (2004) who note that the ratio between R&D expenditure in the EU and in Latin America is more than 8 to 1. Such a difference creates strong incentives for flows of S&Es from Latin America to the EU (or possibly other OECD countries). As can be seen from Table 6.1, which shows the origins of foreign S&Es in a number of EU countries, the flows from Latin America are still rather small, except for when the destination country is Spain. Although one must bear in mind the problems related to obtaining accurate data on international mobility (as discussed in Section 2), both Figure 6.2 and Table 6.1 do indicate that there is quite some variability in how well countries attract foreign S&Es and where they come from. Using Latvia as a proxy for the new EU member states (NMS), it would appear that before the 2004 EU enlargement, most S&Es did not come from other NMS, but from the 'rest of Europe', i.e. from other Eastern European countries, including Russia and Turkey[78]. Unfortunately, time series data to see how things have developed since these data were collected for this particular source are not yet available. The EU Labour Force Survey has however, collected data on tertiary educated foreign-born populations on a yearly basis and this data indicates that many EU countries have increasing amounts of recently (1-5 years) arrived tertiary educated foreign-born immigrants (Eurostat, 2005).

[76] However, the trend is negative when looking at what women choose, in other words, the ratio of women choosing S&E fields of study to women choosing other fields of study has decreased (Eurostat).
[77] A recent EC publication (EC, 2006d) has looked at R&D expenditures *per capita* researcher and across Europe. Interestingly, the countries with the lowest levels of expenditure per researcher (mainly Eastern European countries) have the highest proportion of women in research. Conversely, countries with high levels of expenditure per researcher (the Netherlands, Switzerland) have low levels of women in research. This could simply reflect the gap in salaries for women and men.
[78] For Latvia, the proportion of Russian S&Es may be particularly high because of the sizeable Russian minority there. Although the exact proportion is not known, it can be seen from the original data that other countries have sizeable contributions to the Latvian foreign S&Es as well.

An important obstacle to the free movement of highly educated workers – or brain circulation – has been the complicated legal and administrative procedures required for the entry of both non-EU students and workers. In addition to certain individual EU member states taking actions to increase the numbers of highly-skilled immigrants, the European Union has recently taken steps to ease these procedures by introducing a 'researchers visa' or a 'green card' which must be transposed into national law during 2007 (EC, 2006a).

Figure 6.2. Proportions of foreign scientists and engineers in certain EU countries.



Note: The original data are obtained from the 2001 round of Population and Housing Censuses, and are for latest available year.
Source: Eurostat.

Table 6.1. Foreign S&Es by origin as a percentage of all foreign S&Es in certain EU countries.

Host country	EU-25	NMS	Rest of Europe	Asia	US	Rest of Americas	Africa	Oceania	Total
Denmark	37.3%	2.7%	14.4%	4.2%	3.9%	1.7%	0.8%	0.9%	100.0%
Greece	36.9%	15.8%	10.3%	8.7%	4.3%	2.0%	2.3%	1.8%	100.0%
Spain	29.9%	0.9%	4.4%	2.8%	2.0%	28.4%	3.6%	0.1%	100.0%
France	29.9%	2.4%	3.7%	13.6%	1.1%	2.4%	20.6%	0.2%	100.0%
Ireland	33.9%	1.3%	2.4%	18.3%	1.9%	1.1%	6.2%	2.8%	100.0%
Cyprus	31.9%	1.6%	12.8%	22.2%	1.0%	1.0%	1.0%	0.7%	100.0%
Latvia	4.2%	4.2%	89.8%	1.9%	0.0%	0.0%	0.0%	0.0%	100.0%
Austria	44.5%	8.9%	5.5%	2.7%	1.6%	0.9%	1.0%	0.3%	100.0%
Finland	42.4%	20.4%	3.6%	6.8%	2.3%	1.6%	1.6%	0.7%	100.0%

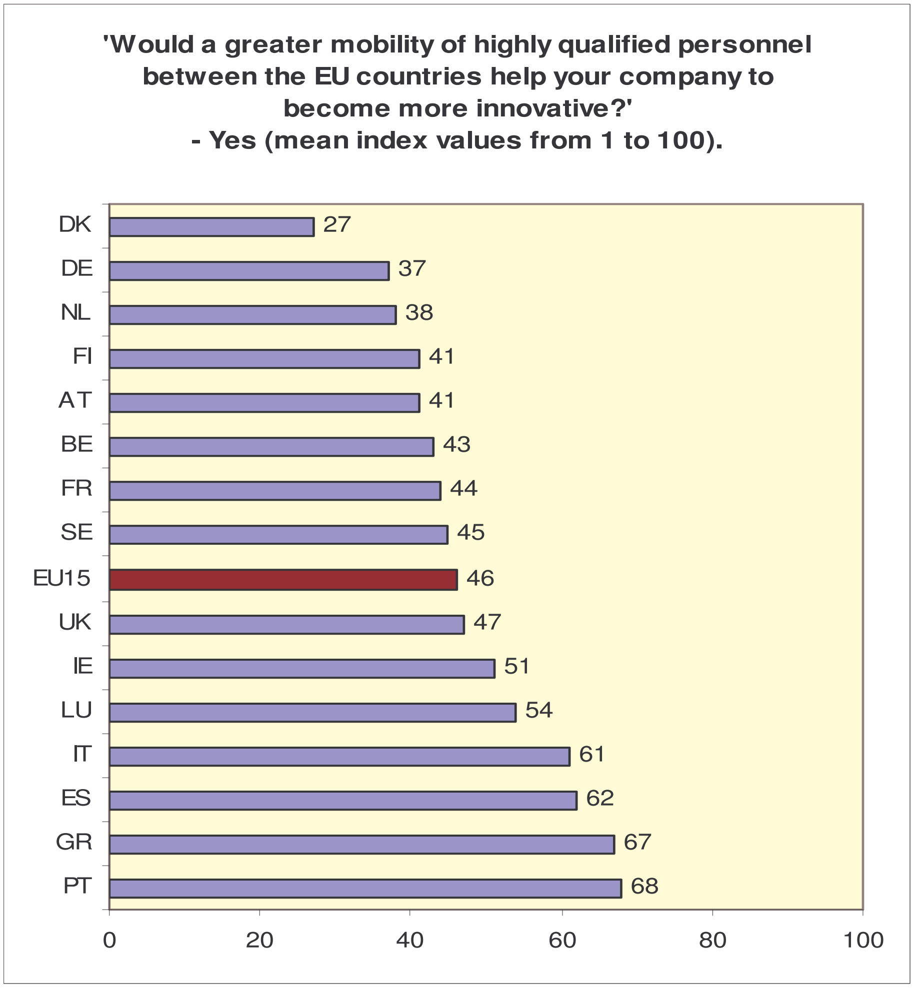
Note: The original data are obtained from the 2001 round of Population and Housing Censuses, and are for latest available year. NMS = new member states.
Source: Eurostat and own calculations.

As discussed in the previous section on international student mobility, an important component for international mobility of scientists and engineers is also intra-EU mobility. Figure 6.3 depicts the attitudes of managers from EU-15 regarding the impact of intra-EU mobility on innovation. The figure indicates that, at least at the time of the Innobarometer in 2001, there was no great overall enthusiasm for such mobility, although some countries (Portugal, Greece, Spain and Italy) were quite positive. However, the Innobarometer also shows that among large companies and exporting companies, the majority of managers considered intra-EU mobility to be at least somewhat important for innovation. The EU LFS data for 2000 and 2004 shows that intra-EU migration of the tertiary educated is increasing in most EU countries (Eurostat, 2005).

Graversen et al.'s (2001) study of migration of the highly skilled between the Nordic countries[79] concluded that migration in this region seemed to lead to overall brain circulation rather than brain gain or brain drain. However, the picture may be different elsewhere in Europe. For example, an underemployed scientist in one of the new EU member states may well find an appropriate S&E job in another EU country, thus increasing the total number of fully employed scientists and engineers in the EU[80].

[79] The study used the national register databases available in the Nordic countries.
[80] This report does not cover the two newest EU member countries Bulgaria and Romania. However, these two countries may also be contributing significantly to such intra-EU mobility in the near future.

Figure 6.3. Potential impact of greater mobility of highly qualified personnel.



Source: Innobarometer 2001 (Flash Eurobarometer 100), Innovation Papers no. 22.

Available US data can be used as a rough model for Europe in terms of brain gain from the developing countries. The data from Finn (1997) indicates that roughly half of all foreign doctoral recipients return to their home countries immediately after their graduation however, almost half continue working in the US for long periods of time (measured in years and decades) thus representing considerable brain gain. This has been, at least until recently, especially true for China and India[81].

[81] On the other hand, even those who stay, have been shown to contribute to their home countries scientific and technological development by networking with researchers in their home countries (see e.g. Choi, 1995), as well as by contributing financially (via remittances) to the development of their home countries. In two thirds of the mostly developing countries studied by Adams (2003), less than 10% of the tertiary educated population migrates. However, for a small number of developing countries, e.g. those close to the US or many countries in Africa, the picture is much bleaker with a large share of the best educated emigrating (Adams, 2003 and Docquier and Marfouk, 2004). OECD (2005) also points out that, small

Human resources in science and engineering include both persons educated in S&E and persons who are working in S&E (most individuals fall into both categories). Thus, for example, inactive and unemployed people who are nonetheless educated in an S&E field are included in the larger pool of potential scientists and engineers and as such, attracting people from this group back to the working world is an important option to consider for the future.

The stock of S&E personnel could also be increased by extending the working lifetime of scientists and engineers before mandatory retirement (see Section 7 for more on issues related to retirement). Furthermore, the numbers could be increased by opening up new opportunities and responsibilities in S&E occupations so that scientists and engineers could collect benefits and rewards of their S&E knowledge and skills without leaving research. Scientists and engineers in other occupations could be re-attracted back into S&E occupations, and older workers retrained for new and more challenging positions. Figure 6.4 shows some data on lifelong learning (LLL)[82]. It can be determined from the figure that women tend to participate at somewhat higher rates than men do in formal education[83] after 25 years of age (at the EU-25 level the proportion of women was 55.2% in 2003). Looking at the S&E fields of study at the EU-25 level in 2003, 39.7% of LLL science students were women and 19.2% of LLL engineering students were women[84] (Eurostat).

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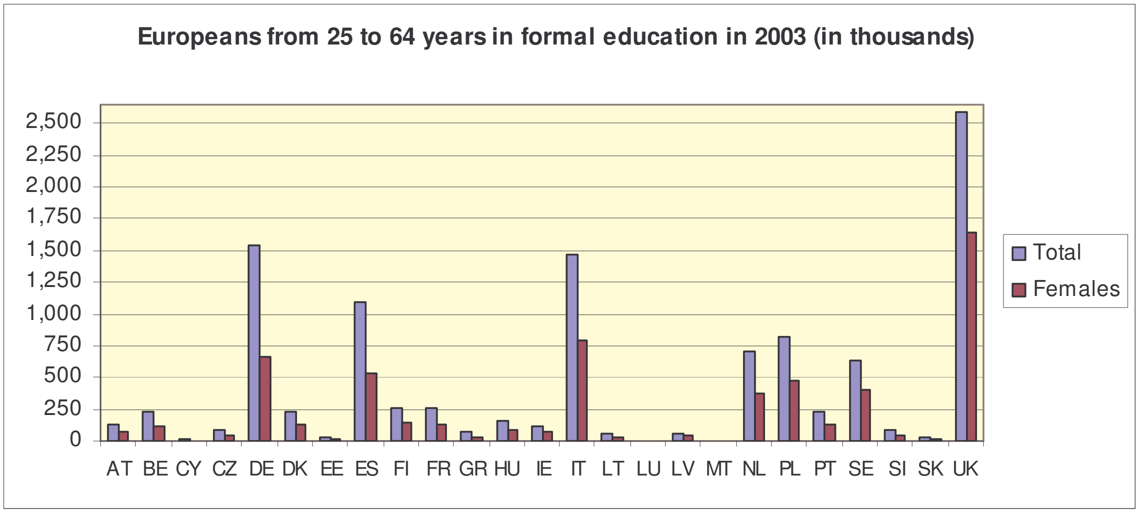
countries, with high rates of emigration of the highly skilled, may not be able to reach a critical mass of human resources necessary for fostering long-term economic development.

[82] Eurostat obtained the LLL data from an ad hoc module of the 2003 EU Labour Force Survey. Therefore, no trend data is available.

[83] Formal education here refers to education and training in the regular system at schools, colleges and universities, and aims for a certification recognised by national authorities. It is therefore not exclusively tertiary education. However, about 90% of those participating in such LLL in formal education have at least upper secondary education completed (Eurostat).

[84] The corresponding ratios (females/total) for all tertiary level S&E graduates in 2003 were: 41.8% and 22.7%, i.e. fairly similar (Eurostat).

Figure 6.4. Lifelong learning in the EU-25.



Source: Eurostat.

6.1 Indicators

The main new data sets within this module include:

- *Immigration data on highly skilled S&E workers from outside the EU:* these data are at least as important as student mobility data and as difficult to obtain. However, as mentioned in Section 2.2, there are some recent efforts to develop better and more accurate indicators for the international mobility of highly skilled workers, including information on the inflow of EU scientists and engineers who return to Europe , andnon-EU immigrants who are scientists and engineers. Change in the supply of highly skilled S&E immigrants could also be estimated from, 1) economic growth rates in supply countries (the lower the rate, the more likely it is that highly skilled workers will emigrate) , and2) increases in R&D expenditures or employment opportunities in supply countries, which in turn, could reduce the potential supply of skilled immigrants to the EU. However, this scenario does not estimate such influences.
- *Data on unemployment:* in this case we can include data on unemployment among the highly skilled, which can be used as an indicator for the potential employable workforce, given there is enough demand. These data are available from Eurostat.

