BENCHMARKING NATIONAL R&D POLICIES

STRATA-ETAN expert working group

HUMAN RESOURCES IN RTD

(including attractiveness of S&T professions)

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Remit

In the present global economy, innovation and effective development are keys to success in the market place. This is reflected in the efforts to create a European Research Area to facilitate Research & Development and, more recently in the expressed intention to raise to 3% by 2010 the proportion of GDP devoted to R&D. This is a substantial increase for most Member States but acknowledges that to catch up and compete with the United States, the proportion of GDP devoted to R&D should be higher that in the USA (currently 2.9%). The human capital deployed in the creation of new products, services and facilities emerges as a crucial element in this economic strategy. The question to be addressed, therefore, is whether the European Union has at its disposal the appropriate skills, at the appropriate time, in the appropriate place and of the appropriate quality and quantity.

Methodology

Training for scientific research is a continuous process requiring the construction and maintenance of a substantial technical knowledge base and the acquisition of analytical and deductive skills, all time-consuming and long-term processes. As such, the provision of trained manpower can be likened to a pipeline where the requisite abilities can be delivered and drawn off at the appropriate stages of development. This does not mean, of course, that all are destined to be researchers; numerate and deductive skills are of great value throughout society and in many different disciplines. There are several key stages in this training process and indicators can be created which monitor the effectiveness of the production system at various critical points. In aggregation and analysis of relevant data sets, the group has been particularly mindful of the state of harmonisation. For that reason, particular attention was paid to trends. This summary outlines the general observations; specific details are found in the body of the report.

Background Issues

The effectiveness of the training-career pipeline is totally dependent on the socio-economic environment and this can be markedly influenced by policy makers. Among the aspects of this environment, the group has focused on:

The Appeal of Science: It is apparent from all surveys that the population as a whole is reasonably interested in sciences though perhaps it is no longer its highest priority. At the same time, the previously overwhelming belief that science usually confers benefits is now increasingly accompanied by concerns that the environment and nature may be placed at risk. A relatively positive attitude towards science is also evident in youngsters of school age. The main providers of information and opinion are the various forms of the Media and the overall impression is that these sources produce both positive and negative effects. The problem seems to be, however, that a general sympathy with sciences is not enough. The school environment is a major factor for the young and here there are considerable problems.

Despite positive European attitudes, science may not command sufficient public interest and support. Good practice for raising awareness through a range of imaginative and interactive events, articles, programmes and exhibitions must be sustained and intensified.

Researchers in the Workforce: The proportion of researchers in a nation's workforce is an important indicator of that nation's capability to compete in a knowledge-based economy. It also profiles the priority given to RTD in its society. The ample data available on this issue, however, must be interpreted along with information on research activity, to indicate the intensity of the RTD effort, its productivity and innovation. The data suggest that only two or three EU Member States display overall R&D activity comparable to the USA and Japan when measured in terms of the human resources involved and the research spent. Public-sector investment is an important driver of innovative research and now plays an increasingly important priming influence on new company start-ups, in addition to underpinning established industries. Despite this, there is evidence of long-term public-sector underfunding, leading to stagnation or even decline in public-sector efficacy and productivity. Private-sector investment in the EU shows a more positive trend, but is still considerably lower than, and being outpaced by, the USA and Japan.

The proportion of researchers in the workforce in the EU is only two-thirds of that of the USA and Japan, and at present growth rates the EU will not catch up. There is a clear need for increased investment and enhanced career attractiveness.

Barriers: The training and efficient deployment of Human Resources for RTD is affected by a number of barriers of variable visibility. Women working in research represent only between one-quarter and one-third of R&D staff in the Member States and the gender imbalance gets more pronounced with increasing rank in the hierarchy. The considerable efforts underway to address this problem should be continued. In a period of increased economic expectation and considerable migration, inadequate financial support and cultural differences may also lead young people away from higher education and research training.

Gender, culture and financing may prevent the EU from making optimal use of all its talent. Targeted public support may reduce the barriers.

Mobility: The mobility of researchers is of high value, and of fundamental importance for the efficient operation of a European Research Area. However, being a highly dynamic process, incorporating both sources and sinks, and operating on several levels more attention needs to be paid to movement into and out of the community and between disciplines and sectors. The data, though incomplete, suggest that some Member States may be experiencing unacceptable hemorrhages of scientific talent. In general, countries whose higher education and research systems are internationalised and which have an environment conducive to entrepreneurship, innovation and financial opportunity are more successful at increasing the pool of foreign talent in science and technology. Mobility between research sectors is low, particularly in comparison with the USA. The EU appears to be a net provider of human resources to the USA, despite a limited number of schemes to attract back the particularly able and distinguished.

Loss of able research talent to other nations and much more significantly, to other activities weakens EU competitiveness in the knowledge-based economy. The opportunities, attractiveness and rewards of a scientific career need to be enhanced.

Decision Stages

The training-career pipeline goes through a number of stages where the individual must decide whether to pursue the path towards higher qualifications in S&T. Thus, it is to some extent an indicator of the attractiveness of the more innovative aspects of public and private R&D. These transition points are crucial. At the same time, they are both easy to monitor and influence. The stages traversed are:

The High School Experience: Paradoxically, the overall interest in science is not reflected in the vigour with which scientific subjects, particularly the core topics of chemistry, mathematics and physics, are pursued at school. The trends in students' choice of subjects is a challenge at a time of changing teacher influence, of shortages in quality teachers in many European nations, and of lowered status of science and scientists in society. In several Member States, the recruitment base for science and technology appears fragile, perhaps now inadequate to needs. In many European countries, the educational system appears to fail in recruiting qualified teachers in science and technology. This, together with unfavourable demographic developments, constitutes a serious threat to the future of Human Capital for RTD. It is necessary that governments play an active role in changing the working conditions so that teachers are given time and space for contemporary education and enlightened management of their schools. In this effort, competitive salary and conditions of employment are key factors.

Defection of pupils from S&T and increasing crises in teaching threaten future EU research recruitment and capacity. Government action is crucial to remedy the position.

The Undergraduate Position: Amongst Member States, the student population is close to 25% of the age group, compared with a value of 40% for the USA. However, the proportion doing science is, in general, slightly higher in Europe. Within Europe, however, these figures demonstrate a wide variation in the share of those training in science and technology (under 25% to nearly 50%). Europe in general is slipping rather than gaining on the supply side. The group is particularly concerned about the diminishing attractiveness of chemistry, mathematics and physics, as well as of engineering and technology. For knowledge-based economies, the present trends in many countries indicate future problems in sustaining the necessary innovative capacity.

Decreased university enrolment trends for core S&T subjects constitute a serious warning of even greater problems for a knowledge-based economy.

Doctoral Training: The single most defining choice in developing Human resources for RTD is a decision to enter Postgraduate training, the implication being that innovative research is the preferred career direction. The prevailing picture is of a slow increase in numbers and proportions throughout the 1990's in most European Countries. The proportions are higher than in the USA or Japan. Some of these increases are due to 'non-domiciled' students who are likely to leave Europe. Some countries are failing to attract the most able students. There appears to be a correlation between PhD production, investment in PhD programmes and PhDs in the workforce, with Finland as a prime example.

The EU must sustain and exploit its advantage in research-degree production, if possible by better support conditions and enhanced prospects.

First Destinations and Postdoctoral Training: Much of the research effort in the Public Sector is shouldered by postdoctoral fellows, almost always on short-term contracts. Recently, there appears to be a reduction of the supply of talent at this stage, as a consequence of the fact that postdoctoral opportunities are seen as leading to less attractive career paths. For newly qualified PhDs, the loss from scientific research can be as high as 40%. A small percentage (5%) go overseas and do not return in the short to medium-term. For some Member States, this adds up to a wasteful 'brain drain', both to other occupations and to other countries.

The transition from training to work is a critical stage where talent is lost to EU scientific research through the perception of poor career opportunities and conditions.

Career Progression: In some countries there is a growing tendency to dispose of mid-career researchers through early or forced retirement schemes or transfer to non-scientific posts. On a national level, this reduces the return on the investment originally made in training. There is a need for an overall view of Human Resources for RTD throughout the career, and for this new statistical data are required.

There are elements of the emergence of the disposable researcher in an ageist workplace, leading to a waste of talent and experience.

Life-Long Learning: The group finds that LLL in its present form has a low impact on the development of Human Resources for RTD. However, considerable opportunities exist, particularly for the mid-career research scientist, to improve their skills base and widen opportunities. There are a number of areas where LLL even today can be exploited for better training and development of Human Capital. The development of Human Resources for RTD must over a reasonably short time period come to terms with LLL as a major new mode of learning, and with the consequences this has for the traditional linear 'learn first – then research' model.

Life-long learning is an under-utilised opportunity for career development of Human Resources for RTD.

Benchmarking and indicators

In the light of the data examined, a number of recommendations are made in respect of the five indicators for benchmarking originally suggested by the High Level Group. It is found that three of these may be incomplete or ambiguous in use. Further indicators are suggested for monitoring the flow through and out of the training-career pipeline and the mobility of researchers.

Benchmarking indicators for Human Resources in RTD should be sex-disaggregated, cover the private sector and contain information on disciplines and nationality (matrix-form indicators).

Each section of the full report provides detailed recommendations that might be employed in order to facilitate progress in some of the problem areas. While the group purposely has been very cautious in promoting best practice cases, it has found that the examples of Finland, Bavaria and Flanders illustrate a positive strategy towards many of the problems encountered, and descriptions of some of these developments appear as a separate appendix.

General Conclusions and recommendations

The training process for Human Resources for RTD in Europe is potentially capable of delivering research and development scientists appropriate to the aspirations of a knowledge-driven economy. However, for most Member States this requires the correction of inadequacies apparent at almost every key stage in the process. There are clearly country-by-country variations but in general the statistical data support the following conclusions:

- In mobilising and retaining resources for RTD, Europe as a whole is lagging behind our strongest competitors in the knowledge-based economies.
- The future supply of graduates of high research competence may be insufficient, even to maintain the status quo, if present trends continue.
- The remuneration and conditions of employment in RTD are inadequate and not sufficiently attractive for the sector to compete for quality Human Resources.

On this basis, it is recommended that:

- A concerted effort is needed to increase the recruitment base in S&T subjects from the secondary school system, this is likely to require a number of priority changes throughout the school system.
- Measures to be taken to meet the crises in teaching, particularly in sciences and mathematics.
- Resources and working conditions at the training institutions should be improved to increase the attractiveness of S&T as a career.
- Special attention must be given to the first-destination phase of recruiting young graduates (PhD) researchers to research careers. The Public Sector is increasingly uncompetitive in some countries.
- Measures should be taken to ensure efficient utilisation of experienced researchers throughout the whole career period.

1. Introduction

In January 2000 the European commission adopted a Communication proposing the creation of a European Research area (ERA). The aim is to strengthen the coherence of research activities and policies throughout Europe with the intention of increasing the impact of European Research.

At the Lisbon European Council on 23-24 March 2000 the Heads of State or Government fully endorsed the project, including a series of objectives and an implementation timetable. Subsequently, the Research Council Resolution adopted on 15 June 2000, called on the Commission, in collaboration with the Member States, to present a full set of indicators and a methodology by October 2000 for benchmarking four themes. This whole process received a further impetus at the meeting of The European Council in Barcelona on 15-16 March 2002 where it was agreed *'. . . that overall spending on R&D and innovation in the Union should be increased with the aim of approaching 3% of GDP by 2010. Two-thirds of this new investment should come from the private sector.'*

With these declarations, the European Union has set itself the goal of becoming the most competitive and dynamic knowledge-based economy in the world. This appears to recognise that in a global economy with open markets, the economic success of any nation within an increasingly knowledge-based world economy will depend on its ability to establish competitive advantages. Clearly the superiority, novelty and value of a nation's products are major factors in that advantage. These are also factors that depend strongly on the human resources mobilised for the tasks of research, innovation and development. In this context, we must ask ourselves how European research policies and practices can deliver the appropriate number of researchers, of the appropriate quality and with the appropriate skills to sustain and develop current and ground-breaking new aspects of science, engineering and technology. Even in the present situation there are indications of a shortage of skills in several highly advanced areas of RTD, and a further expansion of the knowledge-based economy is likely to aggravate this shortage. The problem may conceivably be solved by either exporting the tasks that cannot be done at home or importing more Human Resources to solve these tasks. Neither of these alternatives are, however, likely to lead to the kind of competitive edge that the declarations of the European Union aim at. It therefore remains to develop a strategy for the optimal development and deployment of the intellectual resources within Europe.

The importance of this question is emphasised by public debates taking place in many European countries. These debates centre on themes such as the curriculum of primary and secondary schools and the shortage of teachers in these schools, the 'massification' of higher education, the decline in student enrolment in some areas (most notably in the hard natural sciences), and efforts to recruit IT specialists form outside Europe to compensate for domestic shortages in this sector. Most European nations are in fact already struggling with how to train and deploy their human resources to position themselves for competitive advantage, even with today's demands. The ambitions articulated in the proposal for a European Research Area do, however, reach far beyond this, and envision a mobilisation of these human resources on a broad European front.

It follows quite naturally from this that it becomes important to monitor how well a nation succeeds in the training and deployment of its human resources for RTD. Not only for that nation, but also for Europe. Most of the serious competition in the New Economy comes from large, monolithic nations – USA, Japan, India, China, Russia. Compared to these, the political structure of Europe offers the disadvantage of more loosely coordinated activities in these matters, but also the advantage of drawing on the experiences of a set of varied approaches to the challenge of human resources. If this latter advantage is to be realised, it requires the capability of being able to compare the national policies in the area, results, and the development of more integrated, flexible policies. The challenge of benchmarking is to find those parameters that provide the critical information about this process and the best stages at which to measure these. A transfer of knowledge and best practices between nations requires a reasonably common set of references, but also an acknowledgement of, and respect for, the national differences and cultural traits of the nations involved.

2. Work programme and methodology

The main objectives of the benchmarking RTD policies launched by the European Commission is to provide support for the improvement of RTD policy design and implementation at all levels (regional, national and European) and to promote further development of synergies and coordination of research efforts in Europe, thus improving their efficiency and effectiveness.

The five themes chosen were:

- Human Resources in RTD, including the attractiveness of science and technology professions
- Public and private investment in RTD
- Scientific and technological productivity
- Impact of RTD on Competitiveness and Employment
- Promotion of RTD culture and public understanding of science (added later).