The following indicator is derived from Section 3.3 (International student mobility):

- *The annual number of S&E degrees earned by nationals from outside the EU-25*: This indicator is important in terms of both understanding the growth in output of the education pipeline and estimating the impact on the supply of scientists and engineers from degrees earned by foreign nationals.

Further indicators could be developed to investigate the potential number of S&E personnel that return to S&E occupations from inactivity or from other jobs. We have used data on S&Es returning form inactivity in our simulations. This topic is discussed further in the following section.

Ideally the data should be available by gender for each of the indicators suggested above. The potential contribution of women is particularly important given the ageing of Europe's scientists and engineers and increasing global pressures on the worldwide supply of scientists and engineers. It is also important to consider all levels of university education. Although the literature focuses on indicators for PhD graduates, the majority of research positions are filled by individuals who have Bachelors and Masters' degrees.

6.2 Simulations

Numbers of S&Es increase on a yearly based on, among other factors, numbers of graduates in S&E that stay in the sciences and technology field by finding jobs in the area. An estimate of approximately 65% of graduates in S&E related fields go to work in their fields of education after graduation.[85] That means that 35% of graduates in S&E on average find occupation outside their field of studies, substantially reducing the stock of S&Es in the EU.

Any change in relative numbers of S&E graduates that opt to pursue a career outside the S&E field, would help to increase stocks of scientists and engineers however, it would be a loss of skilled people in other areas.

The proportion of EU nationals that opt to study outside the EU area is very low as compared to EU nationals that opt to study and graduate in other EU countries. Most EU students either stay in their home countries or opt to study in another EU country, most likely linked by similar cultural background or common language. Estimation of EU tertiary students that were actually studying in other countries outside the EU in 2003 amounted to approximately 88,500 considering numbers from 18 EU countries[86]. If we consider that it takes on average, 5 years to complete tertiary education , and that the average proportion of tertiary students in S&E related fields in relation to total tertiary students was 24.1% in 2003, then we can roughly estimate the numbers of EU nationals in S&E fields in non-EU countries that graduated in 2003 to be 4,300 new graduates. The flow of EU graduates in S&E fields outside the EU returning to the EU would increase stocks of S&E; consequently, any incentive to bring these graduates back to the EU would create a positive impact in numbers of S&Es within the EU. If we consider that

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[85] Please refer to comments on footnote 10.
[86] Eurostat and own calculations.

approximately 58% of European nationals that graduate at level 6 in the United States have no plans to return to the EU , and if we apply this same proportion for all European graduates in S&E outside the EU, then we can calculate numbers of European graduates in S&E that are not likely to return to the EU. Any decrease in this proportion would create a positive impact on the stocks of European S&Es.

Furthermore, the following three countries are producing increasing numbers of engineers: the United States, China and India. Although there is much discussion about the actual numbers that each of these countries produces every year, with some suggesting that the US is only producing 70,000, with India is producing 350,000 and China 600,000. Researchers at Duke University in the United States claim that these numbers are not comparable, that the United States is graduating more engineers than India and that the Chinese numbers should be reviewed carefully. The Duke University researchers concluded that when considering strictly four-year degrees without taking into account accreditation or quality, the US is graduating around 138,000 engineers per year vs. 112,000 from India and 352,000 from China[87]. Regardless of who is producing the most, these three countries together produce around 600,000 new engineers every year all of whom look for jobs in their home countries or elsewhere. As such, the EU25 can view these new graduates as a pool of skilled people that can be 'imported' into Europe to help close the gap of S&Es necessary to reach the Lisbon goal of 3% R&D in relation to GDP.

Manipulated variables:

1. Numbers of S&E graduates that find jobs outside S&E field. On average, 65%[88] of graduates in S&E find jobs in their area of education. By increasing this proportion, the EU can gain in absolute numbers of S&E that opt to continue in the field. Furthermore, of those who find work in their field of education, approximately 25% of them end up in research.

Increase the proportion of graduates that opt to work in the field from 65% to 75% as from 2007.

2. Number of EU nationals graduating in S&E outside the EU and staying in their countries of study. Considering that the proportion of EU students graduating in the United States at tertiary level 6 with intentions to continue in the US after graduation is around 58%[89], any decrease in this proportion would increase numbers of EU nationals returning to EU.

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[87] ' About That Engineeering Gap…' – BusinessWeek Online – Vivek Wadhwa – December 13, 2005
[88] Please refer to comments in footnote 10.
[89] Potocnik (2005).

Decrease proportion of EU graduates in S&E outside the EU that opt to continue outside the EU by 5% per year, as from 2007.

3. The EU receives students from outside its borders to study at ISCED levels 5a and 6, in the fields of S&E. Assuming that 65% of those who graduate continue to work in their fields , and that 50% of this group opt to work inside the EU, graduates from this group can make a positive contribution to the stocks of S&E in the EU.

Maintain 50% of foreign students from outside the EU who graduate in S&E within EU borders, by taking jobs in S&E field within the EU borders.

4. Given that the United States, India and China are producing approximately 600,000 engineers per year[90], and that they will look for jobs opportunities either within their home country or elsewhere, the EU25 could work to bring some of these engineers to work within the EU25 borders, thereby contributing to close the gap of S&Es' requirements in the EU.

Bring 10% of this pool of engineers to work in the EU25.

Figure 6.5. Supply of S&E personnel – Impact of changes.

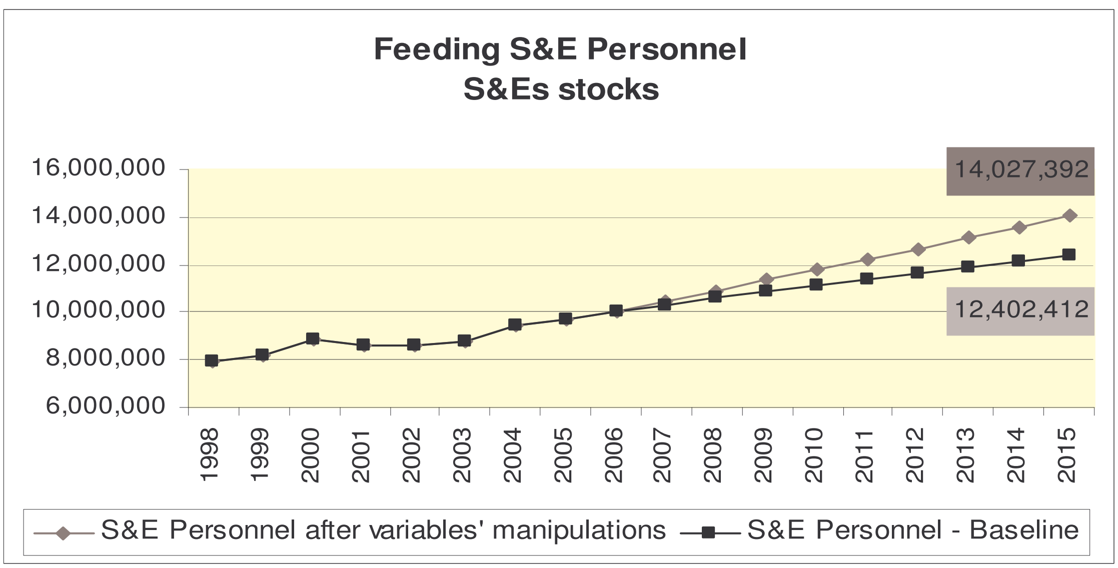


Figure 6.5 shows the effects of the above mentioned changes in the numbers of S&E personnel. By introducing changes such as the percentage of S&E graduates that opt to work in the area of S&E instead of taking other types of jobs; by bringing back European S&E graduates after they have acquired their degrees outside the EU; by keeping part of foreign students who completed their studies in S&E related fields within EU borders ,

[90] ' About That Engineeering Gap…' by Vivek Wadhwa, BusinessWeek Online, December 13, 2005.

and by offering jobs to a part of the pool of American, Indian and Chinese students that graduate in engineering every year in their respective home countries, to work in the EU, the final numbers of S&E personnel by 2015 can be substantially increased. Table 6.2 demonstrates the accumulated impact of such changes in absolute numbers of S&Es and research, considering the period from 2007 to 2015.

Table 6.2. Supply of S&E personnel – Impact of changes in absolute terms.

		Extras S&Es stocks after changes implemented in 2007[91]	
		S&Es	**Researchers**[92]
Graduates in S&E working in the field	Increase proportion of graduates that opt to work in the field from 65 to 75% as from 2007	850,000	212,500
EU graduates in S&E outside the EU	Decrease proportion of EU graduates in S&E outside the EU that opt to continue outside the EU by 5% per year, as from 2007.	12,200	3,050
Foreign graduates in S&E	Maintain 50% of foreign students from outside the EU who graduate in S&E within EU borders, by taking jobs in S&E field within the EU borders.	226,400	56,600
Engineers produced in the United States, India and China	Bring 10% of this pool of engineers to work within EU25 borders	540,000	135,000
Total impact (Accumulated from 2007 to 2015)		**1,630,000**	**407,000**

Many variables in this exercise proved to have a great impact in the actual numbers of S&Es. Maintaining larger proportions of foreign students graduating in S&Es' fields, within EU25 borders, by offering jobs in the area helps building up stocks of S&Es, although this contribution is relatively modest in comparison with the other variables, probably because most of EU25 foreign students are in fact Europeans. Furthermore, increasing the number of graduates in S&E that actually end up working in the field and are not 'lost' to other occupations as well as bring into the EU borders engineers that

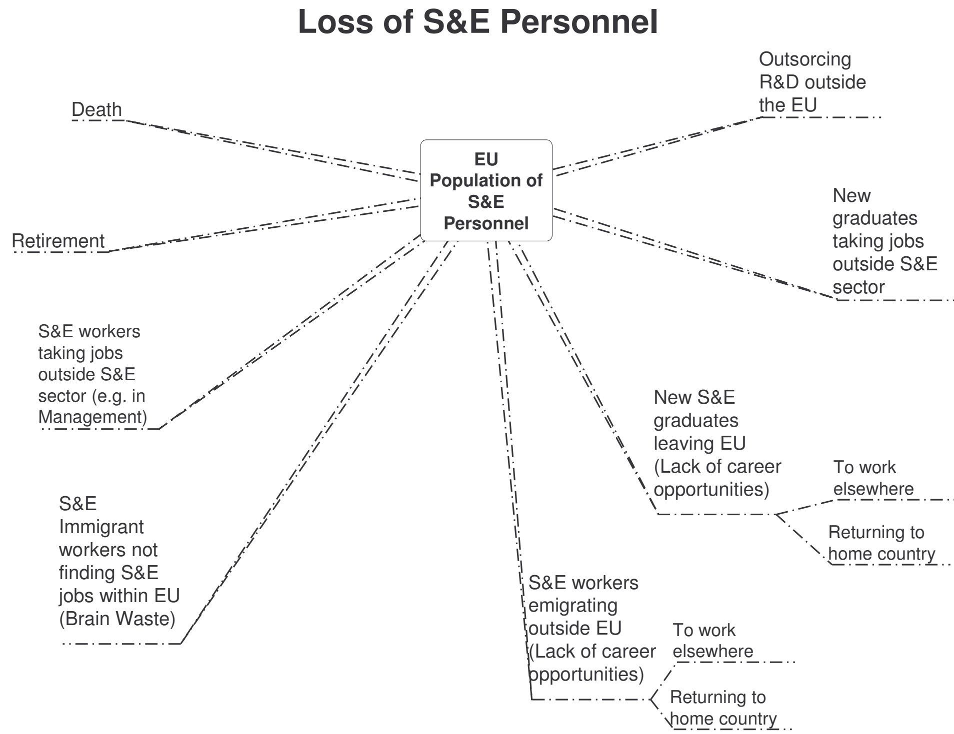
[91] Cumulative effect, as from 2007 when changes were proposed and implemented, up to 2015 (9 years).
[92] At R&D intensity level between 2 and 4% of GDP, the proportion of researchers in relation to S&E is approximately 25%.

were graduated in the United States, India and China can make a substantial difference in the stocks of S&Es. On the other hand, decreasing numbers of European S&Es graduates outside the EU that opt to continue abroad has not proved to create a substantial impact on final numbers of S&Es.

Important indicators for controlling numbers of stocks of S&Es:
Graduates of S&Es working in the field, engineers produced outside the EU (US, China and India), foreign graduates in S&E within EU borders and EU graduates in S&E outside EU borders.

7.0 MODULE ON LOSS OF S&E PERSONNEL

Figure 7.1. Module 4 – Loss of science and engineering personnel.



Note: Dashed line indicates a negative effect.