For each of the themes, groups of experts were set up by the Commission in order to shed light and to analyse the current situation in EU Member States. Additionally, a High-Level Group (HLG) with representatives of Member States was also set up to drive the process. This report represents the work of the Human Resources Group, detailed earlier.

The theme ‘Human Resources in RTD (including the attractiveness of science and technology professions)’, where RTD is the abbreviation for ‘Research and Technical Development’, spans a rather wide field. The data do not, however, include information on the Social Sciences and Humanities and for that reason have not been included in our analysis and conclusions. According to the Terms of Reference for the expert group on Human Resources in RTD, three topics needed to be addressed in detail:

- The overall situation of the research population in the EU Member States: structural analysis and main trends, identification of processes, positive factors and bottlenecks, links with industry and overall economic activity, gaps and outlook.
- Analysis of science teaching across Europe together with initiatives for raising public awareness of science and technology (with a link to the ERA working group on raising the interest of young people for science).

- Training and mobility of researchers in Europe (with a link to the ERA working group on human resources and mobility).

In this work, the overall theme was approached on a broad basis, rather than making these three subtopics the major focus. They will therefore be treated fully, but in the context in which they must be seen as parts of a larger, more complex problem area.

The term RTD may in its broadest sense be interpreted to encompass all disciplines of research without any restriction. The visions for a European Research Area also draw on a broad, general basis of scientific knowledge. However, with the underlying emphasis on industrial development and innovation, there is clearly a specific need to focus on those disciplines that have traditionally contributed directly and most heavily in this sector, namely engineering, the so called 'hard' natural sciences (chemistry, physics), mathematics, together with less traditional natural sciences, life sciences, biotechnology and informatics. We have therefore concentrated our work on the training and deployment of the human resources in these areas, which we band together under the label 'science and technology' (S&T). One important reason for doing so is that many countries today perceive the situation as worrisome with regard to the future of S&T subjects seen as the key to economic well-being. Despite our restrictions to S&T, we have found in working with this theme that many of our conclusions may be carried over to those areas of the humanities and social sciences which may experience difficulties at present. In some countries, for example, the recruitment of foreign-language teachers appears problematic at present. The challenges in strengthening such an area will closely parallel those seen within S&T. No attempt has been made, however, to analyse other than the scientific disciplines specifically mentioned above.

The definition of a researcher here is that given in the so-called Frascati manual (OECD, 1993), namely:

> *'Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, and in the management of the projects concerned.'*

Normally, the doctoral degree, PhD or some equivalent, is regarded as a 'license to carry out innovative research'. The person possessing such a degree or experience is regarded as being qualified to carry out independent research in his/her area of training. There is, however, a further spectrum of skills required to expedite and direct research, which for the most part only comes with informal training and on-the-job experience. At the other end of the certification process, it is worth noting that in some countries, industry prefers to recruit researchers before most of their formal post school academic training, providing instead what they consider a more relevant and efficient training for their own personnel and requirements. Thus, research comes in many guises with a variety of labels and involving a variety of skills and contributions, something which poses a challenge to a comprehensive quantitative survey.

At the outset, the High-Level Group directing the benchmarking exercise formulated five indicators for the Human Resources theme (Table 1).

Table 1. The five official indicators of the Human Resources theme.

1. Number of researchers in relation to the total workforce
2. Number of new science and technology PhDs in relation to the population in the corresponding age group
3. Number of young researchers recruited in universities and public research centres in relation to the total number of researchers
4. Proportion of women in the total number of researchers in universities and public research centres
5. Proportion of researchers from other countries amongst researchers in universities and public research centres

Unfortunately, information from only the first two of these have been provided to the group during the work presented here and even then in incomplete form. The other three, being new indicators, still remain to be developed, a process that will require extensive harmonisation and statistical evaluation of the data involved. At the outset of the benchmarking exercise, the statistical aspect was defined as the domain of Eurostat. The work of this expert group, therefore, has been aimed at providing some perspective on the proposed and available indicators, at suggesting improvements and possible new indicators, and at accruing and analysing other publicly available datasets.

In this task, the group has drawn extensively on public information, freely available. Most European nations have fairly extensive data on their educational sector. Some overall statistics are also available from Eurostat, Eurydice, and the OECD. The situation in the United States is documented in statistics from the NSF. Only a limited amount of these available data is rigorously harmonised. However, in order to show developments over time, harmonisation of the material is not really essential. In most cases, the conclusions emerging from even the unharmonised data are quite robust. A rigorous comparison between different countries, however, requires some care; but unharmonised data may still yield valid comparative perspectives. Because of the availability of a large body of statistical data, less effort has been devoted to case studies, and no public surveys or questionnaires have been carried out.

On a more qualitative level the working group has relied on open information as well as expert evidence. There is a huge literature relevant to the theme of this report, but the focus has been primarily on information that has been of particular value to this analysis and remit. The sources are referenced in the text, but with no claim of completeness. As mentioned above, news media and public debate on issues directly related to this theme have also been consulted in the course of this work, but again we claim no completeness in their coverage. Evidence has partly been collected from presentations given to the group by outside experts, and partly from the extensive experience that the members of the group have accumulated through years of active participation in teaching, research and administration in higher education.

Finally, as will be evident below, there are some areas central to our theme where the European Commission or other agencies have already carried out studies that to a large measure cover questions which arose in our discussions. In these cases there has been no strong reason to repeat comprehensive work carried out by others, and where appropriate their findings have been drawn upon, thereby reinforcing those conclusions of particular relevance to our theme.

It is important to emphasise at this point that in the discussion of the influence of Human Resources on various activities, as well as of the impact of political, social and economic decision on Human Resources, it is vital to have a clear concept of which data are being used to describe such Resources, and exactly in which societal context these Human Resources are viewed. In what follows, we have related Human Resources for RTD to the career path leading (most frequently through a PhD) to the position of an active researcher. However, for the success of the entire knowledge based society, other Human Capital is also necessary. Thus in an overall discussion of productivity and competitiveness, the scope of the Human Capital sector must reach considerably beyond the restricted RTD segment that we are considering in this report. In this broader sense, it may indeed be difficult to unambiguously identify the Human Resources for RTD. (A typical borderline case would be nursing staff at a university hospital).

It is also possible to conceive of models for a knowledge-based society where the Human Resources for RTD in the sense we define it, would be of less importance. An example of this would be a society that relies on importing innovation from other countries, and depends on production and marketing strengths for a competitive advantage. (We doubt strongly whether such a strategy would succeed in Europe in the long-term). Thus any discussion of Human Resources for RTD must be related to the socio-economic framework in which these resources are put to use, and for the discussion to be significant, the data must be of relevance within this setting. To take a somewhat extreme example: Charting the number of university professors as a function of the investment in vocational training may well produce interesting covariations, but is probably of little relevance to a discussion of the financing of Institutions of Higher Education.

Despite all these, qualifications, focusing on the innovative research represents the core element in understanding the health and vitality of a future knowledge-based economy. Thus, the main body of this report describes and analyses what the group considers to be the most important issues connected with the successful development of Human Resources in RTD. There are sections summing up the main messages and recommendations of the group, as well as providing some perspective on areas that it has not been able to treat in great detail within its remit.

3. Issues – Introduction

The process of training and deploying the Human Resources of a Nation may be seen as analogous to sustaining a healthy flow through a pipeline of development. To ensure prosperity, it is the task of any national policies for science education and industry to maintain this flow at a sufficient volume to provide the required base at a number of different levels, and for a number of different purposes. This pipeline analogy highlights the dynamic aspects of this challenge to science policy. The flow of Human Resources is constantly shifting, both in initial volume and in the direction of the outflow. A successful policy formulation must therefore be able to modulate and cope with these shifts, and this requires constant monitoring of the processes involved.

The pipeline analogy (Figure. 1) illustrates the importance of the totality of the task and the dynamic 'feedbacks' that can occur. Constrictions anywhere in the pipeline, including intakes and outflows, will affect the entire equilibrium of the process, and when making adjustments to the system, these must be coordinated, or efforts at improving flow through one section may be negated by constrictions elsewhere. Benchmarking is to some extent equivalent to inserting gauges along the pipeline to monitor flow and pressure. These gauges must be placed in such a way that they are helpful in identifying the causes for changes in the flows through the system.

As we know in many cases where the critical points of the process are likely to be, this is where benchmarking can be applied. These gauges are also positions at which valves, in the form of policies, can be positioned. The outflows in the pipeline at various points represent people leaving the formal training process, or leaving science and research for other professions. Such movements should not be seen as negative as many non-scientific professions benefit from, indeed require numerate, analytical, logical and deductive skills. There is also general value in a well-educated population. The value of the investment begins to fall, however, if the outflows are so great in quality or quantity that it compromises the production of essential manpower at later stages in the training pipeline.

It is worth pointing out that the fluctuations with time through the system are complex, but important for flow regulation. The training of a researcher is a lengthy process. Depending on the starting point and the country, it may take from five to eight years, sometimes even longer. There are demographic fluctuations which have had and will have profound consequences for training and employment. Fortunately, such demographic fluctuations have the advantage of being reasonably easy to foresee and plan for, other variations, such as perturbations in the economic climate may be more difficult to predict and deal with. The economic downturn in the late 1980's affected the training as well as the employment of several classes of students, and in many countries it also had profound effects on the training structure. Any flow-regulating mechanism, to be efficient, must somehow account for these time-related phenomena. It must be realised also that any demand for a sizable supply of new competences at the research level will probably take seven or more years to show effects from the time effective measures are first applied.

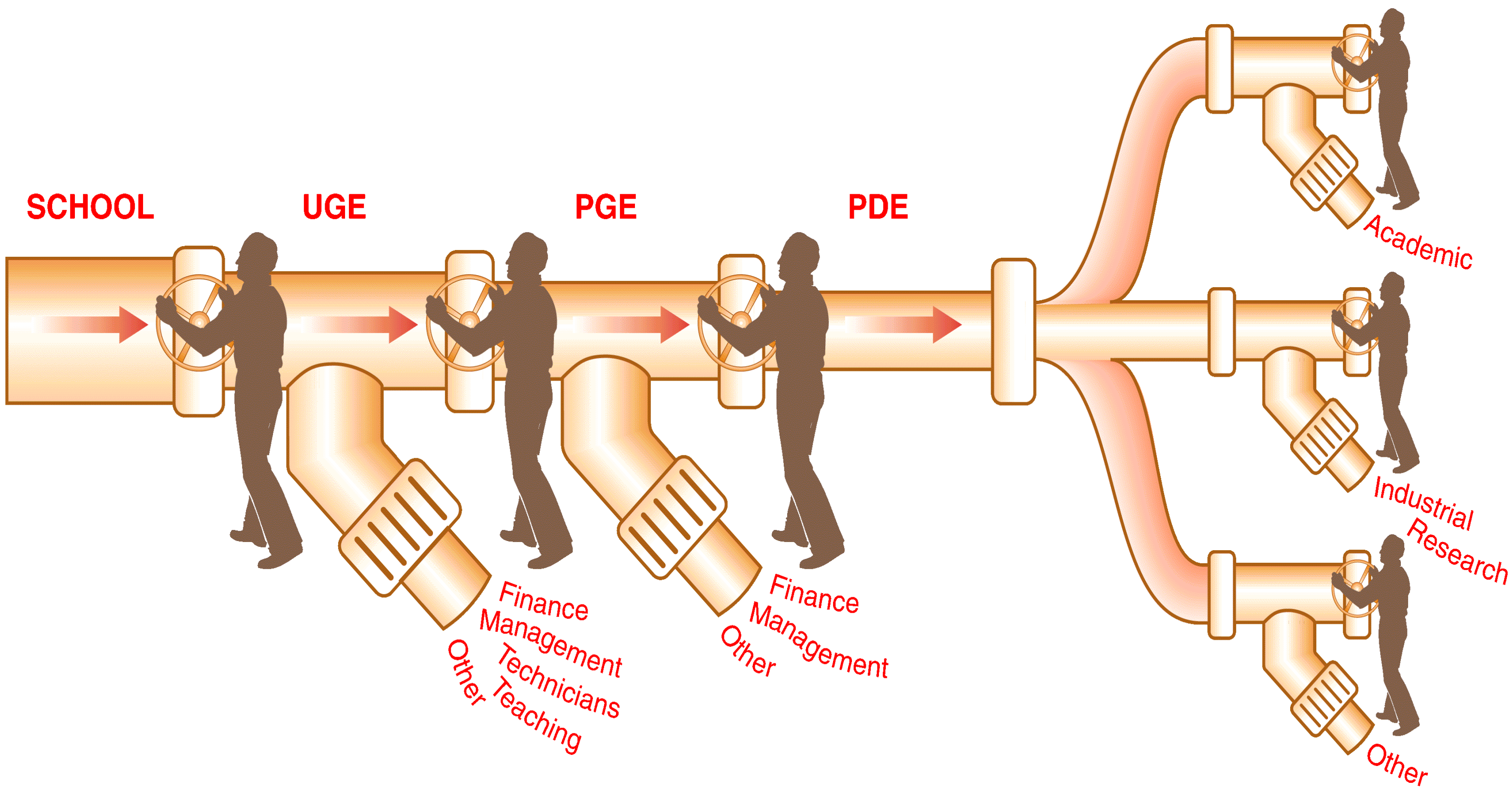

Figure. 1. The Training Pipeline: Key stages are identified as valves in the pipeline, allowing appropriate skills to be drawn off at appropriate stages. Action to tighten or loosen the pressure at these key decision points will affect flow positively or adversely.

UGE - Undergraduates, PGE - Postgraduates, PDE Postdocs

At an early stage of this work, it was found helpful to formulate five key questions which served as vehicles for further investigations of subordinate issues. These five key questions were:

i. *How does the proportion of the younger generations committing to science change? Are the trends similar in all scientific disciplines?*

ii. *To what degree is scientific expertise lost to other parts of the world and/or to other 'non-scientific' employment? Is this loss, on the whole, damaging?*

iii. *Are there social and educational structures, prejudices and restraints on scientific training such as to discriminate against sections of the population who would otherwise benefit society?*

iv. *Is there evidence of barriers against the mobility of scientists? What is the importance of mobility, in particular intersectoral mobility?*

v. *Are the training processes and opportunities appropriate to present and future demands of a knowledge-based society?*

These questions were useful in structuring the work of the group and are echoed in all the observations and recommendations. However, for presentation purposes, it was found more convenient to divide the findings into two broad subthemes.