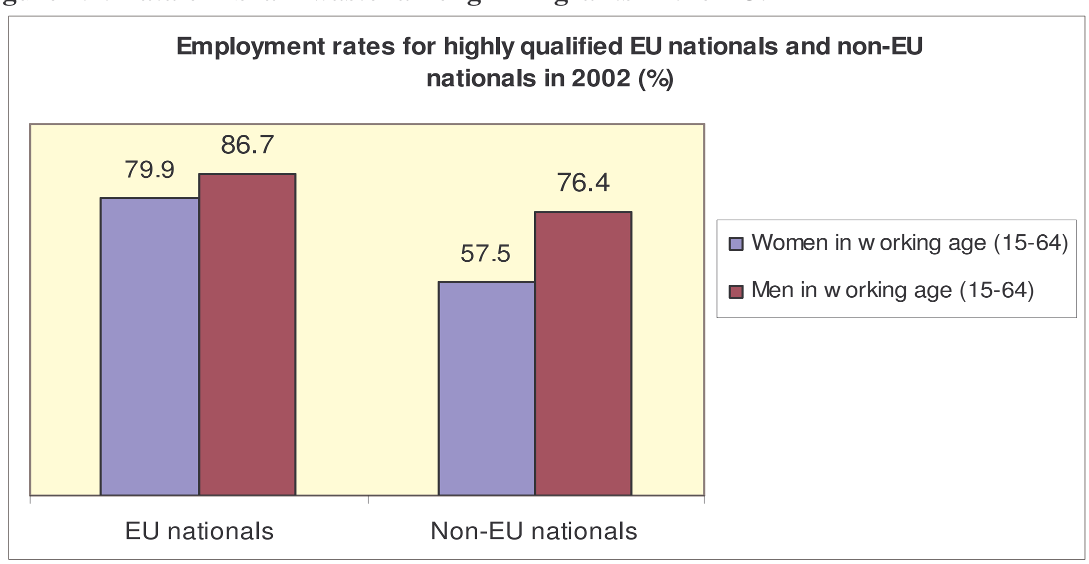
This section identifies factors that contribute the most to the loss of working scientists and engineers , and experiments which might have significant impacts on possible policy changes regarding these factors. However, estimating the feasibility or costs associated with the attempt to reduce losses within any specific factor, is difficult. For example, is it easier or less expensive to reduce losses by increasing the retirement age by a few years, by improving the ability of S&E graduates or S&E immigrants to get an appropriate job in S&E or by trying to retain more European S&Es in Europe? Given the size of contributions from such factors, it would seem that a postponement or extension to retirement age would be most effective.

The main outflow from the stock of scientists and engineers is to retirement. Other important loss channels (as seen in Figure 7.1) are leaving S&E occupations for jobs outside S&E (mainly for management jobs), to emigrate to other countries (or outside the EU-25), or for industry outsourcing of R&D to other countries (or outside the EU-25) where they are employing local R&D personnel in those host countries. Lack of career opportunities in the EU is an obvious reason for emigration or for missing the potential pool of international S&E workers coming to the EU. Similarly, there are other groups of potential S&E workers who for one reason or another do not end up in the S&E pool, for example, S&E graduates who choose other jobs or as important, immigrants with S&E backgrounds who are not able to find appropriate employment within S&E. The latter phenomenon is often referred to as brain waste. Policies involved here include those mentioned in the previous paragraph including immigration policies.

The reserve labour pool in the EU includes those scientists and engineers, including new graduates, who lack suitable career opportunities. If EU member states manage to keep such potential EU researchers from seeking career opportunities in competing countries such as the US (with better funded R&D opportunities), then this newly established pool would represent an opportunity to increase the number of working S&Es in Europe.

Some EU member states may have relatively large pools of unemployed or under-employed S&E researchers or graduates who have sought employment outside science and engineering. For example, there is an apparent lack of job opportunities in Spain and Italy (e.g. in public research), and unemployment and under-employment of scientists and engineers is apparent in some of the new EU member states. According to earlier research by Teichler (1989), in the 1970s and 1980s the proportion of under-employment,

Figure 7.2. Data on 'brain waste' among immigrants in the EU.



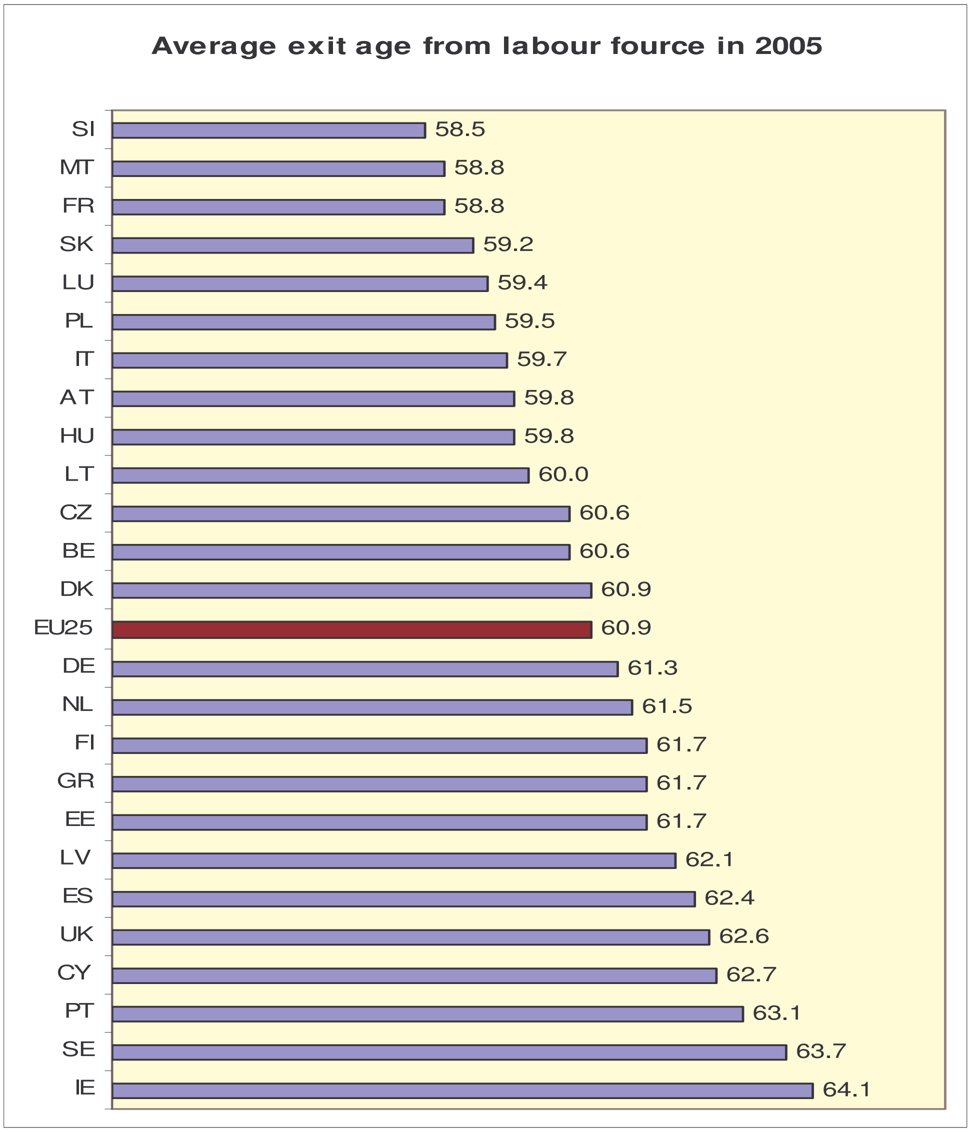
Source: Employment in Europe, European Commission.

mismatch or 'inappropriate' employment among university graduates in general, varied between 3% and 40% in surveys undertaken in various European countries.

This reserve labour pool could also help fill an increase in demand. However, successfully attracting such people back to research activities is not the same as securing an increase of new graduates to join the S&E workforce, as the years out of research are likely to have an effect on the quality of work at least over the short term[93]. On the other hand, these people could replace those already working in S&Es who are planning to move away from S&E to management or other jobs.

[93] To take this fully into account in a scenario model would require adjusting by a quality deflator for the number of years out of research. See also Thurow (1975, quoted in Marey et al., 2001) for the labour queue theory, including the relationship between quality of work performance and unemployment of longer duration.

Figure 7.3. Current retirement age in the EU-25.

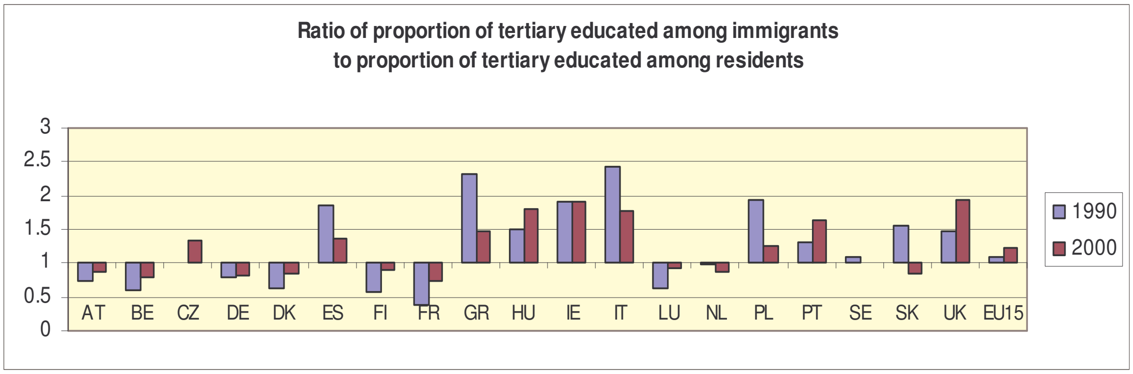


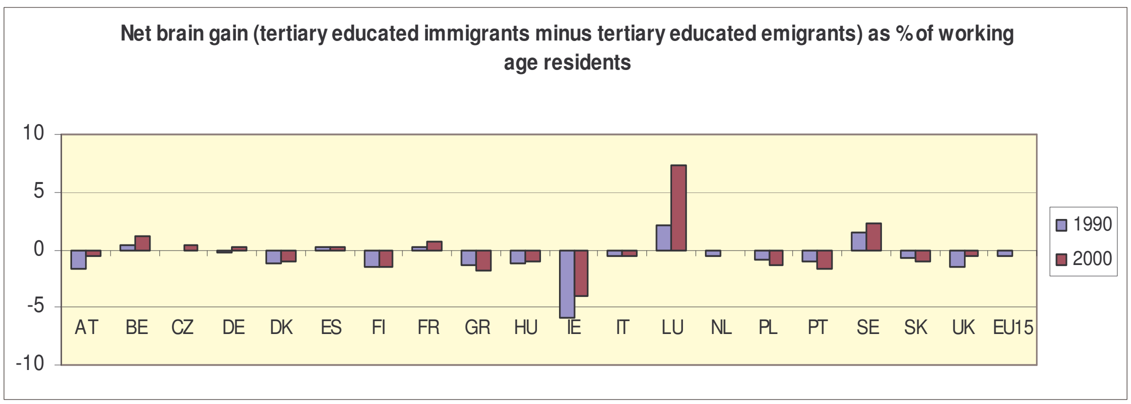
Note: For Germany and Cyprus, the data is from 2004.
Source: Eurostat.

Regarding brain waste, Figure 7.2 shows that the employment rates of the highly educated non-EU nationals in 2002 were on the average considerably lower than the rates for highly educated EU-nationals. This was particularly true for highly educated immigrant women.

Some EU countries are facing a more serious problem from an aging workforce than others. In particular, Latvia, Hungary, the Czech Republic, Greece, Italy and Lithuania had a high proportion at 40% or more of their scientists and engineers in the 45-64 age group in 2005, which is significantly above the approximate 35% rate of EU-25 average (Eurostat, see also Figure 3.1). These countries may have problems replacing their retiring scientists and engineers. Figure 7.3 shows the current average retirement ages in the EU-25. As can be seen, the range is sizeable.

Figure 7.4. Net brain gain in Europe in 1990 and 2000.





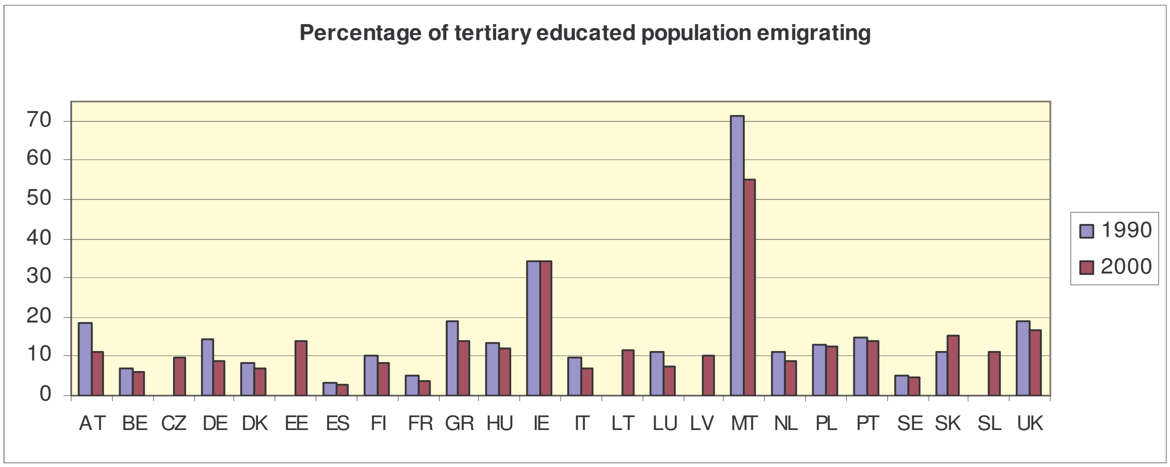
Notes: In the first graph, a value of 1 equals no gain, no loss. For example, the value of nearly 2 for the UK in 2000, means that the proportion of UK immigrants with tertiary education was almost twice as high as the proportion of UK residents with tertiary education.
For the Czech Republic, the data for 1990 is together with the data for Slovakia.
For the Netherlands, the data in the second graph for 2000 is truly 0.0%.
Source: Docquier and Marfouk, 2004.