The first subtheme deals with general background issues affecting Human Resources in RTD. The second consists of issues arising around the decision stages normally involved in a scientific career path. The reason for this is that these decision stages represent some of the critical points along the training pipeline. These are the points at which a young person under training decides on a future career path, or where an experienced researcher decides whether to leave research for some other profession. The advantage of focusing on these decision stages is that they emerge as natural points for monitoring and benchmarking. They coincide moreover with transitions for which most countries already have data, or at least may gather such data reasonably easily. One example is the decision to enter a doctoral program, a crucial stage in a research career, and a transition for which there exist substantial data. (For this particular stage, the official indicator 2 was identified). At the same time, these decision stages also appear as favourable points for the application of policy levers to influence the flow. Such decisions are, to a large extent, made on the basis of a combination of enticements, restrictions, opportunities and career prospects as viewed by the individual, factors which governments can influence to a considerable degree, to ensure appropriate supply to all parts of society and the economy.

The following chapters of the report are therefore structured accordingly. The background issues are presented first after which the various decision stages are treated separately. Conclusions, comments on the benchmarking process, as well as some recommendations follow each subsection.

4. Issues – Background

In this chapter are presented five issues that form the general backdrop for the overall discussion of Human Resources in RTD. It starts by discussing the interest in and awareness of science and technology in Europe, factors which will be decisive in providing a recruitment base for research in this area. The present participation of researchers in the workforce is then described and how this varies between countries. In two separate sections, mechanisms that may have a limiting influence on the full mobilisation of a nation's human resources for RTD are discussed. Finally, an attempt is made at gauging the effects of investment in Human Resources for RTD.

4.1. Appeal and attractiveness of science and technology to youngsters

Summary: It is clear that there is a serious unresolved problem in the study of science in schools. This is reflected in the falling proportion of school-aged children who select scientific subjects to age 18. The causes are many, failure of science to be presented in a positive attractive light, lack of talented instructors and modern curriculum, perception of the subject matter as 'hard' and the low status and rewards in science. Attempts are underway to remedy these deficiencies by a range of imaginative schemes. The outcomes are as yet uncertain but are unlikely to have a major impact until the position of the individual scientist and teacher in society is substantially improved.

This background issue overlaps to a great extent with two other sources of information on the same subject:

- 'Giving the young a taste for research and careers in science', an internal paper produced by Commission services: the ERA working group on *'Stimuler le goût des jeunes pour la recherche et les carrières scientifiques'* (2000).

- The data currently being collected by the newly installed expert group benchmarking 'Promotion of RTD culture and public understanding of science'.

For the sake of completeness, this report gives a general overview of the factors which influence the appeal and attractiveness of S&T to youngsters and the European public at large.

4.1.1. Do Europeans care about science?

The latest available Eurobarometer survey (2001) on European public understanding and attitudes towards scientific research show that science takes the third place (45%) in the ranking of interest, after culture (57%) and sport (54%), but before politics (41%) and economics (38%). These data contrast strikingly with the 1993 Eurobarometer results, which showed that Europeans were on average more interested in medical discoveries (45%), new inventions and technologies (35%), and new scientific discoveries (38%) than they were in politics (28%) and in sports (29%). A number of recent national surveys in Denmark (Siune & Vinther, 2000), in the United Kingdom (Science and the Public, 2000), in the Netherlands (Becker & van Rooijen, 2001) and in Switzerland (Crettaz de Roten & Leresche, 2001)

confirm the 1993 high level of interest in science and technology but do not chart the subsequent relative decline.
The 2001 Eurobarometer survey tested to what extent people felt informed in five areas. As a whole, Europeans felt that they were best informed about sport (57%), with culture taking second place (48.5%) and politics third (44%), roughly similar to the 1993 data. Only about a third of Europeans believe themselves informed about science (33%) and economics (32%). The increasing significance of science and technology in modern societies seems not to be accompanied by a parallel growth in the interest in or exposure to these subjects nor in an increased understanding of basic scientific ideas and ways of thinking (Sjøberg, 2001). Contrast this, however, to the position when special initiatives are taken. In Denmark, for example, the interest in science showed a spectacular increase if special programmes are aimed at the general public (Siune & Mejlgaard, 2001). When combined with the 2001 Eurobarometer results on information about and interest in science and technology, it is evident that a little less than one third of Europeans (29%) state that they are both well informed and interested in science and technology while, 46% feel that they are neither informed nor interested. The lessons here are obvious and the Danish experience is didactic but both manpower and resources are required.

Judging from enrolment into tertiary studies (see later), recruitment into science and technology (particularly chemistry, mathematics and physics) is decreasing in many countries, or at least not developing as fast as needed or planned for. Over the past ten to fifteen years, there have been frequent expressions of concern that so few pupils are taking up science and technology. This relative lack of involvement at school continues into adulthood, as is repeatedly manifested both in surveys of scientific literacy and by the regular calls for more scientists and engineers. Judged as a proportion of the relevant population, young Europeans are increasingly shunning science and technology when it comes to study options and career choices. Sjøberg (2001) has listed a number of possible underlying reasons for the present alarming situation. According to the 2001 Eurobarometer survey, more than half of Europeans (59%, both younger and older; 67% of young people) think that science lessons at school are not appealing enough, 55% (59% of young people) are of the opinion that science subjects are too difficult, and 42% (40% of young people) consider salaries and career prospects in the field of science to be insufficiently attractive.

Only 42% of Europeans think that this lack of scientific vocation in youngsters constitutes a threat for future socio-economic development, and as this threat is not perceived as urgent, it is logical that 54% of the Eurobarometer 2001 respondents believe that companies will always find the skilled people they need. Despite this, almost two-thirds of Europeans support the idea of active public support in this area (three-quarters among those who believe that the lack of vocation is a threat).

4.1.2. How does a young person develop an interest in science and technology?

It would run counter to an open and liberal approach to education for Europe to force young people in the direction of science and technology. As with all aspects of their lives, they want to discover for themselves what is attractive and fulfilling. Thus, it would be preferable to offer opportunities and challenges that are attractive and interesting, rather than overly forceful inducement with special programmes designed solely to benefit a knowledge-based society.

The young frequently make their choices based mostly on impressions often strongly influenced by peer groups, media coverage and parental examples. This is not surprising, for the choices they have to make are difficult because of the flood of information and attitudes from all sources. It is thus paramount that science and technology are presented in a natural way, from an early age and in an environment with which the young are comfortable. S&T appear thus as one natural alternative in the wide range of positive options open to them.

Information on science arising from many different and diverse sources are directed at youngsters: school (contents of curriculum, enthusiasm of science teachers), family (stimulation of interests, family members studying or working in science or technology), science centres (exhibitions, museums*)*, science laboratories at higher-education institutes, and the media (movies, television, books, press, Internet). Bombarded with all this advice, it is not surprising that, school, family and friends undoubtedly constitute the sources with the highest impact on youngsters. Amongst these, school has a heavy responsibility. Frequently, when asking a university science student what motivated his or her choice, one gets the reply: 'Well, there was this teacher in high school …'

4.1.3. Schools

How can schools meet the present day challenge of presenting S&T in a balanced light. It is self-evident that increasing the appeal of science and technology to young people depends on what is done in schools, and here the design of the curriculum is one vital factor. It has frequently been argued that the introduction of scientific ideas should begin in primary school by developing curiosity. Teaching methods in the past have perhaps been too concerned with the need to fill minds with fact rather than to stimulate them. In the 21st century, the education offered has to be varied and customised. Pioneering approaches in contemporary education to retain the individual pupil's interest in science and technology should continue to be encouraged. Innovations in the science curriculum should cross boundaries between conventional disciplines such as physics, chemistry and biology, making the presentation more akin to the complex and multidisciplinary realities of the contemporary world, for example genetic engineering or biotechnology.

O'Donnell & Micklethwaite (2000) have carried out a thematic analysis providing information on science education in several countries (Queensland/Australia, Ontario/Canada, France, Netherlands, and Sweden), and Kitt (2000) has presented a report on the situation of science education at all levels in Ireland. James (1998) has reported on possible innovations to widen the appeal of science in schools, and Miller & Osborne (1998) have given recommendations to adapt the UK science curricula to education schemes for the future. Jenkins (1999) linked the results of studies of the public understanding of science with the form and content of school science education. Finally, Sjøberg (2001), criticising the present science curricula, has given a review of recent trends and responses of social and educational aspects in science and technology, and discussed ways to reform the present systems.

The implementation of these new developments in education requires every encouragement for some of the ablest men and women both to enter and to remain within teaching. The most urgent problem in science and technology education, however, is the growing shortage of talented teachers. The teaching profession will therefore have to become a more attractive career choice; its importance should be stressed by a wider and better recognition of its stature and the financial returns should more adequately reflect the abilities and commitment required in a competitive and challenging environment. These improvements could lead to the entry or re-entry into teaching of people presently employed in other sectors.

4.1.4. Media

The media are the most prominent sources of scientific information for the public. European citizens receive their scientific input mainly from television (on average 60%), the press (37%), radio (27%), school or university (22%), scientific magazines (20%) and the Internet (17%). The media also play an important role in the paradoxical relationship that society has with science and technology. Although society itself has been shaped by scientifically-based developments, the public understanding of the pillars of that knowledge – science and technology – is one of a confused blend of admiration for the achievements, aversion from disadvantages, and reservation about further developments.

Public attitudes towards science and technology are influenced by the media and also by the way science and technology are portrayed in the cinema. The influence of science on everyday life is apparently so mundane that it does not make for good dramatic action: instead the negative effects of science are of greater interest to the makers and the audience of movies. Indeed science and scientists are often depicted in them as the origin of past and future apocalyptic disasters or of present ecological tragedies (ie the 'mad' or 'bad' syndrome).

In recent years, the 'serious' European newspapers and magazines have included science sections in their editions. These sections are usually well written and informative. In the main, they present the positive achievements of science and technology, and their potential benefit for society. But their impact on the general readership is probably small, unlike the political and business headlines. When science is in the headlines or on the front page, there are usually three main reasons: the high-lighting of discoveries because of the need for public funding, the negative impact of some development or the debate between conservationists and scientists on the bad effects of science. Such headlines are often unbalanced and do not contribute to a positive image of the profession. About 36% of Europeans think that scientific and technological developments are presented too negatively in the media, and in addition, 53% believe that journalists treating scientific topics do not have the necessary knowledge or training do justice to the subject matter (Eurobarometer, 2001).

Many of these considerations also apply to television, where science in the news is handled just as in the other media. However, the popular science programmes, and complete channels devoted to science have had a beneficial impact. The spectacular successes of science and technology in astronomy research, space exploration, biotechnology, etc., lend themselves very well to some degree of prime-time 'infotainment'. Most of the attractiveness of science in the public understanding probably stems from these programmes, and television is unquestionably the leading source of information about new developments in science and technology (Eurobarometer, 1993; 2001).

4.1.5. Science centres and the Internet

Two recent phenomena are considerably helping the appeal and the attractiveness of science and technology to youngsters – science centres and the Internet.

Many of the traditional science and natural history museums have metamorphosed into science centres or science parks, and new centres of this type are being established all over Europe. Many major cities and centres of population in Europe are now planning, building, or operating a science exhibit. The rather stuffy and static exhibitions and presentations of the past have been transformed into lively and dynamic environments of science, where experiential and interactive learning are the key features: pupils finding out for themselves the answers to their own questions. To achieve this, these science centres often take the visitor's everyday environment as the starting-point. Such centres are now among the most popular tourist attractions, although still fewer than one European in five (18%) has recently visited such an establishment (Eurobarometer, 2001).

Within the 5th EU Framework Programme (Improving Human Research Potential, Raising Public Awareness), a contract was awarded (HPRP-1999-00015) to a project ('Bringing Pupils to Science and Technology') which aims to improve the expertise of European science centres, to monitor the rapid changes in such centres, and to encourage and facilitate collaboration and exchanges between the centres. ECSITE (the European Collaborative for Science, Industry and Technology Exhibitions) is an organisation that promotes collaboration between its 250 members with more than 25,000,000 visitors every year.

The important role of the Internet in the education of youngsters is evident from the many surveys conducted to study its use. According to such surveys, both in Europe and in the USA, the Internet is generally regarded as a positive force in childrens' education, e.g., 50% of children go online primarily for schoolwork, almost all teachers consider Internet access in their classroom valuable or essential, and parents say they are more involved with their children's education. Youngsters prefer going online to watching television and talking online to using the phone, and they agree that the Internet offers personal benefits in writing and language skills and in their performance as students. The future development of virtual teaching and learning programmes is therefore a logical continuation of the existing use of the Internet. There is a wealth of S&T information to be found on the Internet, but as with any tool, children (and their parents and teachers) need to learn how to use it effectively. A worrying fact, however, is that the majority of many S&T web sites are in English, which inhibits their use by non-English speakers.

4.1.6. Good-practice examples

As mentioned above, many European countries are working actively on the problem of science curricula in both primary and secondary schools. Sjøberg (1999) has described some of the many initiatives that recently have been taken at an official level (State or Ministry of Education) to face the challenges of negative attitudes and falling recruitment of youngsters into science and technology. Within Europe almost every country has developed such initiatives, e.g., the Nordic countries have their NOT or LUMA (Finland) projects, Germany the BLK project, Netherlands the AXIS programme, the UK several programmes for pupils and teachers, Portugal has the large *Ciência Viva* programme, France *La Main à la Pâte*, and

Ireland the Task Force for Physical Sciences. The expert group is reluctant at this stage to highlight any of these as best practice, many of them have only been active for a short time, and it would be premature, as well as beyond the scope of our work, to evaluate this here or now. However, as an example of a concerted effort in this area, we include a description of the strategy pursued by the Flanders region of Belgium to promote the understanding of science and technology (see box below).

Popularisation of science and technology in the region Flanders (Belgium)

From 1993 onwards, Flanders regarded the popularisation of science and technology as an essential part of its overall S&T policy, setting its own strategic goal and subgoals, implemented each year in an action plan. The strategic goal underlying the actions taken is to strengthen support amongst the general public for science, technology and innovation, thereby laying the ground work for a knowledge-base society.

The overall objective is to generate a change of attitude in the public as a whole, whilst specific objectives are directed at target groups, related to specific needs in the society. One of these is the requirement for people skilled in science and technology by the industrial sector, a need that is growing but to which an immediate solution in terms of human capital is not available.