Europeans gain from attracting highly educated foreign workers. However, the other side of the coin is the possible brain drain experienced by the countries – including European countries - supplying the global movement of highly educated workers. Recently, Docquier and Marfouk (2004) have made a significant contribution to this topic by building a database describing brain drain from all of the developing and developed countries to the OECD countries[94]. Figure 7.4 shows some of the results for Europe. First of all, the figure indicates that immigrants coming to Europe have been, at least

[94] Docquier and Marfouk collected data on the immigration structure by educational attainment and country of birth from all OECD receiving countries. Census and register data were available for almost all OECD countries in 2000, and for more than half of them in 1990, the rest of the data are from surveys. The data are estimated to cover 92.7% of OECD stock of adult immigrants in 2000 (and 88.8% in 1990).

recently and on average, better educated than residents[95]. Secondly, the 'net brain gain' as measured in Docquier and Marfouk (2004) was only slightly negative for the EU-15 in 2000 (at -0.1%) and was improved from 1990, when it was -0.5%[96]. Based on these data, the country experiencing the largest brain drain has been Ireland, and conversely, the biggest proportional gains have been experienced in Luxembourg. Data from the OECD in Auriol (2006) indicate that most EU countries are either net beneficiaries of highly skilled migration or that the inflows and outflows balance out. Another report, also using OECD data (OECD, 2005), found that a few EU countries, notably Poland and to a lesser extent, Ireland and Finland, suffer from brain drain, but for most EU countries international mobility of the highly skilled seems beneficial.

Figure 7.5. Emigration rates in Europe in 1990 and 2000.

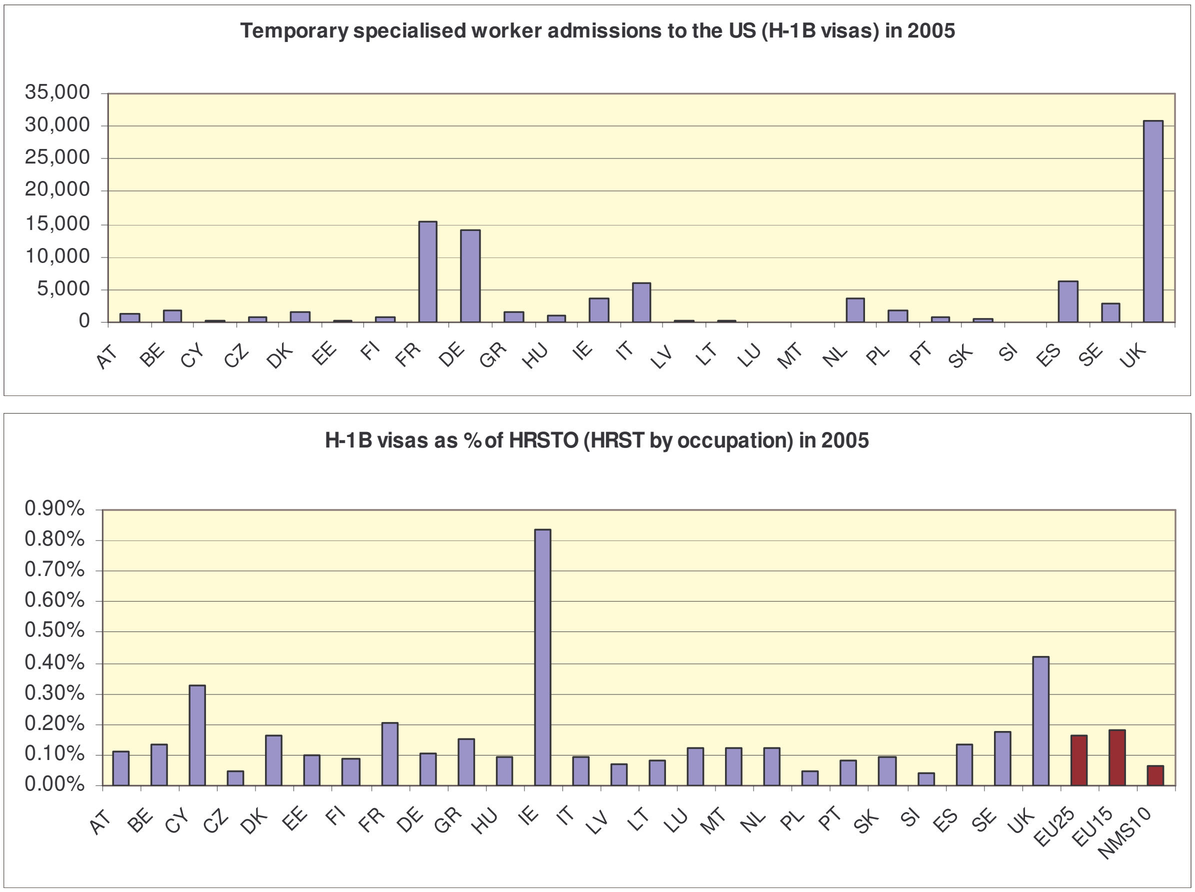


Notes: For the Czech Republic, the data for 1990 is together with the data for Slovakia. For Estonia, Latvia, Lithuania and Slovenia, there is no data for 1990.
Source: Docquier and Marfouk, 2004.

[95] The Docquier and Marfouk data show a ratio of 0.828 for the US in 2000, indicating that Americans are currently, on average, better educated than immigrants. The figure for 1990 was just above one at 1.023.
[96] However, for the US, the 'net brain gain' had risen from 3.6% in 1990 to 5.4% in 2000.

Docquier and Marfouk (2004) have also calculated emigration rates by educational attainment for the countries in their database. Figure 7.5 shows the rates for the EU. For most countries the rates slightly decreased between 1990 and 2000, but Malta (55.2%), Ireland (34.4%), the UK (16.7%), Slovakia (15.3%), Estonia (13.9%) and Portugal (13.8%), still had high or fairly high proportions of their tertiary educated population emigrating in 2000.

Figure 7.6. Brain drain from Europe to the US[97].



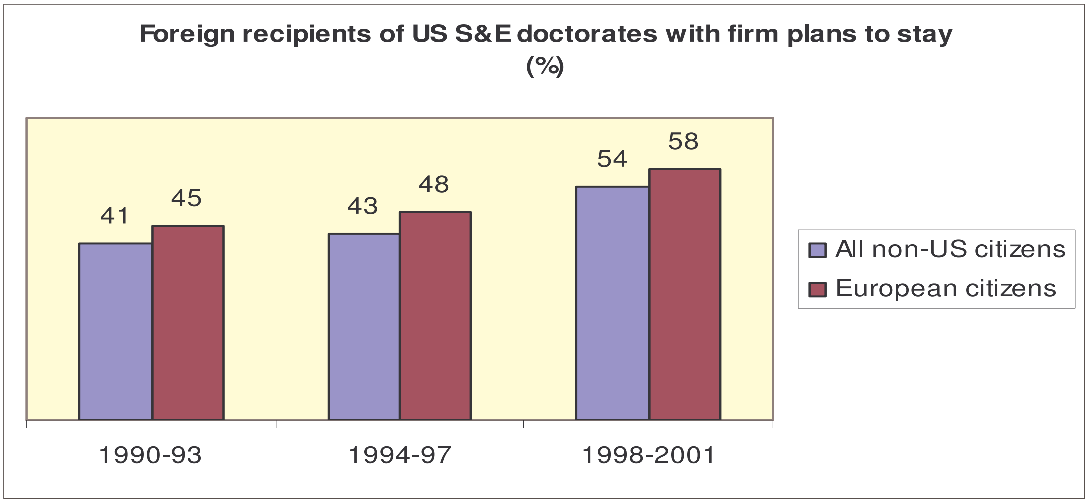
Source: US Dept. of Homeland Security and Eurostat.

There have been abundant data and studies on the United States regarding brain drain (see e.g. OECD, 2001; Gupta, Nerad and Cerny, 2003; Saint-Paul, 2004 or Finn, 1997). the data of which can be used to further assess the brain drain from Europe to the US given that most emigrating S&Es from Europe head for the US. Figure 7.6 shows data on highly skilled Europeans obtaining temporary working visas for the US. In absolute numbers, the UK, France and Denmark ‘lost’ some 60,000 highly skilled workers to the US in 2005, but as a proportion of each country’s HRSTO (HRST by occupation), this

[97] No breakdown to S&Es and other HRSTO is available as regards the H-1B visas. Therefore, this figure looks at all HRSTO instead of just S&Es.

amounts to less than 0.5%. Ireland had the highest proportion of its HRSTO obtaining H-1B visas for the US (0.84%).

Figure 7.7. Trends in plans of foreign recipients of US S&E doctorates.



Source: Potočnik (2005).

With respect to longer term stay in the US, the study by Gupta, Nerad and Cerny (2003), indicates that only around a third of European PhDs trained in the US return home for their first jobs after graduation, with those trained in S&E fields are even more likely to stay in the US after graduation. Those that stay are important to their host country. After all, approximately 25% of US PhDs are foreign born (OECD, 2005). Saint-Paul (2004) looked specifically at European expatriates in the US, and argues somewhat worryingly that even though the absolute numbers of expats may be low, a large proportion of 'European stars'[98] are in the US, possibly slowing down growth and innovation in Europe[99]. Figure 7.7 shows some developments in the plans of foreign recipients of US S&E doctorates since 1990. Firstly, the figure indicates that European S&Es have been on average, slightly keener to stay than other foreign S&Es, and secondly, that staying became more attractive between 1990 and 2001.

Regarding reasons to leave the EU, a study of internationally mobile scientists and engineers (Hansen, 2003)[100] indicated that economic factors such as higher salary are usually not as important as other factors. For EU-born scientists and engineers, the most

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[98] Saint-Paul uses this term for the top 5% of PhDs.

[99] However, even if highly skilled workers stay on after graduation, they may still have plans to return to their home countries after a number of years of foreign experience. For example, Swedish data points to a high return rate for expatriate engineers, with more than 65% returning within eight years stay abroad (Gaillard, 2001), suggesting that expats return according to their original schedule, rather than change their minds and remain abroad. Gaillard (2001) sees this as a home country pull effect for returning expats, rather than a foreign location pull effect for potential emigrates.

[100] The study looked at internationally mobile scientists and engineers originating mostly from the EU or the US.

important reasons to go abroad to work are related to a broader scope of activities and better access to leading technologies.

Outsourcing of R&D to outside the EU-25 is considered a problem for increasing R&D investment within the EU. However, from the point of view of S&E personnel in Europe, there is literature suggesting (see ISA, 1999 or Gaillard, 2001) that expanding businesses outside the EU does not necessarily increase EU brain drain, as domestic employees seem to rarely move permanently to foreign business locations[101]. Companies themselves continue to prefer to locate R&D in their home country, according to the 2005 EU survey on R&D investment trends (EC, 2006b)[102]. The most attractive R&D destinations outside the EU are the US, China and India. Importantly, the report also indicates that high labour costs of researchers – although not insignificant - may not be among the most important factors for deciding where to locate R&D. A more important reason seems to be on the supply side, i.e. the availability of researchers, which can be affected by policy[103]. There can be problems on the other side of the equation as well. The McKinsey Global Institute has studied the offshore markets, and argues that, although the pool is increasing, currently only about 13% of professionals in the developing world (or, as an example, 10% of Chinese engineering graduates) are capable of working for a Western multinational in a high-grade job[104]. The problems are related to cultural and language skills, quality of education , and geography among others.

7.1 Indicators

The main data sets in this module include the following:

- *Outward mobility of S&E graduates and employees:* again, such a brain drain measure is not straightforward due to issues mentioned in Section 2.1, but is nonetheless important to consider. However, the loss of highly skilled S&E employees has important implications for supply scenarios in the EU. The US government agencies collect and provide access to detailed data of highly skilled persons in the US such as highly skilled Europeans working in the US on a temporary basis. Changes in the US, in terms of how many foreigners are hired and where they come from, also have an impact on Europe.
- *Data on S&E graduates choosing jobs outside S&E fields:* there are some data sets containing information on this topic, but mostly for a small number of countries.

[101] It does, of course, most likely lead to loss of jobs in the domestic market.
[102] Nearly 60% of respondents to another survey said that do not currently offshore R&D and do not plan to do in the near future either (The Economist Intelligence Unit, 2006).
[103] Other important reasons for locating R&D were found to be market access, access to R&D knowledge and results, economic and political stability and R&D cooperation opportunities (EC, 2006b). However, these results varied by sector, with pharmaceuticals & biotechnology considering such factors more important.
[104] The study was quoted in an article titled 'Nightmare scenarios – Western worries about losing jobs and talent are only partly justified' in the Economist of 5 October 2006.

- *Data on immigrant workers not finding S&E work:* this measures what is known as brain waste, which is unfortunately relatively common in the EU. Some data are available (see also Figure 7.2).
- *Data on unemployment in S&E field:* includes the numbers of S&Es that are unemployed and consequently could be either immediately re-integrated into the workforce or re-integrated after some (re-)training. There are data available on unemployment within S&Es from Eurostat.

The following indicator is related to the baseline scenario:

- *The effect of changing the retirement age:* the baseline scenario estimates the losses from retirement in the next 10 years or so. In this case, we try to determine what effect changing the retirement age would have on those losses[105].