In 1994 the action plan had a budget of about Euro 750,000 (0,1% of the total budget for S&T policy), in 2001 this budget had increased to about Euro 6,200,000 (0.54% of the total budget for S&T policy).

After some years, five activities within the action plan are benchmarked: science kits, science in the picture (part of the Science Week), science theatre, science centre and a communication campaign to highlight the importance of S&T to pupils in the last year of secondary schools, a time when career decisions are being made.

One of the supporting measures is to establish networks of teachers: since teachers are an important intermediary link to children they can support the scheme by helping to implement certain aspects of S&T within the curriculum. In order to support the teachers, networks of expertise again involving teachers are being set up. A network of primary school teachers is already established and is growing constantly.

4.1.7. Benchmarking consequences

At present, we foresee no easy way to use the population’s interest in science as a benchmark of national science policy nor of assessing its real impact on the uptake of scientific subjects in schools. The Eurobarometer findings are of value, but a clear time relationship would be preferable. For benchmarking purposes, the best that can be done is to analyse statistical data originating from the training process.

4.1.8. Conclusions

- The European public exhibits a reasonable interest in science, however, there is considerable room for improvement, particularly since this interest appears to be waning.

- The role of the schools in fostering this interest and awareness should be strengthened. Resources and instruments be introduced to facilitate this (e.g., specialist personnel).

- The portrayal of science and technology in the media is mixed; on the one hand a great and positive effort is invested in popularising science, on the other hand, the news-coverage is often undeservedly negative towards the individual scientist and the profession as a whole.

- There is room for greater effort at improving the public image, despite the already outstanding work being done by a few individuals. However, with the scientific population already under severe pressure, this additional commitment can only be limited unless additional resources are made available.

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4.2. Researchers in the workforce

Summary: Analysis of research activity of European society as assessed by researchers in the workforce, expenditure on R&D, and paper and patent publications, lead clearly to the conclusion that all Member States are being outpaced in intensity and innovation by the USA and Japan. The position is variable, most severe in Southern Europe and less serious in Scandinavia. In general, both public and private investment in R&D lags, in some cases very markedly, behind that in the USA and the gap is widening.

The relative number of researchers in the workforce is Official Indicator 1 (Table 1) of the Human Resources theme. In many respects, this indicator points to the capacity and the emphasis placed on research, innovation and development in the European Community, both Public and Private. Tables 2

Table 2. Researchers per 1000 workforce and annual growth of the number of researchers. All data of latest available year. (EU-15 without Luxembourg).
Data sources: Key Figures 2001 (Eurostat).

Country	Researchers per 1000 workforce	Average annual growth (%) of researchers
Austria	4.86	7.86
Belgium	6.11	4.59
Denmark	6.46	3.96
France	6.14	1.22
Finland	10.62	12.68
Germany	6.07	1.00
Greece	2.57	6.29
Ireland	5.12	16.51
Italy	3.33	0.34
Netherlands	5.05	4.71
Portugal	3.27	7.61
Spain	3.77	6.79
Sweden	8.44	4.66
United Kingdom	5.54	2.66
EU-15	5.28	*2.89
USA	8.08	**6.21
Japan	9.26	2.57

* For 1995-1998; ** for 1995-1997. According to the OECD (2001), the growth rate in the period 1995-1999 was similar in the EU-15 and the USA (about 3% annually).

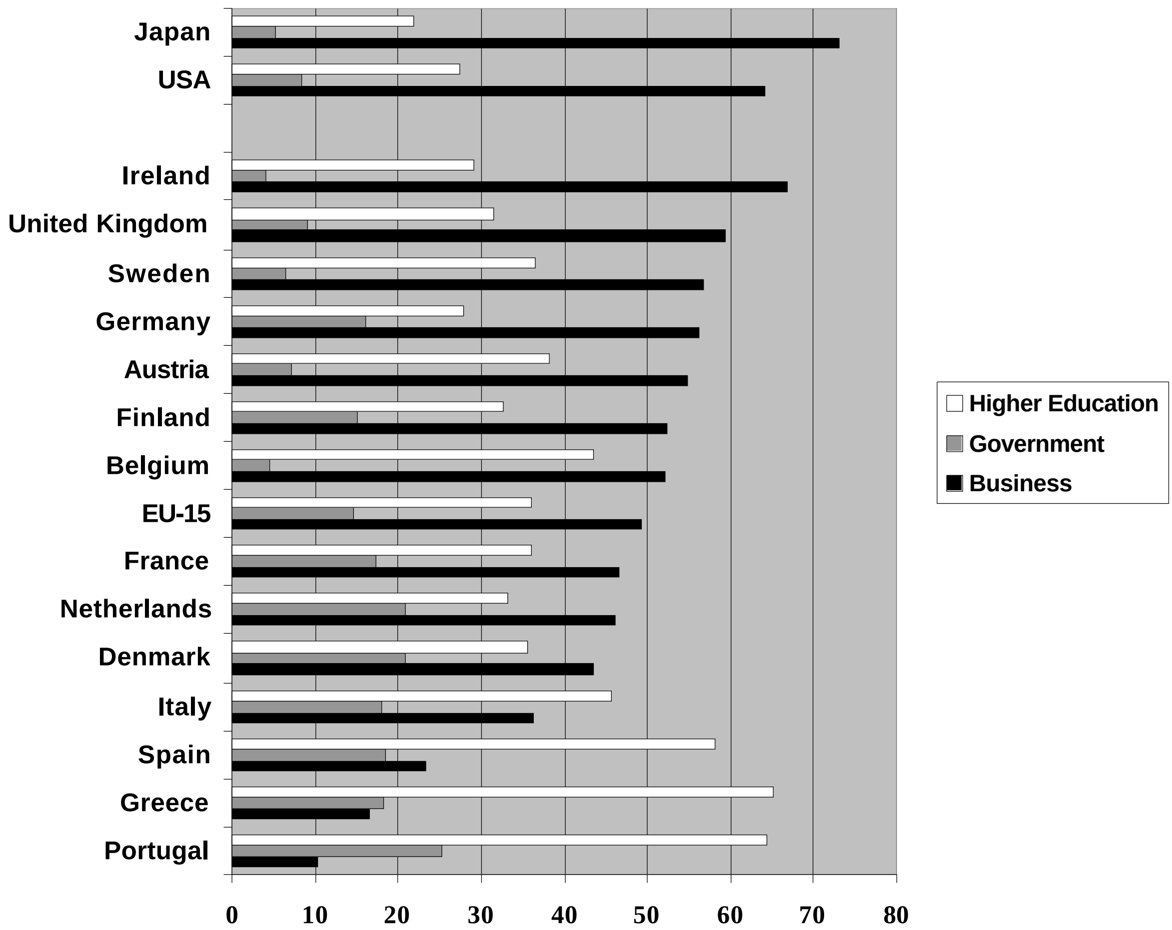


Figure. 2. Researchers per sector (%). All data of latest available year. (EU-15 without Luxembourg). Data source: Key Figures 2000 (Eurostat), except USA (NSF).

and 3, and Figure. 2 illustrate the trends and reveal wide and growing differences between Europe and its two principal competitors, the United States and Japan. Comparable data for the likes of China and India are not available but may reveal an increase which is greater than any of those shown here. In other words, the proportion of the European workforce engaged in research and development in the areas of science and technology is lower than and/or rising more slowly than Europe's principal competitors. If one considers that the European starting point is lower than that in Japan and the USA, then there is serious cause for worry about the capacity for innovation.

Tables 2 and 3, Figure. 2 and various other sources (see 5.2.6) give data for individual Member States, the distribution between the private (business) and (semi-)public (government and higher education) sectors, and research funding in these two sectors. The data in Tables 2 and 3 and Figure 2 give rise to the following observations:

- Human resources in science and technology grew significantly between 1995 and 1999 in southern Europe (with the exception of Italy), Ireland and Finland.

- Only Finland and Sweden show relative research efforts comparable to the USA and Japan.

Table 3. R&D expenditure (%), breakdown by institutional sector.
(EU-15 without Luxembourg)

Country	Business Enterprise	Government	Higher Education
Austria	n.a	n.a.	n.a.
Belgium	72	3	24
Denmark	63	16	21
France	65	18	17
Finland	68	12	20
Germany	70	14	16
Greece	26	24	51
Ireland	74	7	19
Italy	54	21	25
Netherlands	54	19	27
Portugal	25	31	43
Spain	54	17	30
Sweden	75	3	21
United Kingdom	69	11	20
EU-15	66	14	20
USA	78	7	15
Japan	74	10	16

Data source: R&D expenditure and personnel in Europe in 1999 and 2000 (Eurostat).

- Overall, the R&D intensity values have not changed significantly from one year to the next, but in the period 1995-2000 increases are noticeable in Finland, Belgium, Denmark and Austria.

- A strong concentration of R&D expenditure in one or two regions of a Member State is a common feature. The concentration is particularly strong in Greece, Finland, Portugal and Austria.

- Countries with low overall participation rates (Greece, Italy, Portugal, Spain) are characterised by a low proportion of research workers in the industrial/business sector. However, this proportion appears to be rising.

- The most recent data show that the business sector provided more than 60% of domestic R&D funding in OECD countries, a slight increase from 1990. In the EU, the share of R&D expenditure at constant prices of business enterprises was 66% in 2000 (63% in 1995). In the United States business enterprises accounted for 78% of R&D expenditure in 1999, and in Japan for 74% (Table 3).

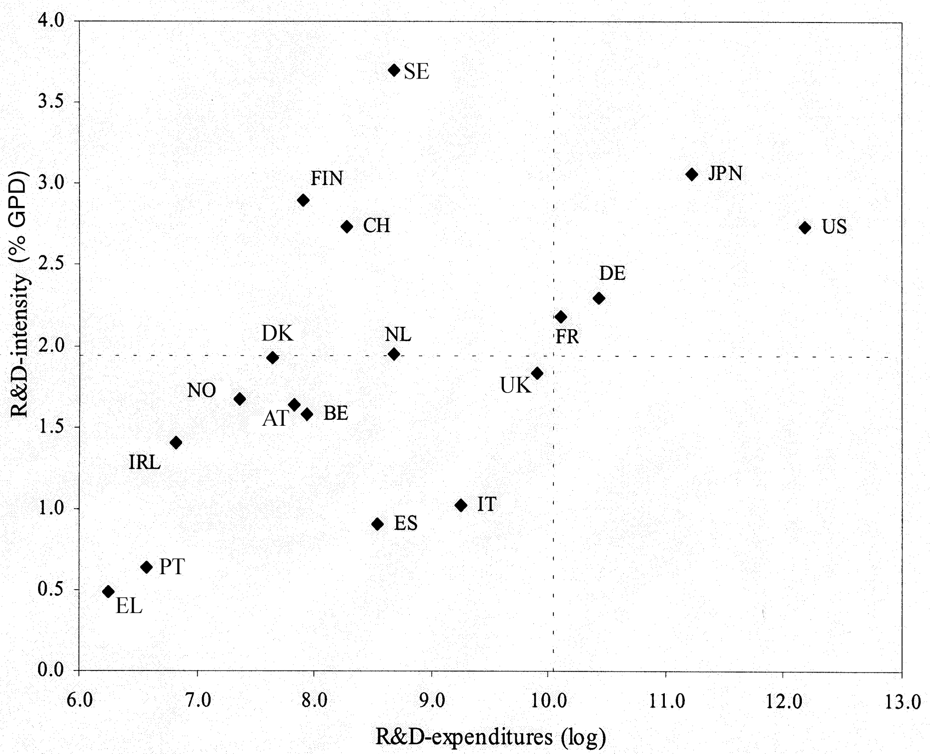
- In most countries, government's role in funding R&D declined over the 1990s. The strongest decrease, between 1995 and 2000 is observed for the United Kingdom, where government R&D expenditure declined by an annual average of rate of nearly 5%.

Ø Some countries, often starting from a lower base, are growing rapidly and significantly, particularly in the public sector arena (Austria, Finland, Greece, Ireland, Portugal, Spain).

Ø However, there are very alarming growth trends in some of the more developed Member States (France, Germany, UK); others are not impressive. Taken together, few countries may sustain the present distribution, inadequate though it appears to be.

Ø Italy presents a potentially very damaging combination of low researcher proportion coupled with a negligible growth rate.

Total R&D-expenditure (logs) and intensity, 1998.



The vertical axis shows the R&D-intensity, measured as the ratio of R&D-expenditure to GDP. The horizontal axis shows the natural logarithm of the R&D-expenditure, measured in 1990 US dollars. The dotted lines show the average R&D-intensity resp. log of average R&D-expenditure. For Belgium 1995 data were used, for Switzerland 1996 data and for Greece, Ireland, Norway, Portugal and Sweden 1997 data.
Data: OECD; source: MERIT.

Figure. 3. Total R&D expenditure and R&D intensity: an international perspective. Source: Science and Technology Indicators 2000, The Netherlands Ministry of Education, Culture and Science (2001).

Key for Country Codes: AT – Austria, BE – Belgium, CH – Czechoslovakia, De – Germany, DK – Denmark, ES – Spain, FIN – Finland, FR – France, IRL – Ireland, IT – Italy, NL – The Netherlands, NO – Norway, PT – Portugal, SE – Sweden, UK – United Kingdom, JPN – Japan, US – United States of America

4.2.2. R&D intensity and expenditure

Clearly, the overall rather sombre picture given above reflects the funding of research. One way to gain a perspective on this is to review simultaneously the two most important R&D indicators (Figure. 3): intensity and total expenditure. On this basis three groups of countries can be recognised. The first group consists of the large industrial nations (Germany, France, United Kingdom), all trailing the USA and Japan on both counts. A number of medium-sized countries are in the second group (Belgium, Denmark, Finland, Ireland, The Netherlands, Norway, Austria, Sweden, Switzerland) on one or both counts. The third group contains the Southern European countries (Greece, Italy, Portugal, Spain), which look problematic. Of the EU Member States, Finland and Sweden are clearly exceptional on the intensity score-board.

Figure. 3 shows the R&D intensity in % of the GDP, and shows that only a limited number of EU Member States are even at a 2%, never mind the 3% proposed level. In the first group (large industrial countries), industry finances two-thirds to three-quarters of research expenditures (Table 3). Also in the medium-sized countries of the second group, industry is a large research funder, but there are marked differences between the various countries (large share by the private sector in Ireland, Sweden and Finland; below average in Denmark, Austria and The Netherlands). An important aspect of funding can be seen in the third group (countries of Southern Europe), where government is much the largest research funder, especially in Portugal and Greece. It is clearly important that the latter countries continue to foster/encourage private investment; scientific entrepreneurs may clearly be important here. It may be that the more vigorous public sector may in time feed through to private investments in these Member States. Any slackening of public funding could be disastrous.

4.2.3. Women in the research workforce

In recent years attention has been focused on the absence of EU statistics on women in the scientific workforce, especially in the industrial sector, where it is extremely difficult to obtain relevant data (see also 5.3.1). Women working in research represent between one-quarter and one-third of R&D staff in the countries for which these data are available (1997). The proposed Eurostat indicator 4 (Table 1), 'Proportion of women in the total number of researchers in universities and public research centres', is still under development, but some reports (see 5.2.6) have published initial findings for the public sector (higher education and government institutions, Table 4). The majority of public researchers in the EU are men (70%), and no Member State departs from this male dominance. The EU average of female researchers is only 34% in government institutions (highest in Portugal, Greece and Spain), and about 26% in higher education (highest in Ireland, Greece, Portugal and Finland). Some countries have a generally low share of female researchers; such is the case with Belgium (perhaps Germany) and the Netherlands, where there are only 15% female researchers overall. Even within the fields of social sciences and humanities, the female presence is barely over 20%. There is a field-gendered situation in public research in all Member States: female researchers are more likely to be found in the medical sciences, social sciences and humanities, than in natural sciences, engineering and technology. Gender imbalances and their causes are further commented on in the next section dealing with barriers.

Table 4. Share (%) of female researchers and professors in the Higher Education sector and of female researchers in Government Institutions.

Country	Female researchers in higher education	Female professors in higher education	Female researchers in government institutions
Austria	25	23	34
Belgium	15	14	n.a.
Denmark	27	21	31
France	29	29	31
Finland	37	36	n.a.
Germany	19	9	n.a.
Greece	n.a.	22	n.a.
Ireland	46	12	25
Italy	28	28	29
Luxembourg	n.a.	n.a.	26
Netherlands	15	15	n.a.
Portugal	43	n.a.	53
Spain	n.a.	32	n.a.
Sweden	32	33	n.a.
United Kingdom	36	24	n.a.
EU	26	26	n.a.

Table 5. Publications and Patents per million population. All data of latest available year. (EU-15 without Luxembourg). Data source: Key figures 2001 (Eurostat).

Country	Scientific papers per million population	Highly cited scientific papers per million population	European patents per million population	USA patents per million population
Austria	717	26	134	77
Belgium	810	42	126	88
Denmark	1214	69	185	94
France	652	26	120	69
Finland	1157	50	298	129
Germany	657	29	258	133
Greece	340	7	7	2
Ireland	542	27	65	43
Italy	457	18	62	32
Netherlands	963	55	191	93
Portugal	248	8	6	1
Spain	471	12	20	8
Sweden	1431	58	375	196
United Kingdom	949	54	109	72
EU-15	613	31	135	73
USA	708	50	144	315
Japan	498	12	134	249

4.2.4. Productivity and innovation

The theme of Productivity and Innovation is the province of another expert group; here we only give a brief comment on research output in terms of peer-reviewed publications and patents (Table 5), a measure that is neither complete nor without flaws, but which nevertheless provides some perspective on the work carried out in this sector. The first obvious implication to be drawn from these data is that only Sweden, Finland and Germany are competitive with the United States and Japan in terms of patents. In publication terms, Europe is in general performing well and in some Member States better than the external competition.

One interpretation of this is that the public sector is highly productive and competitive (particularly considering the numbers involved), despite the pressures placed on it, but the private sector is on the whole not performing comparably to the United States and Japan.

Table 6. RTD productivity by scientific publications and patents.

	1	**2**	**3**	**4**	**5**	**6**
Country	Relative number of scientific publications per researcher in the **(semi-)public** sector			Relative number of EPO patents per researcher in the **private** sector (mean score = 100)		
	1993-1994	1995-1996	1997-1998	1993-1994	1995-1996	1997-1998
Austria	1.28	1.46	1.64			
Belgium	1.01	1.15	1.22	110	95	98
Denmark	1.35	1.29	1.11	88	103	87
France	0.90	0.90	0.89	104	97	89
Finland	0.88	0.98	1.00	116	145	132
Germany	0.82	0.88	0.95	112	121	128
Greece	0.86	0.78	0.76	n.a.	n.a.	n.a.
Ireland	0.92	1.47	1.53	36	40	28
Italy	0.83	0.93	0.95	103	111	112
Netherlands	1.31	1.36	1.42	171	156	145
Portugal	0.28	0.29	0.36	23	21	20
Spain	0.82	0.82	0.85	39	44	46
Sweden	1.45	1.51	1.47	97	93	94
United Kingdom	2.42	2.28	1.90	57	56	58

Columns 1-3: Index = number of publications per pair of years, divided by the average number of researchers in the (semi-)public sector in the previous pair of years. Data sources: OECD, SCI, SSCI, etc., presentation by Netherlands Centre for Science and Technology Studies. Columns 4-6: Number of patent applications with the European Patent Office per pair of years, divided by the average number of researchers in the private sector in the previous pair of years (mean score = 100). Data sources: EPO, OECD, presentation by Netherlands Centre for Science and Technology Studies.

Table 6 illustrates the trends in publications and patents over the last five years, country by country. In both areas, there are significant differences in what may be termed ‘productivity’ between different Member States. These differences are narrowing, however, because of a pattern of modest progress in some Member States, coupled with relative stagnation in others. The rises in publications in Austria, Belgium, Ireland and Portugal are welcome but the falls in

Denmark and the United Kingdom give cause for concern. The reasons for these deficits cited by researchers are many, but bureaucratic pressure, steadily declining investment, major falls in the staff-to-student ratios and new recruit quality appear to be having a damaging effect on the principal engines (the universities) of novel production. There appears to be little or no compensation from the private sector, which shows a rather static picture.

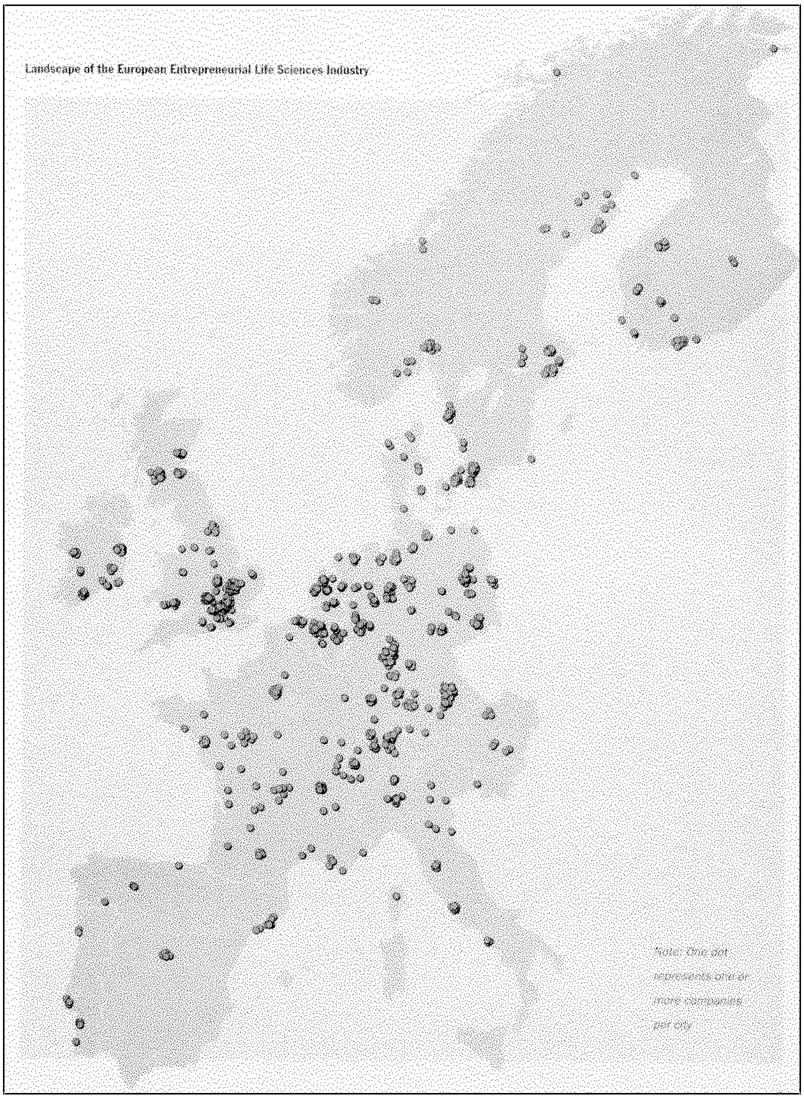


Figure. 4. Landscape of the European entrepreneurial life-science industry. Source: Ernst & Young's 7th Annual European Life Sciences Report, 2000.

If Europe is to become a leading knowledge and technology-based economy, the momentum of innovation and progress has to be increased. For this it is clear that industrial investment and development must be at the least maintained, but preferably enhanced, particularly in those States with a lower baseline. The final analysis on this issue concerns the new industrial sector. Figure. 4 illustrates company start-ups in the life sciences an area likely to be a major feature of future commercial activity. It dramatically illustrates that these are largely concentrated in areas of high research activity – namely the locations of universities and/or research institutes. They are also the sites for the most innovative (and hence riskier) developments. The figure shows high activity in Belgium, France, Germany, the UK, The Netherlands, Sweden and Denmark. The lesson here seems to be that the stimulus of public investment to initiate these new enterprises is important. Moreover, the research carried out by the public sector is absolutely essential to the future well-being of a sophisticated knowledge-based economy, particularly one that may require inward (to Europe) investment. It should be borne in mind that R&D in the private sector is much more targeted than public research. Hence dramatic new technologies, molecular biology is a good example, are more likely to arise out of the public sector.

4.2.5. Examples of good practice

It is difficult to point to any really good uncontested practice in this area. Finland and Sweden, with their high proportion of researchers in the workforce, stand out as interesting examples. However, it has been argued that these statistics are a consequence of a particular industrial structure – small countries with a few dominating high-tech companies. Nevertheless, the human infrastructure must have been in place to allow this to happen, and it is fair to assume that the interconnections between the availability of human resources on the one hand and the investment and industrial structure on the other must be fairly strong. Moreover, a stimulated public sector is itself an impetus to private development.

4.2.6. Benchmarking consequences

The total number of researchers in the workforce is, as already pointed out, one of the indicators selected for benchmarking (Tables 1 and 2). There is no doubt that this is a valuable, even necessary indicator, although some further comments on it are given below. There is a clear need to see this indicator in relation to others monitoring the investment in scientific research and development. The proportion of women in the total number of researchers in universities and public research centres is also one of the indicators selected by the High Level Group (Table 1). Extensive comments on this indicator are given in section 7.1.4.

4.2.7. Conclusions

- Only Finland and Sweden show relative R&D activity (in terms of both human resources and funding) comparable to the USA and Japan.

- There is a potential loss of human capital in that women (and possibly some minority groups) are underrepresented in the R&D workforce.

- Private Sector investment is a key element in economic development. It is being constantly outpaced by the USA and Japan, particularly in Member States in Southern Europe.

- Public Sector investment remains a key driver of innovation and new company start-ups. There is evidence in some of the more scientifically developed Member States of stagnation and even decline in funding leading to reduced public sector research activity and consequently, private investment.

4.2.8. References

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4.3. Barriers

Summary: Women are under-represented in the scientific workforce both in the public and private sectors (although data for the latter are limited). Along with minority groups they comprise a valuable capital resource whose participation is inhibited by working practices, financial constraints, cultural barriers, ageism and other forms of prejudicial action. The on-going work to promote the role of women and minority groups in science should be re-enforced.

In academia, in employment and in society at large, various unnecessary or artificial obstacles exist which prevent groups of people from realising their full potential. The existence of such barriers is counterproductive in a knowledge-based economy where there is an overriding concern to mobilise all available intellectual resources. These barriers may also serve to disrupt attempts at producing a cohesive society. One important effect of such barriers is that they may hamper the training, mobility and development of researchers. The problem of improving mobility of researchers has been the subject of a separate high-level expert group, whose findings form the foundation for a communication from the Commission to the Council and the European Parliament: ‘A mobility strategy for the European Research Area’ (COM 2001-331, 20.06.2001). We refer to our section on mobility for a discussion of the barriers hampering international mobility. Here we will concentrate on those barriers, which mainly act within a nation (although these may also have consequences for internationalisation).

The main barriers of this type involve gender, financial status or cultural background, affecting mainly women, low-income groups and immigrants, respectively, each of which will be addressed in turn although they are not mutually exclusive.

4.3.1. Gender

The proposed Eurostat indicator 4 (Table 1), 'Proportion of women in the total number of researchers in universities and public research centres', is presently still under development, but preliminary data are available, and have been presented in section 4.2.3. Some gender-disaggregated data may be found in the 'Statistics on Science and Technology in Europe' compiled by Eurostat, as well as in OECD's 'Education at a Glance'. For many countries there are national statistics which (while unharmonised) provide trends, both as time series and through the various stages of education and research training. Thus, at least within a national framework, several important and robust conclusions can be drawn. By far the most comprehensive survey of the situation in this area is being undertaken by the 'Helsinki Group' on women and science, which has been established by the European Commission in order to prepare comparable European statistics and indicators for monitoring the involvement and progress of women in science.

One such conclusion emerging from national data concerns the proportion of women at various stages of the academic career structure. As an illustration, we present statistics (Table 7) for Sweden for the academic years 1986/87 and 1998/99, which show the percentage of women at the different steps of the academic ladder.

Table 7. Percentages of women in the Swedish academic system.

	1986/87	**1998/99**
Applications to basic higher education	NA	60
New students in basic higher education	58	57
Degrees 3 years or longer	47	61
New postgraduate students	32	42
Graduating PhDs	21	35
Senior lecturers	17	26
Professors	5	12

Statistics for Norway show that while roughly 32% of the workforce in the university sector is female, the corresponding number for government research institutes is 29%, and that for private enterprise 18%. Note also that these data cover all fields of research: the participation for women is even lower in physical sciences and mathematics. Similar trends can also be observed for other European countries, giving rise to what has been termed the 'scissor diagram', with a rising branch for male participation and a shrinking one for female participation. (See, e.g., ‘The leaky pipeline’, an article by D. Weis in ‘Women and science: making change happen’, European Commission, DG Research, 2001, p. 65-77). While these data have been taken from academia, there is no reason to believe that things are better balanced in private enterprise – indeed probably even worse.