Additionally, data on issues such as outsourcing of R&D to locations outside the EU-25 could help develop a better picture of the overall situation, even if outsourcing doesn't necessarily take EU employees out of the EU, it still (potentially) reduces R&D performed in the EU-25.

7.2 Simulations

Stocks of S&E are reduced by many factors, such as death, retirement and movements of S&E to outside the EU borders. To reduce the loss of S&Es, a few variables can be manipulated to create a positive impact in stocks of S&Es in a certain year.

The number of specialized European temporary workers (H-1B visa holders) in the United States was around 96,000 in 2005[106], the equivalent of 0.2% of the total number of European HRSTO and 1% of European S&Es[107]. If we assumed that the EU25 would not have any temporary workers in the United States, this pool of specialized workforce would contribute to an increase of S&Es within the EU25 borders.

Age of retirement is probably the variable with the largest potential impact in retaining the numbers of S&E. Any increase in the compulsory age of retirement will positively impact the stocks of S&E. The average age of retirement has been increasing and is predicted to continue to increase in the EU. Any process introduced to speed up the increase to the mandatory age of retirement would have a positive influence in the numbers of S&E.

Numbers of S&Es can also be increased if unemployed S&Es could be reintegrated into the workforce either through re-training or by discouraging this group of skilled workforce from looking for jobs outside the EU. Although there are no data for S&E

[105] There are, however, considerable differences among the 25 EU member states in the average retirement ages.
[106] US Homeland Security (Office of Immigration Statistics) data.
[107] So, even if all the European H-1B visa holders were scientists and engineers (which they are not, but no breakdown is available), they would only represent 1% of EU S&Es.

unemployment, there are data on unemployment for Human Resources in Sciences and Technology. Given that the numbers of S&E in relation to total numbers of HRST have been on average 10.9% between 2000 and 2004, we can estimate the number of S&Es that are unemployed by approximation. Furthermore, using the estimation of unemployed S&Es, we can calculate the percentage of S&Es unemployed in relation to the total stocks of S&Es, which had been on average 2.73% from 2000 to 2004. Any reduction in this percentage would have a positive impact in the number of active S&Es within the EU.

Manipulated variables:

1. Number of specialized temporary workers in the US

Consider that the EU25 do not send any specialized temporary workers to the US.

2. Average age of retirement – Increase in age of retirement

Increase the average age of retirement by one year every year from 2007 up to a maximum of 65 years old.

3. Unemployment within S&E

Reduce the percentage of unemployed S&Es in relation to total stocks of S&Es which has been on average 2.73% by 10% per year as from 2007.

Table 7.1 presents the impact of variables' manipulations in terms of avoiding loss in stocks of S&E.

Table 7.1. Loss of S&Es – Impact of changes in absolute terms.

		Extra S&Es stocks after changes implemented in 2007[108]	
		S&Es	**Researchers**[109]
Number of specialized temporary workers in the US	Considered that the EU has no skilled temporary workers in the US.	141,000[110]	35,250
Average age of retirement	Increase to 65 years as from 2007	2,000,000[111]	500,000
Unemployment of S&Es	Reduction on unemployment rate in this field by 10% per year as from 2007	185,000[112]	46,250
Total impact		**2,326,000**	**581,500**

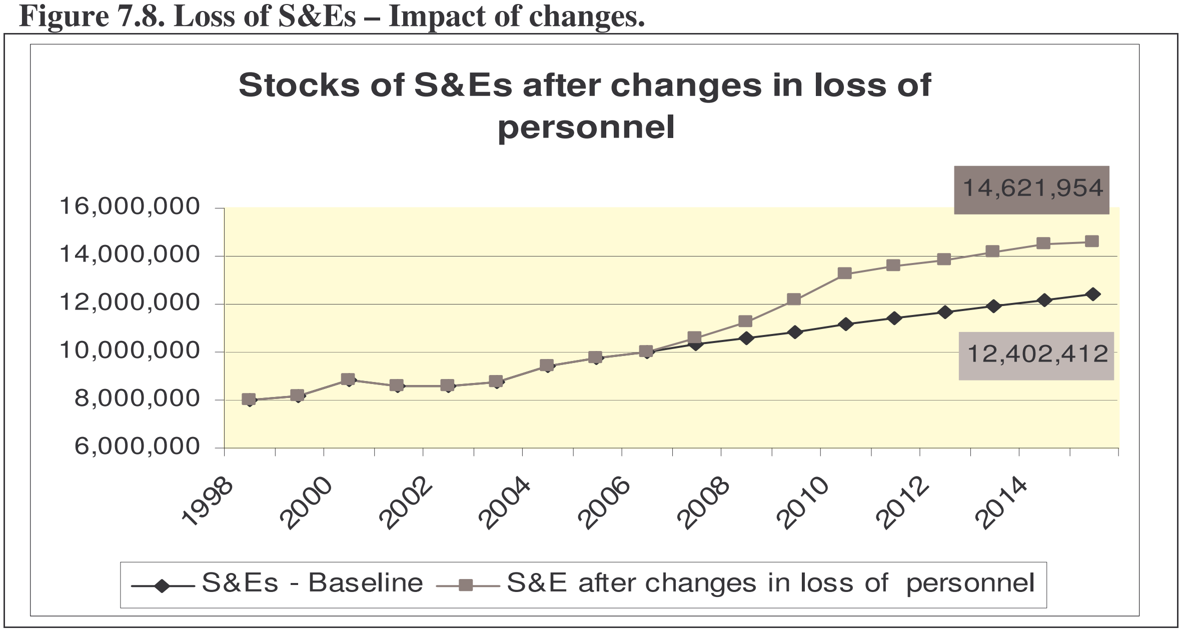
[108] Cumulative effect, as from 2007 when changes were proposed and implemented, up to 2015 (9 years).
[109] At R&D intensity level between 2 and 4% of GDP, the proportion of researchers in relation to S&E is approximately 25%.
[110] Projected numbers of specialized workers that would go to the US by 2015.
[111] Average gain in S&Es numbers per year once the retirement age reaches 65 years old.
[112] Estimated numbers of S&Es that could be reintegrated into active workforce as a proportion of estimated stocks of S&Es by 2015.

A major impact in terms of avoiding losses in stocks of S&Es, is undoubtedly related to a postponement of retirement age. By simply increasing the average age for retirement to 65 years old, the EU25 could retain on average per year, 2.0 million more S&Es in its active stocks. Furthermore, by reducing unemployment in the field and reintegrating S&Es in the workforce, the EU will be able to further increase its stocks. The number of temporary specialized workers in the US may also increase EU's stocks of S&Es, however, by restraining the temporary workforce abroad, the EU would be losing in terms of other benefits (e.g., learning, exchange of technology), the result of which such exchange programmes bring about.

It is important to note that when considering these losses in stocks of S&Es and changes proposed to reduce the impact of such losses, we are not taking into account the quality of S&Es. When doing this exercise, our main focus is on quantitative stocks of S&Es and not on the quality of such stocks. Consequently, reducing unemployment in the field and bringing back S&E workers from retirement (or retaining workers through a postponement of retirement) are factors that will help to increase final stocks, regardless if these stocks have the required quality to conduct research.

Figure 7.8 illustrates the changes in stocks of S&Es by manipulating variables age of retirement, numbers of skilled temporary workforce in the United States , and unemployment rates in S&E. The new projected number of S&Es amounts to 14.6 million by 2015.

Figure 7.8. Loss of S&Es – Impact of changes.



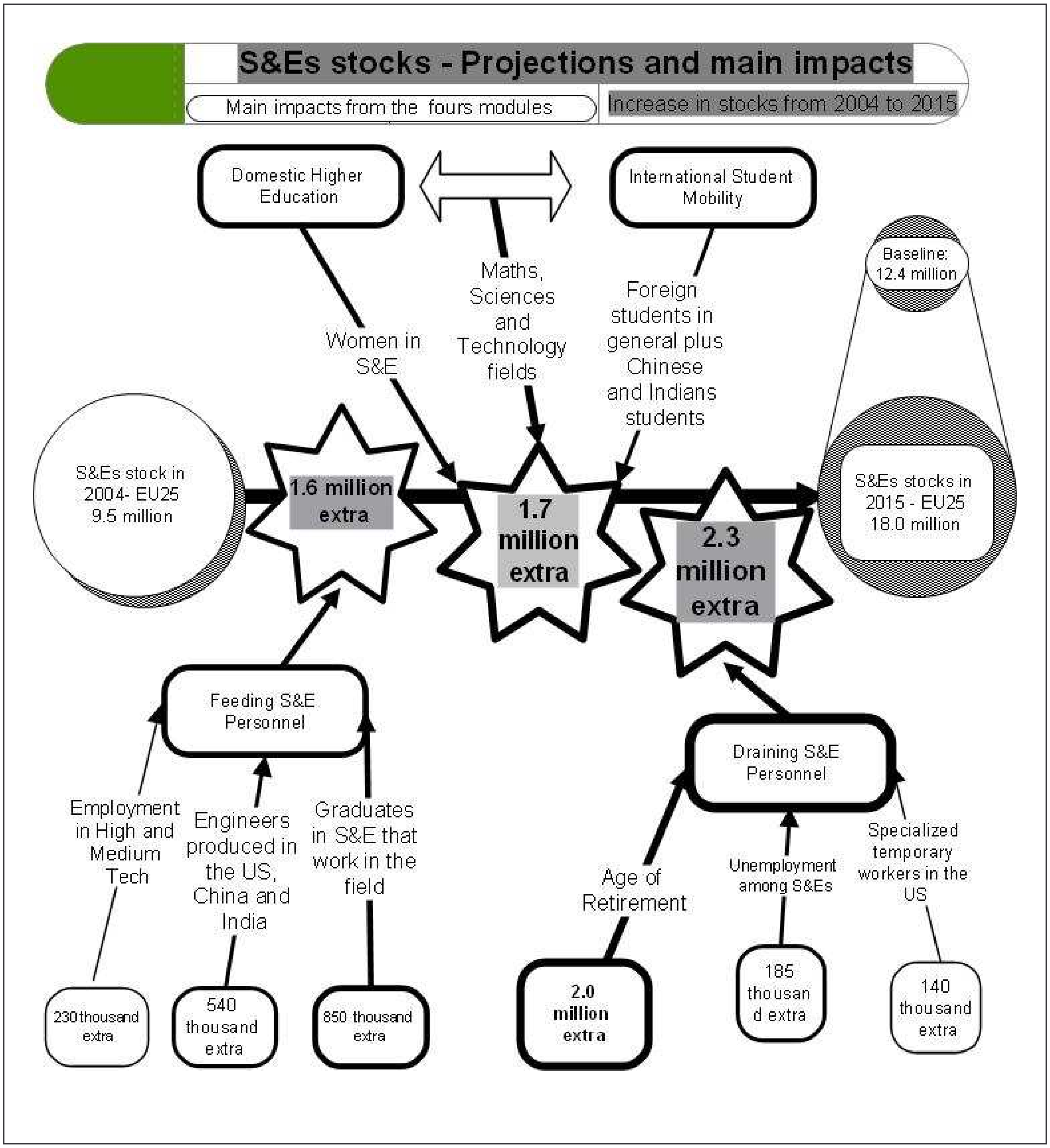
Important indicators for controlling losses in S&E stocks:
Numbers of specialized temporary European workers outside the EU borders, age of retirement and unemployment in S&E fields.

8.0 THE BIG PICTURE

Figure 8.1 helps illustrate the ‘big picture’ by quantifying some of these influences and showing some potential pathways of reaching the goals of additional scientists and engineers.

Subsequently, separate contributions from the various modules are discussed shortly , and finally, these contributions are put together to show their total impact on the stock of scientists and engineers in the EU in the next ten years.