The trends emerging from the data quoted above are well known: despite a high under-graduate participation and graduation rates, there is a loss of women in the transition to postgraduate studies, and further relative attrition through the academic hierarchy. There is no reason for believing the situation is any better in the private sector. However, the development over time is positive in many countries. For both Norway and Sweden, workforce participation of women is approximately equal to that of men, so the imbalance reflected by these data is significant for women in research.

The reasons for this may be many, and an extensive description is not appropriate at this reporting stage when other groups are more directly involved (we refer to the Helsinki Group on women and science, the Eurogramme project on ‘Design and collection of statistical indicators on women in science’ (monitored by the Research DG and Eurostat), and the recent book by H. Etzkowitz, C. Kemelgor & B. Uzzi: ‘Athena Unbound, the advancement of women in science and technology’, Cambridge University Press, 2000, 288 p.).

4.3.2. Financial considerations

Two main economic barriers that may prevent a young person from entering a career in science and research are recognised – the difficulty in financing high-level education, including doctoral studies, and the inadequate economic reward from pursuing a research career after qualification. The long-term commitment is not seen as being justified by the return.

To our knowledge, statistics comparing, on a European basis, the various forms of support available for a young person wanting to pursue a research career, have not yet been collated. Indeed, even within single Member States there is a huge disparity from being essentially self-supporting (e.g., the UK) to high levels of support (again the UK). Consecutive training stages of relative poverty also usually come on top of a period without earnings, or of dependence on one’s family for support or of accumulating debt. The possible pay-off of small investment in training is successively postponed at each career decision step where a research career is preferred. This requires a huge degree of trust and commitment which is increasingly seen as misplaced.

At a time when most sectors of private enterprise hire prospective doctoral students at rates considerably above those offered by academia, inadequate funding is known to discourage talented students from entering a doctoral program. This effect may end up eroding, or at least lowering the quality of the recruitment base. The competition for talent is likely to harden with the development of the knowledge-based economies, and broad research training as we know it may be a serious casualty. In the long run, this could lead to degradation of the quality of research at the universities, and a shift in the burden of research training to the private sector. However, for the purposes of the present case study, it is sufficient to acknowledge that inadequate possibilities for financing research training may present a barrier to prospective talent for such training.

In a discussion of the deployment of human resources for science and technology, it is of importance to know how society rewards a research career. Granted, there are intangible rewards in research, but with an increasing emphasis on material welfare in Western societies, it is probable that the monetary 'gap' is now too large for those, particularly the most gifted, contemplating a research career. Not many occupations would provide lower remuneration on the assumption that it can be substituted by intellectual satisfaction. National wage policies are a matter of great sensitivity, and salaries and conditions are not easily comparable across borders, but prospective doctoral students are naturally influenced by future financial prospects when deciding on a career. Limited data on 10-year salary trends tend to show that from a common (post-PhD) starting point, the salary escalator for the research scientist has a much shallower incline than that for the equivalent individual leaving science for other professions. The market economy operating at both undergraduate and graduate levels is clearly having a substantial effect in the larger Member States (see First Destinations later).

The salary problems may be further aggravated in countries with hierarchical and rigid academic organisational structures, in which the opportunities for promotion may be limited. Note also that with some of the newer incentive- and production-based academic salaries, low wages may work in negative synergy with gender barriers to further discourage women from taking up a scientific career. A female scientist with a period of reduced research activity due to pregnancy and childcare might end up being doubly punished.

4.3.3. Culture

Statistics of any volume or quality that deal with intranational cultural barriers have not been located, and indeed there are countries where the collection of information regarding cultural background is severely restricted, partly to prevent possible discrimination. We suspect that there are scattered studies on this theme in various countries, at least on a qualitative level, but we have not been able to carry out a survey of this item within the scope of this work.

Cultural barriers may conveniently be classified either as guild-admission requirements, cultural dissonances or taboos. By guild-admission requirements we mean those barriers that prevent people from taking up a career because they do not fulfil some formal qualifications. The typical unfortunate example from the newsmedia is that of highly qualified immigrants or refugees who are unable to use their skills in their new country due to non-fulfilment of local requirements that otherwise are of little consequence for the work to be done. This is most important as a mobility barrier, but it may also prevent a country from utilising human resources already developed and available trained teachers or engineers as taxi-drivers is an anecdote often quoted. The proposed Eurostat indicator 5 (Table 1), 'Proportion of researchers from other countries amongst researchers in universities and public research centres' will probably be affected by the existence of such barriers, but will mainly be an overall measure of mobility, dominated by other obstacles to the mobility of researchers.

It should be emphasised that most guild-admission requirements are perfectly justified, e.g., it is obvious that nobody can be allowed to practice medicine in a country without fulfilling the official national requirements. Unfortunately there are also examples, e.g., in academia, where the qualifications for entrance to an RTD profession are (unnecessarily) given a form which greatly favours those already in the system. The German institution of *Habilitation* (recently reformed) has been cited as an example, and there are probably subtle and not-so subtle mechanisms in other countries to give a competitive advantage to graduates from their own systems. If the goals of the European Research Area are to be reached, however, such practices must be phased out.

Cultural dissonances may arise when the universities and the research community fail to communicate with a minority group, thus losing it as a possible recruitment base. The higher education of a country is almost invariably cast in the premises of the majority population. If the overall setting of higher education is insensitive to minority groups, and to their cultural references and values, the barriers for these groups to embark on a scientific career will be high. Innovative and inducive remedies are needed.

Taboos are more difficult to deal with. These may arise out of religious or cultural restrictions on activities that persons can undertake, or in the kind of environment in which they can work. Dealing with these barriers is difficult though important from an ethical, social and personal point of view. For the overall volume of human resources in science and technology, however, this is probably a marginal effect.

4.3.4. Benchmarking consequences

In order to monitor the type of barriers discussed in this section, there is not only a need for gender-disaggregated data, but also data that differentiate on the basis of economic and cultural backgrounds. This points in the direction of a matrix approach to data collection, rather than simple point data. As an example, indicator 1 (Table 1), ‘Number of researchers in relation to the total workforce’, is not gender-disaggregated, and thus of limited usefulness in elucidating the extent to which a nation succeeds in mobilising both sexes for high-quality knowledge-based work. The proposed indicator 4 (Table 1), on the other hand, aims at describing the participation of women, but it is restricted to universities and public research centres. This neglects the participation of women in the private sector, which must be expected to play a much more important role in the European Research Area (see also ‘The new production of knowledge, the dynamics of science and research in contemporary societies’ by M. Gibbons, C. Limoges, S. Schwartzmann, M. Trow, P. Scott & H. Nowotny, Sage Publications, 1994, for a view on how the traditional research constellations may be changing). Also for the other indicators proposed here, the application to the entire field of knowledge-based industry, as well as disaggregation on gender and culture will be of interest in order to obtain an fuller understanding of how these resources may be used to the nations’ advantage.

4.3.5. Conclusions

- The present data show that there are clearly gender imbalances in research. There is a considerable effort under way addressing this problem. Essential to this will be the work carried out by the Helsinki group on women and science.

- The financing of research training required urgent reform in Member States, in order to make research a competitive career track.

- Salaries in research professions are a major competitive factor in the European Research Area. Countries that fail to reward researchers adequately are likely to undermine their development in a knowledge-based economy.

- Cultural and social barriers to tertiary education and to research training may well be significant and need to be researched.

4.3.6. References

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4.4. Mobility

Summary: There is a good degree of mobility of European research scientists. However, there is a limited, but permanent, loss of talent to the USA, particularly of the more able. There is no substantial compensatory inflow, and repatriation appears difficult. Mobility from the private to the public sector is almost non-existent, but movement in the other direction is substantial. Although measures have been put in place to encourage retention and return of scientists, further improvements need to be made in job availability, remuneration and scientific opportunities, especially in the public domain.

In general, mobility of scientists is of high value. It increases the scientific competence of the individual, stimulates the status and performance of the host institution, and can help to overcome supply shortages of expertise and manpower. However, there is a potentially severe downside in that such mobility is simply often an indicator of the relative attractiveness of the host, be it due to national science/research systems, local career opportunities, financial returns and so on. In such circumstances, there can be local depletion of human capital and persistent decline. While it is difficult to measure the international mobility of scientists, there is every reason to believe that it can have a substantial impact on countries' performance in the field of science and technology and therefore on growth. Benchmarking this activity should, therefore, reveal trends that are both positive and negative. Five aspects of mobility have been identified as relevant:

- Mobility of students who provide a potential highly qualified reserve of labour that is familiar with prevailing rules and conditions in the host country.

- Mobility between Member States will reveal whether there are long-standing and persistent flows in one direction. Care needs to be taken in this analysis to assess whether these 'flows' are in any significant sense permanent, for that would cause local impoverishment on the one hand and complacency on the other.

- Mobility out of the Community, where the main recipient is the United States with all other hosts (Japan, Australia, Canada, etc.) contributing only at a low level to the situation. The inflow and return flow are important factors in the analysis of any long-term problem.

- Mobility into the Community, where the UK, Germany and France have traditionally received a sizeable number of foreign students, both at the undergraduate and doctoral level, as well as a somewhat more limited number of foreign researchers (particularly after the disaggregation of the former Soviet Union, and the decline of research financing in the former Communist countries).

- Mobility out of science (there is little or no significant flow in the other direction) into other (non-scientific) areas. Such 'outflows' are very marked at undergraduate level, significant at postgraduate level and still real at postdoctoral level. All are essentially irreversible. They can have both positive and negative impacts.

We note from this that while mobility is in general a positive feature for the 'Europeanisation' of research, it also has a more problematic face in respect of competition for the human resources. In short, one nation's brain drain is another nation's brain gain. This will undoubtedly have consequences for employment conditions within this sector. In the long run, any nation that offers its researchers poorer working conditions (in all its facets) than its competitors may find itself lacking the essential manpower for competing in the knowledge-based economy.

In general, the information available on students', but especially researchers' and other migrants' lengths of stay, emigration flows, return rates and alternative forms of mobility is patchy and inadequate. There are proposals to revise the 'Canberra Manual' and to improve and harmonise longitudinal data on the mobility of Human Resources in Science and Technology (HRST (cf., Auriol & Sexton, 2002, p. 13-38).

4.4.1. Mobility of Students

Since the 1950s the number of international students has increased in all industrialised countries, e.g., from 2% to 3.8% with regard to Australia, Canada, France, Germany, United Kingdom, and USA. Consequently, the total number of university degrees, including PhD degrees, has grown. The college-age population has decreased in the past two decades in all major industrial countries, but this decline has been partially compensated for by increased participation rates in college or university education. It is projected that demand around the world for higher education will continue to rise in the next two decades along with economic growth and increasing global population, especially in the 18-24 age cohort. Students are increasingly likely to seek to study in other nations. There was a total of 1.4 million students studying abroad in 1992, and this number is expected to rise to 2.8 million in 2010 and 4.9 million in 2025 (cf., Johnson, 2001; Mahroum, 1999; Schneider, 2000).

Five major factors contribute to the variability in student mobility:

- larger-country populations seem to reduce outward mobility (mainly because a larger population allows greater diversity of educational services, thus covering all fields of study to the highest level)
- linguistic proximity/language used in the education system
- institutional proximity (as shown by the high level of intra EU mobility), supported by policies on freedom of movement, recognition of degrees, existence of exchange programmes and geographical and cultural ties
- geographical remoteness which acts as a brake on inward mobility
- economic considerations, i.e., tuition fees, costs of living, salary rewards.

From a European perspective, analysing international student flows is important. In general, the large European countries (United Kingdom, France, Germany), the United States and Australia, Switzerland and Austria appear as major net receivers. The effect, however, is highly concentrated on a limited number of nations as 80% go to only five countries: the United States (34%), the United Kingdom (16%), Germany (13%), France (11%), and Australia (8%) (cf., Tremblay, 2002, 51). Asian countries are the main donors, accounting for 45% of the total for OECD countries, high numbers of students coming from China, Korea, Japan, India, Hong Kong (China) and Malaysia. This points to demographic issues but also to active policy initiatives to acquire skills abroad (Guellec & Cervantes, 2002, 77).

Major migratory flows can be identified between Africa and France, between the Asia-Pacific region and the United States, and between non-OECD countries and Denmark. Switzerland and Austria mainly take in Europeans, while the United Kingdom and Germany take in students from the Asia-Pacific region and Europe (cf., Tremblay, 2002, 53).

Overall, student mobility in all OECD countries is greater, principally due to the higher level of education. The proportion of foreign students in science and engineering is roughly equal to that in the social sciences and the humanities. There appears to be a slight ‘humanist’ bias in Austria and Germany, while science and engineering appear to be more internationalised in Australia, Denmark and Switzerland (data for the United States, the United Kingdom and France are missing) (cf., Tremblay, 2002, 56).

Stay rates are a decisive factor in measuring future HRST generated by student migration: US data demonstrate very large variability in the propensity of students to settle in the United States. India, China, Argentina, Peru and Iran as well as some OECD member countries such as the United Kingdom, Greece, Canada, Germany and New Zealand do seem to experience long-term loss of a considerable share of their students who study for a PhD in the United States (cf., Tremblay, 2002, 44).

4.4.2. Mobility of Marie Curie Fellows

A useful measure of the migration within Europe can be obtained from the EU Marie Curie Fellowship schemes, which provide substantial resources within Europe for the mobility of young researchers amongst Member States and FP5 Associated States.

The most recent data for Marie Curie Fellowships awarded within the Fifth Framework Programme confirm the trends that have been most evident in the last few years and possibly will hold for the future unless regulations change. In terms of incoming researchers, the United Kingdom stands out as being the main net beneficiary of the scheme, followed by the Netherlands, Sweden and Belgium. For Germany and France there is a rough balance between incoming and outgoing Marie Curie Fellows. The biggest outgoing nationality groups are from Italy, Spain and Greece. As a partial compensation for these movements, the indications are that most of these mobile scientists return to their country of origin. Against this, some go on to the United States, often on a more permanent basis. So there may be little long-term gain to the host Nation, with the exception of the USA. A novel feature is the migration of researchers from the new Associated States. They choose preferably the UK, France, Germany and the Netherlands as host countries – their long-term status is as yet unclear.