Figure 8.1. S&E stocks – Projections for 2015 and main impacts

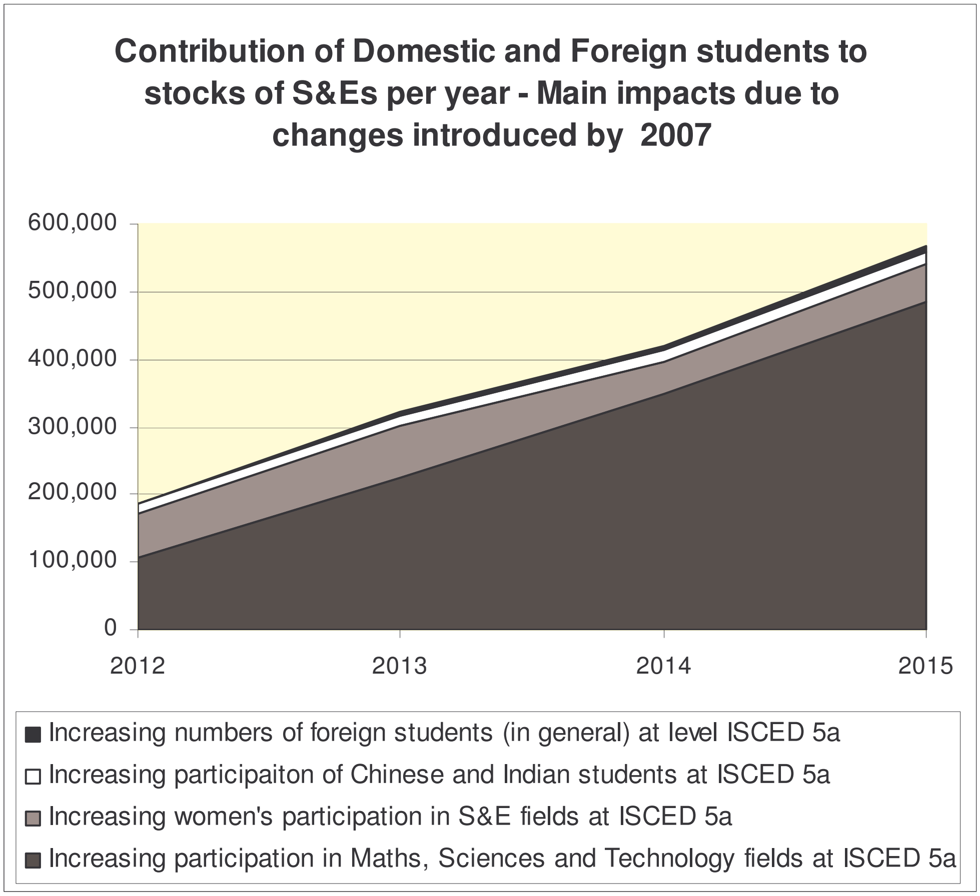


8.1 Contributions per module

Modules 1 and 2 – Domestic and foreign education

The simulation exercise identified a few variables that produce significant impacts on the numbers of S&Es. Building on the baseline estimates for S&Es graduates (based on historical times series), we added up the numbers of S&E graduates coming from different sources according to manipulated variables. Increasing the proportion of students who choose science and engineering fields is the most important variable, followed by increasing female enrollments in the field , and increasing the participation of specifically Chinese and Indian students that would otherwise go to tertiary education in the United States. Attracting foreign students (in general) at ISCED 5a level also proved to contribute to increasing numbers of graduates in the field. Although increasing the number of entrants from the age cohort 20_24 by improving education attainment in this group also had some impact on future numbers of S&E graduates, its impact was not important when compared to other variables. Other variables manipulated in this exercise also proved to contribute to the increase in the numbers of graduates, although their impact was marginally significant. Figure 8.2 summarizes the main contributions in the final numbers of S&Es.

Figure 8.2. Contributions from modules 1 and 2 – Domestic and foreign students.



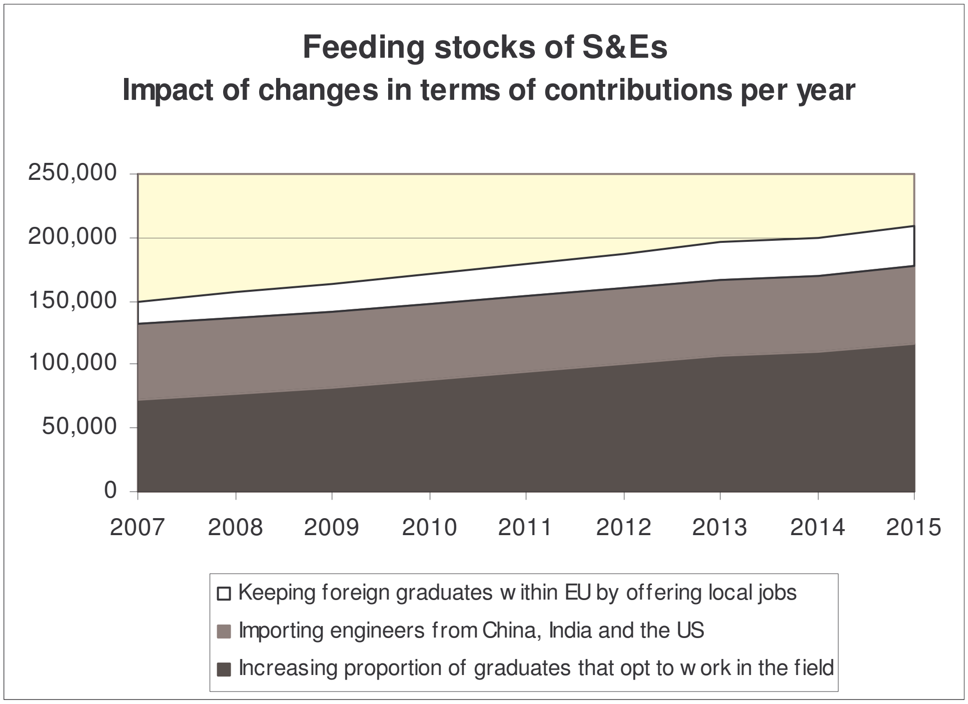
Note: Changes introduced by 2007 at tertiary level will only have an impact on the numbers of S&Es graduates by 2012 (5 years to conclude tertiary ISCED 5a)

Module 3 – Supply of S&E

Increasing the proportion of S&E graduates who work in the field was the variable that contributed the most to the increase in stocks of S&Es, followed by importing a percentage of engineers produced in the United States, China and India , and by maintaining a part of foreign graduates in S&E who studied in EU and who would otherwise return to their home countries for jobs. Bringing back part of Europeans who graduated outside of Europe in S&E fields has not had much of an impact to the stocks of S&Es.

Figure 8.3 summarizes the individual contribution of each manipulated variable in this model.

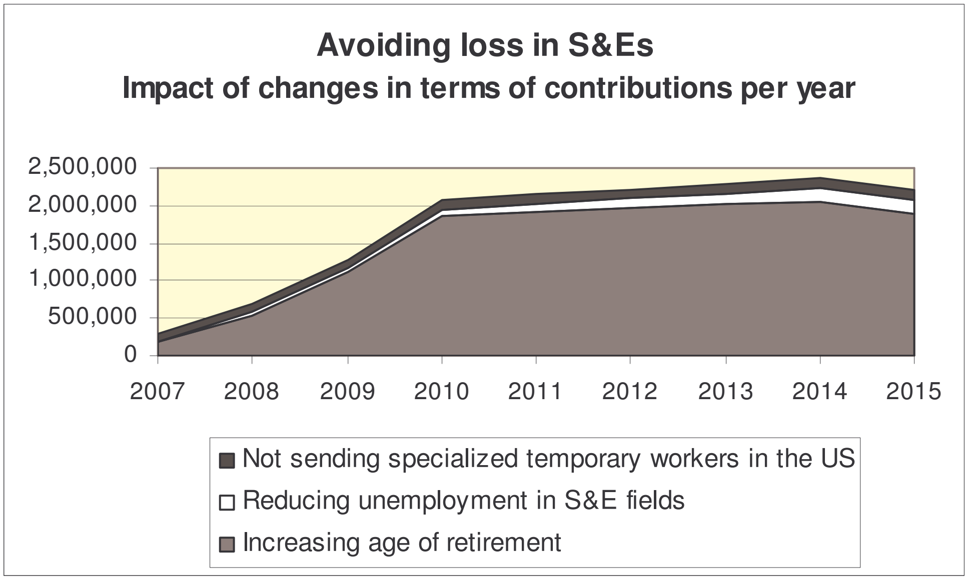
Figure 8.3. Supply of S&Es.



Module 4 – Loss of S&E

Finally, when it comes to avoiding losses on S&Es stocks (see Figure 8.4), a few variables proved to have a substantial impact on the final numbers of S&Es. Increasing the age of retirement was the variable with the greatest impact, followed by reducing unemployment in the field, and preventing specialized temporary workers from moving to the United States.

Figure 8.4. Avoiding the loss of S&Es.

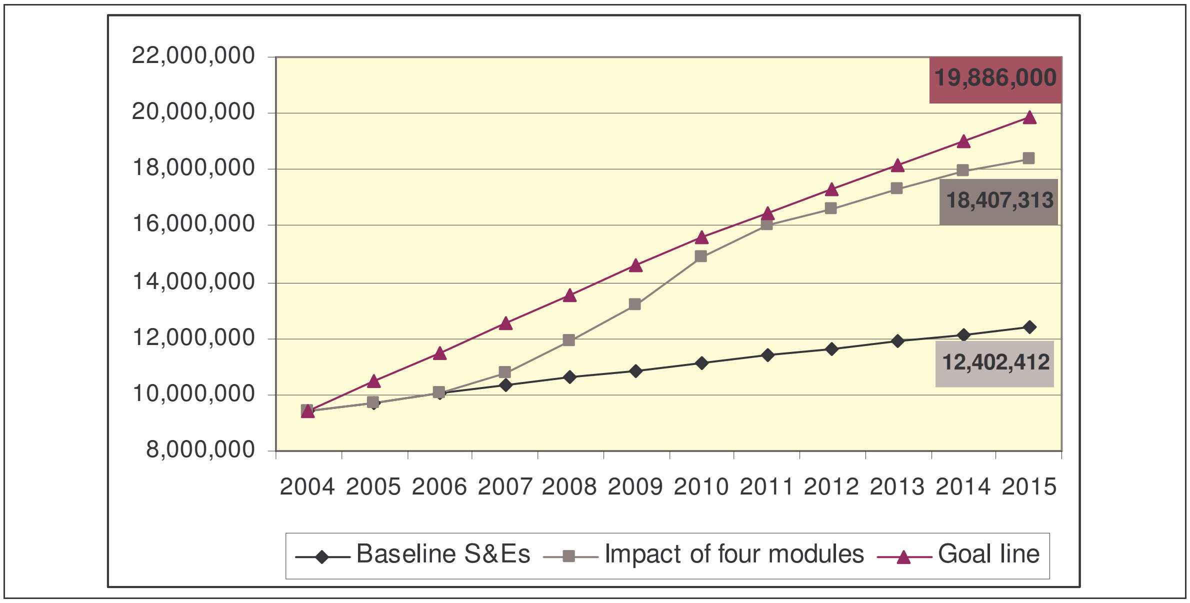


8.2 Putting the modules together

Our model was built by first looking at students in tertiary education at levels ISCED 5a and 6, more specifically in the S&E fields, and then graduate numbers of S&Es. Then we looked into stocks of S&E and the variables that were influential not just in increasing projected stocks but also those that would have a negative impact in S&E stocks and consequently, if manipulated, would have a less significant influence in final numbers of S&Es. Before introducing these changes, final stocks of S&Es are expected to reach 12 million by 2015. After the changes, such stocks are forecasted to reach 18 million by 2015. All of the changes combined could therefore create a net impact of close to 6 million extra S&Es by 2015.

Figure 8.5 depicts the projections of S&Es for 2015 before and after the proposed changes and compares them with goals projected as per Table 3.2, Required and projected numbers of S&Es for 2010 and 2015.

Figure 8.5. Stocks of S&Es – Baseline and projected numbers after changes compared with goals for 2015



When all variables that have been manipulated in order to increase numbers of S&Es by 2015 have been included, it becomes clear that there are a few variables that have a greater impact on final numbers than other variables. Table 8.1 summarizes the key variables.

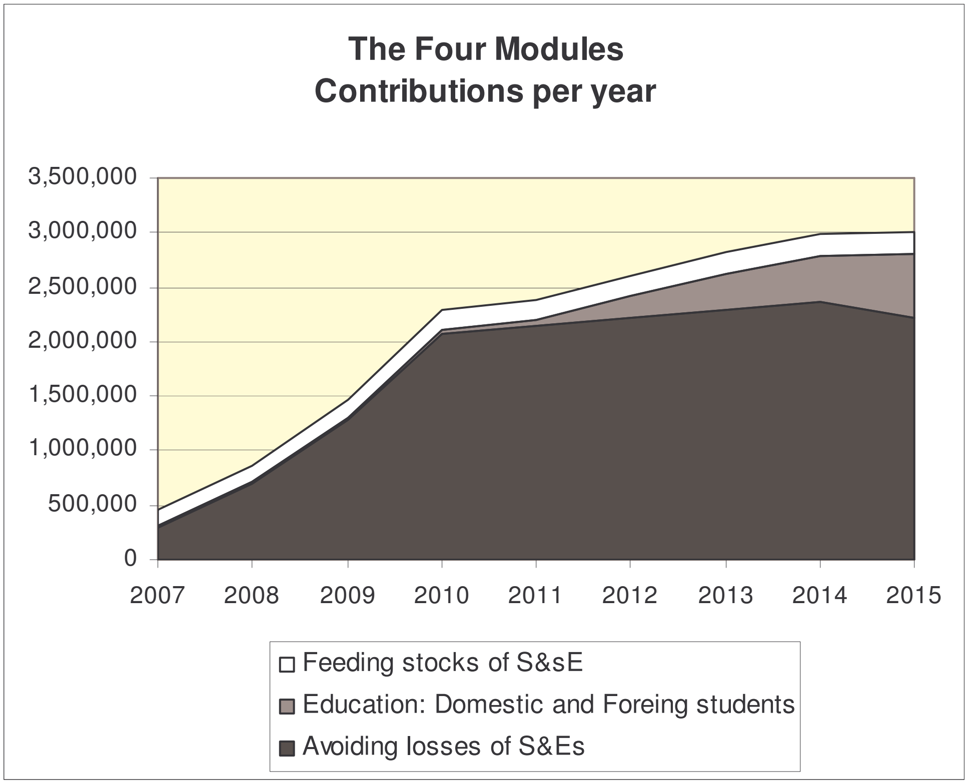
Table 8.1. Impact in S&Es numbers – Absolute terms.