Previously, see data from the Training and Mobility (TMR) Programme in Table 8, France showed the second largest number of incoming fellows whereas Germany showed a significant outflow. It is noticeable that the emphasis has changed recently. During the TMR Programme, Germany, in general, encouraged research experience abroad, whereas today foreign incoming researchers are targeted. On balance, therefore, these intra-European migrations currently appear positive.

4.4.3. Obstacles to the mobility of researchers

Following the Resolution of 15 June 2000 of the Research Council (OJ C 205, 19.7.2000, p. 1), the Commission set up a High-Level Expert Group on Improving the Mobility of Researchers (HLG-IMR), composed of national experts appointed by the Member States which reported on 4 April 2001.

The study mostly concerned transnational mobility (between countries) and movement between industry and academia and between the private and the public sectors. Researchers in all fields of research, in both the public and the private sectors, were considered at all career stages (PhD student, junior, mid-career and senior researcher).

Table 8. Mobility pattern of Marie Curie Fellows (TMR Programme, FP-4, 1994-1998).

Nationality	Host Country																			
	A	B	CH	D	DK	E	FIN	F	UK	EL	IRL	IL	I	L	NL	NO	P	S	Total	*% of total*
A		1		11		1	1	7	15	1			2		4				**43**	***1.2***
B			1	7	1	10	1	35	37	3	2		5		9	2		2	**115**	***3.2***
D	16	21	1	7	13	36	9	171	235	4	9	1	31		35	6	4	22	**621**	***17.4***
DK		2		3		1		7	9	1			3		6		1	4	**37**	***1.0***
E	4	23	7	74	6	85	5	140	202	1	5	1	24		38	3	6	13	**637**	***17.9***
FIN	2			10	2			8	15	1	1		3		3	1	2	4	**52**	***1.5***
F	2	49		85	7	47	2	8	222	7	11	3	30	2	35	5	7	18	**540**	***15.2***
UK	2	9	1	30	11	16	4	76	1	5	11		25		27	5	8	7	**238**	***6.7***
EL	2	11	4	22	4	2		40	76	70			6		16	2		4	**259**	***7.3***
IRL		2		7	1	3	1	11	37	2	20				6	1	1	1	**93**	***2.6***
IL		1				1		5	8		2		1		1		2		**21**	***0.6***
IS				1				1	2	1			2						**7**	***0.2***
I	6	32	5	70	8	27		163	213	7	4		20		31	3	5	16	**610**	***17.1***
LI				1															**1**	***0.0***
L								1	1										**2**	***0.1***
NL	3	5		28	7	11	1	29	65				12		1	3	1	4	**170**	***4.8***
NO					1	2		1	5						1			2	**12**	***0.3***
P		1		5	2	2		5	13						9	1	1		**39**	***1.1***
S	3	2		2	5			6	32			1	5		5	3	2		**66**	***1.9***
Total	**40**	**159**	**19**	**363**	**68**	**244**	**24**	**714**	**1188**	**103**	**65**	**6**	**169**	**2**	**227**	**35**	**40**	**97**	**3563**	***100.0***
% of total	***1.1***	***4.5***	***0.5***	***10.2***	***1.9***	***6.8***	***0.7***	***20.0***	***33.3***	***2.9***	***1.8***	***0.2***	***4.7***	***0.1***	***6.4***	***1.0***	***1.1***	***2.7***	***100.0***	

The objective of the work of the HLG-IMR was to identify the main obstacles to mobility and to suggest ways of overcoming them. The obstacles are interdependent, but for the sake of clarity have been divided into four groups:

1. legal and administrative obstacles to transnational mobility
2. social, cultural and practical obstacles to transnational mobility
3. obstacles to a European dimension in research careers
4. obstacles to intersectoral mobility.

In general, it was stated that there was a striking lack of comprehensive statistics about the migration of researchers, which needs to be rectified. However, results of a questionnaire suggested that there seems to be a particular concentration of obstacles for mid-career researchers on medium-term stays. Social, cultural, linguistic and economic factors, often resulting from a lack of recognition of qualifications and of relevant social and economic information, constitute further barriers. The appropriate implementation of regulations can also cause problems. The HLG-IMR recommended that these obstacles have to be removed and adequate funding be provided to encourage mobility. They listed actions in the form of information and assistance (e.g., information coordination), networking activities (e.g., good-practice workshops) and personal initiatives (e.g., language support and family and gender support). Less emphasis was given to the obstacles to intersectoral mobility because the situation is more complex and requires additional study and data.

In the communication ‘A Mobility Strategy for the European Research Area’ (COM 2001, 331, final) a strategy was presented to create a favourable environment for the mobility of researchers. It is recommended that special attention should be devoted to the encouragement of reciprocal intersectoral and to interregional mobility in order to avoid a ‘brain drain’ in less-developed regions.

It is concluded that in order to develop specific actions as specified in the Communication, a more reliable and comprehensive collection of data and studies on the mobility of researchers is needed.

4.4.4. Migration from Europe to the USA

It is of little help to a nation if investment in education and training only prepares its young, talented labour force for harvesting the benefits of this training abroad and, in the process, contributing to another nation’s economy. This brain-drain phenomenon is well known, with the post-war exodus to the USA as the prototypical example. The Institute of International Education (IIE) in New York provides comprehensive data on the number and countries of origin of students and scholars entering the United States and the number and countries of destination of US-American students and scholars leaving the United States. From this, some indication of the scale of the migration experienced by European Member States, can be determined.

Undergraduate and postgraduate students

From 1954/1955 to 2000/2001 the population of international students in the USA (about 550,000 in 1998/1999) rose from 1.4 to 3.8%, with 55% and 15% of those coming from Asia and Europe, respectively. The main providers from the European Union are Germany, the United Kingdom, France, Sweden and Spain. In contrast, in 1999/2000 only about 145,000 USA students migrated abroad, with the United Kingdom, Spain, Italy and France as leading destinations in Europe. The share of foreigners in the United States among graduate students and doctoral recipients experienced a sharp increase in the 1980s and has since maintained these high levels. The share of foreigners is particularly high in Science and Engineering. It is higher at the PhD level and above than at the undergraduate level. Major donating countries in these categories are again in Asia but the United States remains the main destination for European students at the PhD level, although European countries are increasing their attractiveness. According to an Italian study, 33.5% of PhD students reported a preference for going to the United States for a study abroad period compared to 50% preferring the United Kingdom, Germany and France (Guellec & Cervantes, 2002, 77).

Finally, it should be pointed out that whilst almost all USA scholars return to their country of origin, that is not true for some of those who go to the USA (see 4.4.1). The flow is, therefore, not only unbalanced, but for postdoctoral scholars also permanent.

Scholars (PhD and above)

The number of foreign scholars at USA academic institutions rose from 65,494 in 1997/98 to 79,651 in 2000/2001. Over four in ten of these (45%) come from Asia with Chinese (14,772) and Japanese scholars (5,905) taking the lead. Europeans make up 36% of this group (28,668), German nationals (5,221) being the most prominent in terms of numbers (Table 9).

Table 9. Number of foreign scholars at US academic institutions.
Selected Countries (2000/2001)

Country	**Number**
World	79,651
China	14,772
Japan	5,905
Germany	**5,221**
Canada	3,735
United Kingdom	**3,352**
Russia	3,253
France	**3,154**
Italy	**2,226**
Spain	**1,706**
Netherlands	**1,037**

- 79.2% of all foreign scholars in the USA are involved solely in research activities. Most are concentrated in the fields of health sciences (26.9%), the life sciences (14.7%), physical sciences (14.7%), and engineering (12.6%).

- According to NSF statistics, roughly 450,000 foreign-born scientists were employed in the USA R&D sector in the mid-1990s. The proportion of foreigners in the R&D sector is proportionally higher than in the total population (16% vs. 9%).

- The most alarming indication from monitoring the longer-term residences is that 60% or more of these migrants were still present in the USA five years later. This trend is reinforced by a significant number of European scientists in USA universities and industries and is not in any way matched by the number of USA citizens in European institutes. Variations of stay rates, however, appear across nations and fields: Whereas most German graduates, who finish their Ph.D. training in the United States return (ca. 75%), only ca. 30% of English graduates do so; at the same time, for example, 7% of British engineering graduates stay compared to 65% of life sciences, and 60% in physical sciences (Mahroum, 1999, 179).

The push-pull factors which affect mobility are shown in the accompanying box on the next page. In summary, the major drivers of international HRST mobility include the relative demand and supply of labour in various countries (including job creation and differences in wage levels), career and earning prospects, attractiveness of the education and research systems, the global R&D activities of companies and the availability of risk capital and strategies for individuals seeking international experience. A special driving force at the beginning of the 21st century is the demand for IT specialists in the United States and in European OECD countries (cf., Guellec & Cervantes, 2002, 79). Thus, any nation which is serious about being competitive in a knowledge-based society must address such factors.

4.4.5. Return Migration into the Community

Data on foreign scholars in public research laboratories in France show that most visiting foreign scholars are concentrated in information and communications technologies, agricultural sciences and health and medical research. Most foreign researchers in computer science and information technologies come from Europe, followed by North Africa, central and eastern Europe and the Americas (cf., Guellec & Cervantes, 2002, 78).

Agglomeration dynamics play a role not only in the United States but also in Europe. In the United Kingdom, for example, the universities of Cambridge and Oxford alone received some 15% of all foreign academics employed in the country between 1994 and 1997 (cf., Mahroum, 1999; Guellec & Cervantes, 2002, 83).

Return flows of French PhD graduates are quite high: three years after completing their dissertations, only 7% of them reside abroad (mainly for postdoctoral work in other European countries), and 60% of these scholars wished to return to France as soon as possible. The prospect of receiving an indefinite contract (as opposed to a fixed-term contract in their host country) appears to be a major incentive to return to France (Martinelli, 2002, 126). More than 10% of all new appointments at CNRS Institutes had undertaken a postdoctoral position in the United States. This suggests a pattern of brain circulation rather than brain drain in the French case (cf., Guellec & Cervantes, 2002, 92).

Push-Pull Factors

Qualitative studies indicate various push-pull factors influencing researchers to leave/enter a specific country. Recent studies have been conducted with regard to the migration of German scientists to the USA but may be more widely relevant to European scientists. Many of these factors can be expected to exert their influence also in an inter-European context.

Push Factors (Out of Europe)

- Lack of autonomy and rigid hierarchies within the German professorial system.
- Rigid employment rules, e.g., five-year maximum employment of postdocs within one organisation.
- Proof of international research experience that becomes an implicit norm for successful research careers ('footstep dynamics': students follow the examples of their teachers who went to the USA in the past).
- Lack of employment opportunities in Europe.
- Lack of re-entry positions in Europe.
- Insecurity of career paths combined with rigid sectorial segregation (no job mobility): decision about tenure at a comparatively late stage of the career; little job opportunities for those who do not get tenure (special disadvantage for women and late entries into an academic career).
- Overly competitive funding situations in some Member States – lack of industrial support.
- Inadequate personal remuneration.

Pull Factors (Into the USA)

- Agglomeration dynamics: internationally well-known centres of excellence/competence attract international researchers.
- High demand for postdoctoral scientists, which cannot be met by the USA higher-education system; foreign researchers who bring their own money are particularly in demand.
- Career opportunities: compatible USA career paths between academic and non-academic research organisations; postdoctoral positions are attractive as entry-level positions for foreign-born scientists; follow-up opportunities exist at the end of postdoctoral stay: assistant/associate professorships; tenure to secure further career path.
- Innovation: willingness to devote financial and human resources to innovative, often interdisciplinary, fields of research; higher degree of competitiveness.
- Internationality: high share of foreign-born scholars (16% of R&D personnel; 21% of university faculty; 50% of all postdoctorals).
- Working conditions: flat hierarchies, small teams, accessible group leaders/professors, little admin/teaching obligations, good equipment, upbeat team spirit/goal oriented mindset, flexibility (e.g., to change fields of investigation).
- Better salaries and living standards.

A similar picture can be seen with Sweden: emigration rates are highest among holders of doctoral degrees (30% in 1995/96 as opposed, for example, to 8% of the total of Swedish students in 1999/00). According to a 1998 study, most of these young PhDs leave for postdoctoral work abroad. Roughly 50% of them returned the year after they left; two years after departure, one third were still abroad. It is expected that many of this 30% also return subsequently. In the professional fields, it is estimated that 2-3% of new Swedish graduates go abroad (with even higher rates in business administration and management). But while this rate has been steadily increasing since the beginning of the decade, this emigration has not resulted in any major net loss of numbers in the various professional contingents, again because of a high tendency to return home (Gaillard, 2002, 231-2).

Return flows to the United Kingdom appear to be lower, the special tradition of the United Kingdom as a country of emigration rather than immigration may be significant (cf., Rollason, 2002, 328). Somewhat less than 10% of recent PhD graduates (see later) depart for the United States. The return rate may be of the order of 50%. For Germany it is estimated that approximately 25-35% of all PhDs that go to the United States remain there for a longer period of time. The stay rate is particularly high in the natural sciences, especially the life sciences and physics.

The problem that requires some attention, however, is that the proportion that migrate to the USA and subsequently remain there may be populated by the more able ambitious, research scientists.

Amongst European countries, therefore, it is on balance, more appropriate to talk about brain circulation and brain exchange rather than brain drain. The behaviour of primarily young researchers, mainly at the PhD level and above, follows the recognised pattern of international training, postdoctoral residencies, temporary relocation as members of a consortium, etc. In many European/OECD countries the shortage of highly skilled S&T workers is due to an overall deficit of national graduates, combined with an inverted age pyramid, rather than a substantial brain drain to other countries, predominantly the United States. Although the permanent flow to the USA is positive, it is not as damaging in numbers as the restricted production in European States.

4.4.6. Migration to other disciplines

Migration to other types of employment, finance, management, law, administration, etc., occurs at various stages. Unsurprisingly, the greatest volume is at first-degree level. Recent trends suggest that at least 25% and probably more than 50% of science graduates leave the overt practice of science. Although the skills and knowledge they carry are likely to be of value to their new profession, the volume movements and, of much greater concern, the quality of some of these migrants is beginning to appear more as a negative ‘leak’ than a positive ‘outflow’. It is clear that the difficulties in science as a career and the lack of rewards are serious concerns for the most able. It is equally disappointing that too small a proportion of these first-degree graduates enter science teaching as a preferred career. Migration after PhD is discussed in Section 6.4 – first destinations.