			Extra S&E and researcher stocks after changes implemented from 2007	
Module	**Variable**	**Change**	**S&Es**	**Researchers**
Loss of S&Es	Age of retirement	Increase average age of retirement to 65 years as from 2007	2,000,000	500,000
Domestic and Foreign Students	Maths, Sciences and Technology fields	Increase proportion of students choosing this field in relation to total fields by 2% per year	1,165,000	290,000
Supply of S&Es	Graduates in S&E working in the field	Increase proportion of graduates that opt to work in the field from 65 to 75% as from 2007	850,000	212,500
Supply of S&Es	Engineers produced in the US, China and India	Bring 10% of this pool of engineers to work within EU borders	540,000	135,000
Domestic and Foreign Students	Women's enrolments in S&E	Increase participation of women in these fields by 10% per year, by shifting from other fields	385,000	96,000
Supply of S&Es	Foreign graduates in S&E	Maintain 50% of foreign students (outside the EU) who graduate in S&E fields within EU borders by taking jobs within EU	226,400	56,600
Loss of S&Es	Unemployment of S&Es	Reduction on unemployment rate in this field by 10% per year as from 2007	185,000	46,250
Loss of S&Es	Number of specialized temporary workers in the US	Considered that the EU has no skilled temporary workers in the US	141,000	35,250
Domestic and Foreign Students	Chinese and Indian tertiary students	Increase participation of Chinese and Indian students at tertiary level, by shifting 25% of this pool of potential students from the United States into the EU.	63,000	16,000
	Total Impact		**5,555,400**	**1,387,600**

The key indicators in Table 8.1 can also be considered in terms of two types of factors: bottlenecks – critical areas, which Europe, or at least certain countries within the EU, have problems with - and policy decision points – currently debated or otherwise significant policy questions. These factors are closely related, as some of the bottlenecks (e.g. scientists and engineers retiring too early, science subjects not being popular enough at school, Chinese and Indian S&E students going to the US instead of the EU, or lack of women in S&E) can create opportunities for policy intervention.

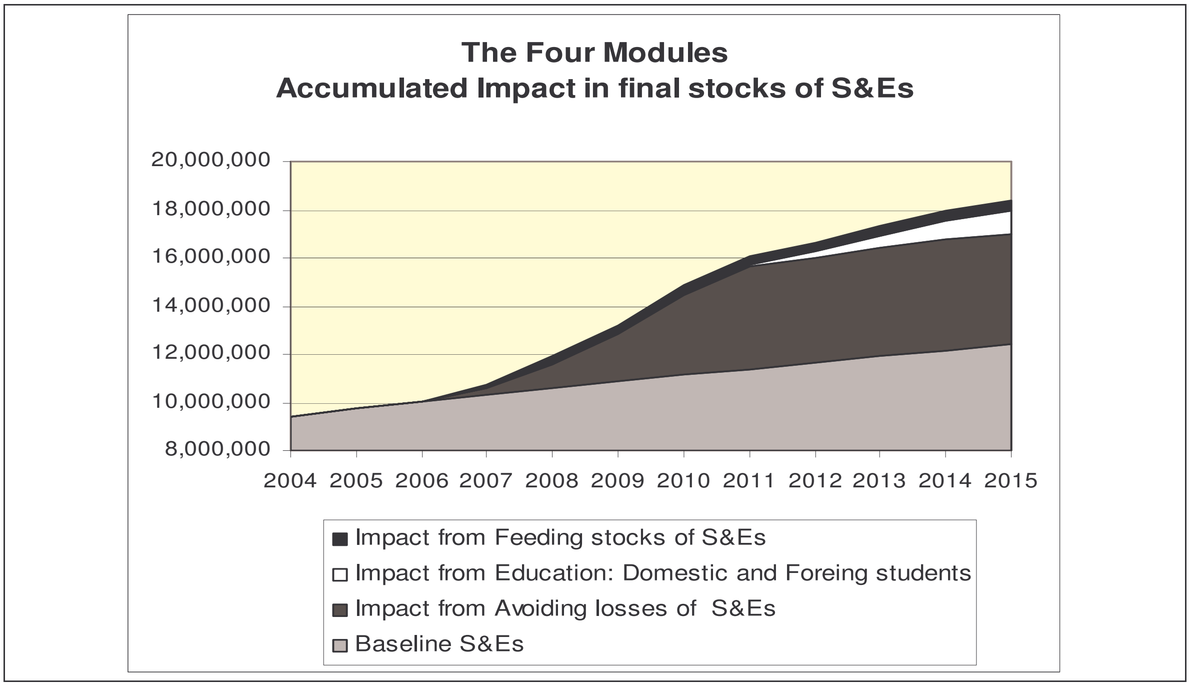
Figure 8.6 illustrates the impact of the four modules on the numbers of S&Es and the individual contribution of each module on a yearly basis[113] while Figure 8.7 shows the accumulated impact of changes due to changes in the four modules.

Figure 8.6. The four modules – Impact of changes on yearly basis



[113] Note: Modules 1 and 2 on domestic and foreign students were simulated together

Figure 8.7. The four modules – Impact of changes – Accumulated from 2007 to 2015



9.0 CONCLUSIONS

9.1 Overall results

This report has examined how a large increase in the supply of researchers – or scientists and engineers - could be attained in the next ten years or so, and investigated the factors that influence the supply of researchers. Where relevant, simulations have been used to manipulate variables that might have an effect on the stocks of scientists and engineers and to identify key factors. The report has used a number of indicators (listed in Annex B, Tables B-1 and B-2) and identified the key indicators among these that can be particularly helpful to the policy community for tracking progress towards the goal of increased supply of researchers and S&Es (see Table 9.1)[114]. Further, the report has discussed issues related to a number of additional potentially relevant indicators. Finally, the report has forecasted possible outcomes that might occur if certain actions, trends or other developments would take place, or alternatively, if current trends would continue unchanged.

The estimates of required numbers of scientists and engineers discussed in this report vary from around 3.5 million[115] to as much as 10 million[116] depending on what the point of departure is (in terms of R&D intensities - R&D against GDP - and what proportion of S&Es is considered to be reasonable among S&Es). The overall conclusion is that, if we look at the highest target estimate, the EU is not likely to meet it domestically, and therefore must look outside its borders to both international S&E students and scientists and engineers who are already working in their fields. On the other h, and the lowest target estimate would be fairly easy to reach.

At a more detailed level, the report (in Section 3) has identified groups of member states, varying from countries that should not have too much trouble in meeting their goals (including Scandinavian and other Northern European countries, as well as France, Germany and Austria), to countries, such as the new member states and Southern Europe, that would seem to have considerably greater difficulties in reaching the desired numbers of scientists and engineers.

In Sections 4 to 7, the following four separate modules have been considered within the overall picture of the supply of S&Es: the domestic higher education system in the EU, international student mobility, the main supply channels to the stock of European S&Es ,

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[114] The key indicators in Table 9.1 can also be considered in terms of two types of factors: bottlenecks – critical areas, which Europe, or at least certain countries with the EU, have problems with - and policy decision points – currently debated or otherwise significant policy questions. These factors are closely related, as some of the bottlenecks (e.g. scientists and engineers retiring too early, science subjects not being popular enough at school, Chinese and Indian S&E students going to the US instead of the EU, or lack of women in S&E) can create opportunities for policy intervention.

[115] This lowest estimate is based on the estimate from the European Commission that around 700,000 (see EC, 2003a) additional researchers would be required, and the 19% current reseachers to S&Es ratio in the EU. Applying a 25% ratio of researchers to S&Es, observed in those countries that have their R&D intensity currently between 2 and 4%, would give an even lower estimate of 2.8 million additional S&Es.

[116] This highest estimate is based on the individual EU member state R&D intensity targets agreed in 2006 and the calculations made in Section 3 of this report.

and the main loss channels that decrease the number of S&Es in the EU. Within each module, the report has discussed some of the related literature, available data and indicators. Subsequently, simple simulation exercises have been performed with data from the 25 EU member states. In these simulations, the data have been manipulated according to a number of fairly realistic assumptions of growth or reduction.

Section 8 has brought all the four modules together to look at the big picture. The conclusion from the manipulations performed in Sections 4 to 7 is that the stock of scientists and engineers in the EU could be expected to reach about 18 million by 2015. All the changes combined could therefore create a net impact of close to 6 million extra S&Es by 2015 (on top of the expected around 12 million from the current trends in the stock of S&Es). Such an increase would cover most of the estimated goals for S&Es in this report – except for the highest estimate of 20 million. Consequently, the overall goal of 3% R&D intensity could (nearly) be reached in this manner provided the identified changes could be adequately encouraged.

One of the main goals of this report has been to identify key indicators for tracking the success of the EU in reaching its R&D intensity goals in terms of the pool of scientists and engineers. The key available indicators identified in this report, together with the impacts of 'adjusting' these indicators, are presented in Table 9.1.

It can be seen from this table that nearly 90% of the total impact in this exercise comes from the reasonable manipulation of only five indicators:

- Increasing average retirement age in the EU
- Increasing proportion of students choosing S&E studies
- Increasing proportion of S&E graduates getting S&E employment
- Bringing in more scientists and engineers from countries like China and India (or even the United States)
- Increasing proportion of women studying S&E fields.

More than 50% of the impact comes from the top two indicators listed above. On the other hand, individual impacts from factors, including trying to keep non-EU students working in the EU after graduation, reducing unemployment in S&E fields, trying to retain EU scientists and engineers in the EU (as opposed to letting them migrate, for example, to the US) and, getting more Chinese and Indian students to choose the EU for their studies, all remain small at somewhere between 1 and 4%.

Table 9.1. Summary table of key indicators and the impacts of reasonable change.

Module	Indicator	Change	Extra S&E stocks by 2015 after changes implemented from 2007	Percentage contribution to total number of additional S&Es
Loss of S&Es	Average age of retirement	Increase average age of retirement in the EU to 65 years	2,000,000	36.0%
Domestic and Foreign Students	Students in S&E fields	Increase proportion of students choosing S&E fields instead of other fields by 2% per year	1,165,000	21.0%
Supply of S&Es	Employed S&E graduates	Increase proportion of graduates that opt to work in S&E fields from 65% to 75%	850,000	15.3%
Supply of S&Es	Engineers produced in the US, China and India	Bring 10% of this pool of engineers to work within EU borders	540,000	9.7%
Domestic and Foreign Students	Female enrolments in S&E studies	Increase participation of women studying S&E fields by 10% per year, by shifting from other fields	385,000	6.9%
Supply of S&Es	Foreign S&E graduates	Retain 50% of foreign EU S&E graduates (coming from outside the EU) and keep them working within EU borders	226,000	4.1%
Loss of S&Es	Unemployment of S&Es	Reduce unemployment rate in S&E fields by 10% per year as from 2007	185,000	3.3%
Loss of S&Es	Number of specialized temporary workers in the US	Retain all those S&Es who would otherwise migrate to work in the US	141,000	2.5%
Domestic and Foreign Students	Chinese and Indian tertiary students studying in the US	Increase participation of Chinese and Indian students at EU universities, by shifting 25% of the pool of potential S&E students from the United States into the EU.	63,000	1.1%
Total Impact			**5,555,000**	**100%**

9.2 Issues with indicators

In addition to all of the indicators used in this scenario (listed in Annex B, Tables B-1 and B-2), other useful and desirable indicators exist and/or data for them could be collected. In the case of many of these indicators, greater detail is required than what has, at least until recently, been available. Also, a significant issue is related to having enough consistency between countries, both in terms of what data are collected and how indicators are defined, these points being particularly important for international mobility data.

Table 9.2 includes some of the missing or underdeveloped indicators, their policy relevance and other associated issues. Rectifying some of these problems could help further assess the progress towards greater numbers of scientists and engineers, and therefore researchers, in the EU.

Table 9.2. Suggestions for a number of improved indicators for the EU.

Indicator	Relevance to assessing the future changes in the stock of S&Es and researchers	Current state of affairs	Policy relevance		
			High/ Medium/ Low	Importance to quantity/ quality of stocks	Potential impact and further actions
Educational background of researchers	To assess the origin of researchers	Currently Eurostat collects data on the educational background of S&Es, but does not collect such data on researchers.	na	na	Improved data quality in this key HR category.
Age distribution of HRST, S&Es and researchers	To assess historic and future trends in the stocks, in particular, to assess the losses to retirement from the stocks	Currently data on the age distribution of HRST and S&Es are collected, but the age brackets are too wide, especially at the higher end (45-64 years).	Medium	Quantity	For example, increasing the compulsory retirement age affects the numbers of S&Es and researchers.
Numbers of high school pupils studying S&E subjects by gender	To assess the potential contribution of such pupils to university enrollments in S&E fields	Currently, there are data for the overall ISCED97 level 3, but a breakdown at levels 3a (high school), 3b and 3c would be required.	Medium	Quantity	Relevant to the extent that the EU and member states would want to try to influence the popularity of science as a school subject.
Numbers of S&E students in higher education	To assess the potential contribution of S&E graduates to S&E fields and research performed in the EU	These data are collected, but there is room for improvement, as there are inconsistencies between countries in counting university students, especially at the PhD level (level 6 according to ISCED97).	Medium	Quantity	Improved data quality.
Survival rates in education by field of study and gender	To assess whether S&E fields are facing more or less difficulties than other fields in getting students to graduate, and to assess which gender finds it easier to finish studies	Survival rates are currently collected by the OECD, but not by field of study.	Low	Quantity	Improved data quality.
Numbers of mature students by educational field, age and gender	To assess the potential contribution of mature S&E graduates to the S&E fields of work and R&D in the EU	Eurostat currently collects data on mature students by age *or* by field of study, but not combined by age *and* field of study.	Low (quantity) Medium (quality)	Both	Potential mature students could be encouraged to take up S&E studies and their future employment prospects could be improved. Mature graduates are likely to be better equipped for subsequent work than their younger counterparts.

Indicator	Relevance to assessing the future changes in the stock of S&Es and researchers	Current state of affairs	Policy relevance		
			High/ Medium/ Low	**Importance to quantity/ quality of stocks**	**Potential impact and further actions**
Further careers of graduates – e.g. in 1, 5 and 10 years after graduation	To assess the true contribution of S&E graduates to the S&E fields of work and R&D in the EU, to assess the true contribution of graduates in other fields to the S&E stock (many S&Es have graduated from other fields), and also to assess what *the large proportion (possibly a third) of S&E graduates, who do not work in S&E*, end up doing with their careers	There are a number of country studies focusing on graduate careers, and at least one study covering several countries (CHEERS), but no EU level data collection has taken place so far, although there are some current plans for this.	High	Quantity	The EU and member states should know what the pool of S&E graduates not working in S&E do (and why they do it), possibly to encourage or enable them to come back to S&E.
Numbers of foreign students by nationality, gender and field of study	To assess the potential contribution of such students to the stock of S&Es and researchers	Foreign student data is not currently available by field of study form Eurostat. Additionally, there are great inconsistencies in how international students are defined and counted, or not counted as is often the case (see Section 3 for more). There are some current positive developments here.	Medium	Quantity	The EU and member states can have some influence on the flows of students into the EU.
Numbers of foreign graduates by nationality, gender and field of study	To assess the potential contribution of non-EU graduates to the stock of S&Es and researchers in Europe	Graduate numbers are not currently collected by foreign/non-EU vs. domestic/EU basis.	Medium	Quantity	Improved data quality.
Further careers and locations of non-EU graduates	To assess how international S&E graduates contribute to the stock of S&Es and researchers in Europe (vs. outside Europe)	There is currently no EU wide collection of such data.	Medium	Quantity	Improved data quality, but also, it may be possible to improve survival rates in S&E fields.
Quality indicator for EU universities/S&E programs	To assess the true relevance of university/program quality on e.g. enrollments rates of EU or non-EU students	No such indicator currently exists, but it could be created, e.g. along the lines of the 'Shanghai index' of top 500 universities	Low (quantity) Medium (quality)	Both	Improved data quality, but also, if better students are attracted to better universities, better availability of information on good EU universities should raise the quality of international students.

Indicator	Relevance to assessing the future changes in the stock of S&Es and researchers	Current state of affairs	Policy relevance		
			High/ Medium/ Low	**Importance to quantity/ quality of stocks**	**Potential impact and further actions**
Numbers of immigrants by educational background and gender	To assess the actual flows of immigrants and their potential contribution to the stock of S&Es and researchers	There are great inconsistencies in how immigrants are defined and counted (see Section 3 for more). Some countries collect data on the educational background of immigrants, but most do not. There are some recent developments to improve such data availability.	High	Quantity	The EU and member states may want to try to encourage immigration of the better educated.
Employment rates of immigrants by gender	To assess the potential contribution of immigration to the stock of S&Es and researchers	There is some data on this, but it is not adequate enough across countries.	Low	Quantity	The EU and member states can try to influence the hiring rates of immigrants.
Relevance of educational background of immigrants to current employment	To assess the current actual contribution of immigration to the stock of S&Es and researchers	Such data is mostly not collected.	Medium	Quantity	The EU and member states could have some influence on the hiring of highly qualified immigrants in appropriate jobs.
Data on outward mobility of S&E graduates and personnel	To assess the brain drain from Europe	Adequate exit data is not currently widely collected in EU member states.	Low (quantity) High (quality)	Both	Relevant, if the EU and member states would attempt to keep such emigrating S&Es in Europe[117].

Note: na – not applicable.

[117] See Saint-Paul (2004) for his argument that European 'star' researchers are overrepresented in the US, and therefore the emigration of EU S&Es is disproportionally draining the high quality research pool in Europe.

9.3 Policy considerations

In general, important policy considerations include both policies to increase supply and to increase demand. The former includes total funding for higher education, immigration policies, coordination of EU higher education and provision of sufficient and easily accessible information on it outside the EU, funding for teaching positions in the public sector, retirement policies , and retraining policies. Policies to increase supply by creating demand include funding for research positions in the public sector, increasing the number of post-doc places, subsidies to firms to hire new S&E graduates , and subsidies to firms for R&D in general. Table 9.1 indicates that, based on this exercise, the most important policies are related to retirement, education and immigration. The role of women in increasing the supply of scientists and engineers in the EU should also be considered a policy priority[118].

As shown in Table 9.2, there are a number of ways in which the relevant indicators and data collection could be improved on. One important point is that most data should be broken down by gender.

[118] Moreover, increasing the participation of women in the S&E work force has implications for social policy (e.g. child care, work arrangements, making it easier for workers to leave and re-enter the workforce).

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ANNEX A

Detailed list of indices used for clustering

A- Competitiveness

Index	Source	Index Composition
Global Competitiveness Index 2006-2007	World Economic Forum	1- Institutions 2- Infrastructure 3- Macro economy 4- Health and Primary Education 5- Higher Education and Training 6- Market Efficiency 7- Technological Readiness 8-Business Sophistication 9- Innovation
http://www.weforum.org/en/index.htm		

B- Corruption

Index	Source	Index Composition
Corruption Perceptions Index CPI - 2006	Transparency International	
The CPI relates to perceptions of business people and country analysts.		
www.transparency.org		

C- Digital / ICT

Index	Source	Index Composition
Networked Readiness Index (NRI) 2005	World Economic Forum	1- Network Use Index 2- Enabling Factors
The World Economic Forum's Networked Readiness Index (NRI) measures the propensity for countries to exploit the opportunities offered by information and communications technology.		
http://www.weforum.org/en/index.htm		

Index	Source	Index Composition
Digital Opportunity Index (DOI)-2005	International Telecommunications Union	• Opportunity • Infrastructure • Utilization
The Digital Opportunity Index (DOI) is a composite index that measures 'digital opportunity' or the possibility for the citizens of a particular country to benefit from access to information that is 'universal, ubiquitous, equitable and affordable'. As such, it is a measure of each country's performance and prospects for progress in building an Information Society.		
http://www.itu.int/osg/spu/statistics/DOI/_page		

Index	Source	Index Composition
Digital Access Index (DAI)- 2002	International Communication Union - Market, Economics and Finance Unit	• Infrastructure • Affordability • Knowledge and Quality • Actual usage of ICT
The Digital Access Index (DAI) measures the overall ability of individuals in a country to access and use new ICTs. The DAI is built around four fundamental vectors that impact a country's ability to access ICTs: infrastructure, affordability, knowledge and quality and actual usage of ICTs.		
www.itu.int		

Index	Source	Index Composition
ICT Diffusion Index -2005 (2004 numbers)	United Nations	• Access Index • Connectivity Index
It evaluates ICT development using indicators of ICT diffusion across countries. It measures the average achievements in a country in two dimensions: access and connectivity.		

D- Environment

Index	Source	Index Composition
Environment Index - 2004	World Travel & Tourism Council	• Population Density Index • CO2 Emission Index • Environmental Treaties Index
The index measures environmentally friendliness.		
http://www.wttc.org/		

E- Gender / Role of Women

Index	Source	Index Composition
Gender Empowerment Measure (GEM) Human Development Report 2005	**UNDP** (United Nations Development Programme).	• EDEP for parliamentary representation • EDEP for economic participation • EDEP for income
GEM captures gender inequalities.		
http://hdr.undp.org/reports/		

F- Governance

Index	Source	Index Composition
Governance - Voice and Accountability - 2005	World Bank	
The extent to which a country’s citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.		
www.worldbank.org/wbi/governance		

Index	Source	Index Composition
Governance – Political Stability and Absence of Violence - 2005	World Bank	
Perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including domestic violence and terrorism.		
www.worldbank.org/wbi/governance		

Index	Source	Index Composition
Governance – Government Effectiveness - 2005	World Bank	
The quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.		
www.worldbank.org/wbi/governance		

Index	Source	Index Composition
Governance – Regulatory Quality - 2005	World Bank	
The ability of the government to formulate and implement sound policies and regulations that permits and promotes private sector development.		
www.worldbank.org/wbi/governance		

Index	Source	Index Composition
Governance – Rule of Law - 2005	World Bank	
The extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence.		
www.worldbank.org/wbi/governance		

Index	Source	Index Composition
Governance – Control of Corruption - 2005	World Bank	
The extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests.		
www.worldbank.org/wbi/governance		

G- Human Resources

Index	Source	Index Composition
Human Development Index - HDI (2003) Human Development Report 2005	United Nations Development Programme (UNDP)	1- Life expectancy index 2- Education Index (Adult Literacy and Gross Enrolment ratio) 3- GDP index
http://hdr.undp.org/reports/global/2003/indicator/indic_27_1_1.html		

Index	Source	Index Composition
The Human Resources Index – (HRI) - 2004	World Travel & Tourism Council	• Adult Literacy Rate • Combined Enrolment Ratio (Primary. Secondary and Tertiary)
http://www.wttc.org/		

Index	Source	Index Composition
Social Index - 2004	World Travel & Tourism Council	• Human Development Index (HDI) • Newspaper Index • PC Index • TV Index
http://www.wttc.org/		

ANNEX B

Table B-1. List of indicators used[119]

Indicator	Eurostat indicator name	Source	Data availability
Modules 1 and 2			
Total Population (Average)	Demo_pjan	**Eurostat**	**1950-2005**
Population 15_19 (Average)	Demo_pjan	**Eurostat**	**1950-2005**
Population 20_24 (Average)	Demo_pjan	**Eurostat**	**1950-2005**
Proportion population between 25_49 on total population	demo_pjanind	**Eurostat**	**1950-2005**
New entrants tertiary 15_19	Educ_entr	**Eurostat**	**1998-2004**
New entrants tertiary y20_24	Educ_entr	**Eurostat**	**1998-2004**
New entrants tertiary 25+	Educ_entr	**Eurostat**	**1998-2004**
Youth education attainment level - total – Percentage of the population aged 20 to 24 having completed at least upper secondary education	Ir091 Educ-iatt	**Eurostat**	**1992-2006**
Education attainment Percentage of the population aged 25 to 64 having completed at least upper secondary education	Educ_iatt	**Eurostat**	**1992-2006**
Participants / enrolled in tertiary 5a	Educ_enrl	**Eurostat**	**1998-2004**
Participants/ enrolled Females in ISCED 5A	Educ_enrl	**Eurostat**	**1998-2004**
Foreign students in ISCED 5A	Educ_enrl	**Eurostat**	**1998-2004**
Foreign students by citizenship	Educ_enrl	**Eurostat**	**1998-2004**
Graduates in ISCED 5a	Educ_grad	**Eurostat**	**1998-2004**
Females graduate – 5a	Educ_grad	**Eurostat**	**1998-2004**
Graduates (ISCED 5-6) in Maths. Science and Technology fields - as % of all fields	educ_itertc	**Eurostat**	**1998-2004**
Graduates ISCED 5a – ef4+ef5	hrst_fl_tegrad	**Eurostat**	**1998-2004**

[119] Not all indicators were available for all the 25 EU member countries. However, for the purpose of the simulations, missing data were estimated.

% of women in ISCED 5A – EF4+EF5	hrst_fl_tepart	**Eurostat**	**1998-2004**
Universities in the top 500		**Institute of Higher Education, Shanghai Jiao Tong University**	**2005**
Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students	educ_thflds	**Eurostat**	**1998-2004**
WM % on total S&E 5a	Educ_enrl	**Eurostat**	**1998-2004**
Enrolled in 6	Educ_enrl	**Eurostat**	**1998-2004**
Women enrolled in 6	Educ_enrl	**Eurostat**	**1998-2004**
Absolute numbers enrolments at ISCED 6 – ef4 + ef5	Educ_enrl	**Eurostat**	**1998-2004**
Foreign students in 6	Educ_enrl	**Eurostat**	**1998-2004**
Graduates in 6	Educ_grad	**Eurostat**	**1998-2004**
Graduates in 6 – ef4+ef5	hrst_fl_tegrad	**Eurostat**	**1998-2004**
EU citizens with PhDs in S&E in US			
Module 3			
Scientists and Engineers y45_64	hrst_st_ncat	**Eurostat**	1994-2006
Human Resources in Science and Technology - Unemployed	hrst_st_nunesex	**Eurostat**	1994-2006
Temporary workers in the US			2005
Average exit age from the labour force - Annual data	lfsi_exi_a	**Eurostat**	2001-2005
Module 4			
Numbers of EU nationals outside EU		**Atlas Student Mobility**	2003
Numbers of engineers from the US, China and India		**Duke University**	
Numbers of S&Es Scientists and Engineers	hrst_st_nocc	**Eurostat**	1994-2006

Table B-2. List of variables manipulated

Variables
Modules 1 and 2 – Domestic and Foreign students
New entrants tertiary Y15_19
New entrants tertiary Y20_24
New entrants tertiary Y25+ (Mature students)
Foreign students in ISCED 5A
Proportion of students in Maths, Sciences and Technology fields in ISCED 5A
Women enrollments in S&E fields in ISCED 5A
Foreign students in ISCED 6
Chinese and Indian foreign students
EU citizens with PhDs in S&E in the US
Module 3 – Supply of S&E personnel
Graduates in S&E working in the field
EU graduates in S&E working outside the EU
Foreign graduates in S&E
Engineers ‘produced’ in the US, China and India
Module 4 – Loss of S&Es
Number of specialized temporary workers in the US
Age of retirement
Unemployment among S&Es