4.4.7. Intersectoral mobility

Although there are perceived advantages to both short- and long-term movements from academia to industry and vice-versa, such exchanges are not frequent. There are rare instances of both senior and junior academics taking up permanent positions in industry. The flow in the other direction, however, is almost non-existent and when it occurs is seen mostly at a more senior level. However, there are instances, e.g., in The Netherlands, of programmes to stimulate the latter and they are seen as constructive and promising.

More disappointing is the frequency of short-term exchanges like sabbatical mobility. Clearly there are institutional and work-pressure barriers that inhibit what could be a very positive process. The expert group registers that although there has been much support for intersectoral mobility over the last decade, or even longer, this possibility appears to have been the victim of increased analysis of the benefits of such exchanges relative to the costs of substitution and loss of expertise. By its nature intersectoral mobility appears as a long-term investment, and in times of heightened competition pressures, such measures will frequently lose out to short-term needs.

4.4.8. Examples of good practice

The problem of mobility by its very nature must find a solution at a European level. The experience gained with the different measures within the Marie Curie Programme and similar exchange programmes are valuable. Beyond this we refer the reader to the recommendations of the High-Level Expert Group on Improving the Mobility of Researchers, as communicated in 'A Mobility Strategy for the European Research Area' (COM 2001, 331, final). Clearly, Europe has to increase its attractiveness to both its own and foreign scientists.

The Commission's most recent proposal for a specific programme for the Human Resources and Mobility activities under FP6 (COM 2002, 43, final) envisages the promotion of researcher mobility with a view to the successful creation of the European Research Area. This will involve a coherent set of actions, largely based on the financing of structured mobility schemes for researchers, and geared essentially at the development and transfer of research competencies, the consolidation and widening of researchers' career prospects, and the promotion of excellence in European science.

With a view to further reinforcing the human potential for European research, this activity will also aim to attract the best and most promising researchers from non-European countries, to promote the training of European researchers abroad and to stimulate the return of European scientists from abroad.

4.4.9. Consequences for benchmarking

Brain-drain/brain-gain statistics require complete sets of entry and exit statistics and international comparisons for a sound assessment of any particular set of data. In the USA, these data are available and relevant to Europe since this is overwhelmingly the preferred destination for research scientists. However, they are largely missing for movements back to native domiciles. In general, there are no internationally comparable data on flows and stocks of highly skilled migrant workers, and it is difficult to get a complete picture of the situation, even for one given country (cf., Guellec & Cervantes, 2002, 72).

4.4.10. Conclusions

- European Science appears to be a net provider of human resources to the USA although much of this migration is temporary. The outcome for Europe on RTD in all these cases is negative and not compensated for by migration in the other direction.

- European Science is a major provider of human resources to other (non-scientific) professions. This movement is likely to be permanent, depleting the research pool. The volume of this movement out of research to currently too large, particularly of the more able student.

- International fellowship schemes such as the Marie Curie Fellowships are an important instrument of mobility.

- In general, countries whose higher-education and research systems are internationalised and which have an environment conducive to opportunity and reward are more successful at increasing the pool of foreign talent in science and technology.

- Germany, France, Spain and to a more limited extent other countries have provided funding schemes to attract foreign students and postdoctoral fellows (e.g., EduFrance in France, HiPotentials in Germany). There are also a limited number of schemes in most countries to attract back the particularly able and distinguished. This will be enhanced by new instruments in the 6th Framework Programme.

- There is relatively little intersectoral mobility.

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4.5. Investing in Human Resources for RTD

Summary: A direct unequivocal relationship between investment, human resources and economic benefit is hard to establish. However, there is a general perception of a strong causal link. The EU nations divide themselves into three blocks: high investment and human resources in Finland and Sweden, a middle group showing modest investment, consisting of the remaining Member States with the exception of Greece, Italy, Portugal and Spain which make up the third group, characterised by low investment. The available data indicate that the low investors spend money chiefly on training and not on capitalising on this investment in terms of strengthened R&D. For the high investors, training is just a minor part of an overall strong investment in R&D.

If we consider the process of training a researcher, it is obvious that investments of considerable magnitude are required. Infrastructure, teaching staff, supervisors and student financing all represent expenses that society hopefully will capitalise on as the researcher pursues his or her career. While all nations have committed these investments to a larger or smaller extent, little appears to be known about the returns they give. Is there a simple linear relationship, between the production of Human Resources for RTD and the investments required, or is there a law of diminishing returns requiring larger investments per researcher as we strive to train a greater part of the population for RTD? Is there under- or over-investment, and if so, how can it be recognised? While the subject *Private and Public Investment in RTD* is the domain of another expert group, there is necessarily an area of overlap concerning the effect of these investments on Human Resources for RTD. Some view from this angle is, therefore, included here.

There is no reliable economic model which proves a direct causal link between investment and development of Human Resources for RTD. Indeed, it is rather problematic even to try to trace the flow of investments that might influence this sector. The reason for this is that these investments nowhere emerge simply and unambiguously from the available economic data, they are mostly parts of the overall cost combined with other budgetary items. This does not mean that they are insignificant – personnel costs/salaries are frequently the largest component of both university budgets and of project costs for individual research projects. A rule of thumb is to expect 75% of budgeting to cover the Human Resources costs, but there are large margins on both sides of this figure, and variations between the scientific fields, that make estimates on the basis of total spending on R&D rather problematic.

4.5.1. The relationship between higher-education expenditure and the research population

A first, and quite crude, indication of the kind of relationships connecting Human Resources for RTD with investment may be obtained from existing data. As a measure of the Human Resources for RTD we may use the proportion of researchers in the workforce as given by indicator 1. These are presented in Figure. 5 for the EU 15 (without Luxembourg) plus Norway (see also Table 2). As can be seen, the nations may be divided into three groups, one consisting of Finland, Sweden and Norway with a relatively high population of researchers (over 7.5 per 1000 workforce), one middle group ranging from Denmark at 6.46 to Austria at 4.86 and containing the traditionally large industrial nations, and one group with a value below 4.0. As will be seen these clusters also appear in the further analysis.

These data may be combined with various forms of information on investment. For this simple exercise, the higher-education expenditure on R&D (HERD) is used. Total numbers for this investment parameter are of limited value, but there are two relative measures that are of interest: either one can use the HERD as percentage of gross domestic product (GDP), indicating a measure of the priority that HERD is given in the overall economy of the nation. Or one can use HERD as a fraction of general expenditure on R&D (GERD), showing the role of this investment in the overall R&D effort. For these investment parameters, data from the MSTI database (STI, March 2001) and the ANBERD database (STI, March 2001) have been utilised.

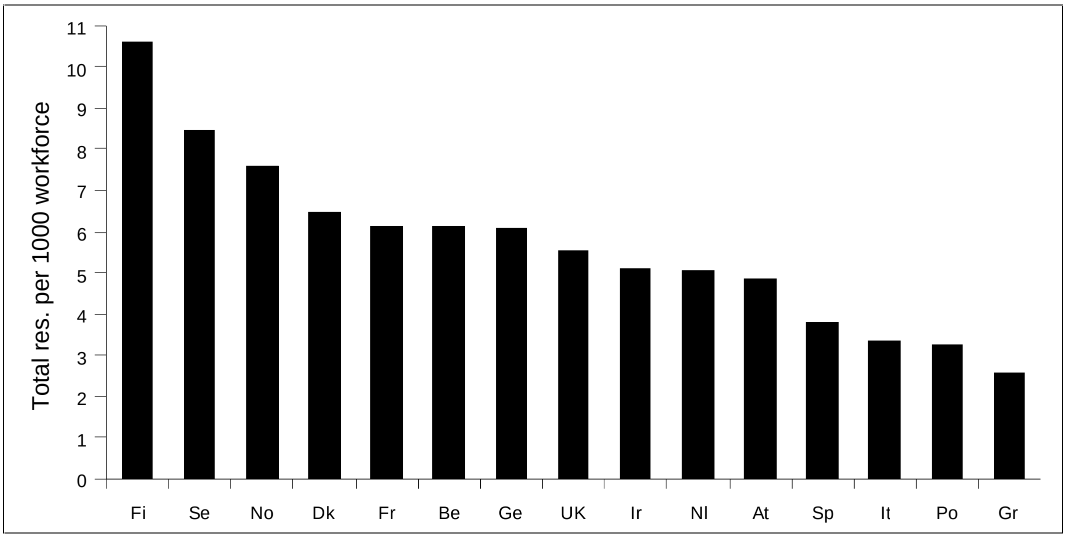

Figure. 5. Researchers in the Workforce.

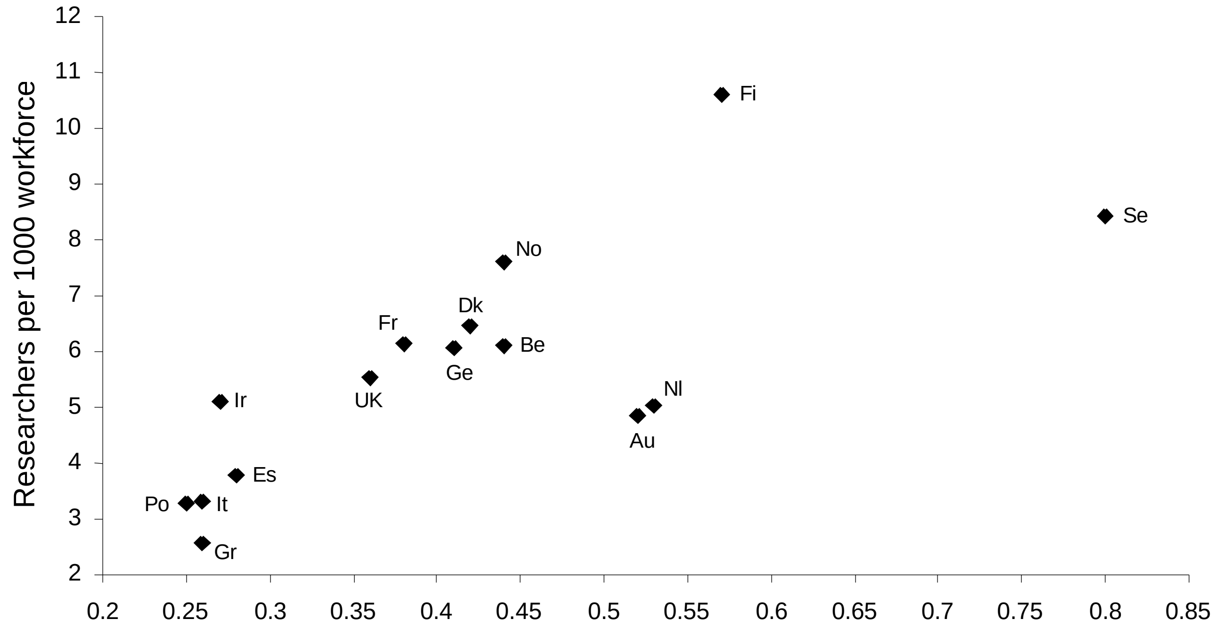

Figure. 6. Higher-education expenditure on R&D (HERD) in % of GDP.

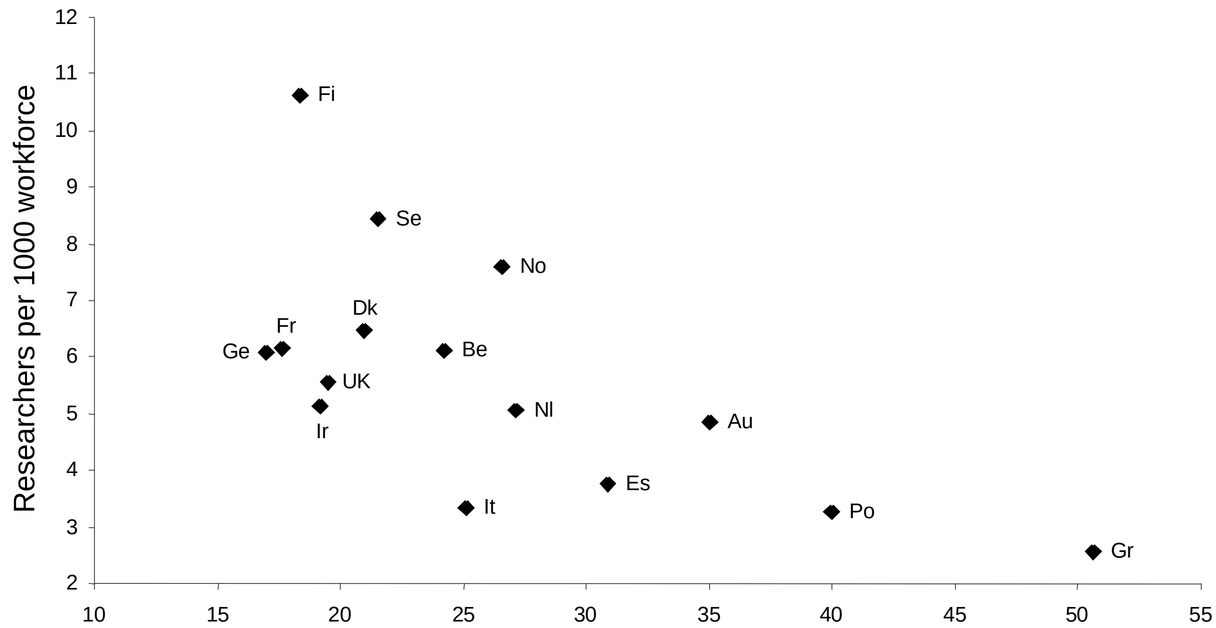

Figure. 7. Higher-education expenditure on R&D (HERD) in % of GERD.

Key to country abbreviations for Tables 6 – 8
Au – Austria, Be – Belgium, Dk, Denmark, Es, Spain, Fi – Finland, Fr – France, Ge – Germany, - Gr – Greece, Ir – Ireland, It – Italy, Nl – Netherlands, No – Norway, Po – Portugal, Se – Sweden, UK – United Kingdom.

Analysis of the variation in the research population as a function of investment in terms of fraction of the GDP, reveals not unexpectedly, a reasonable correlation as shown in Figure. 6. The pattern is quite similar to that of research intensity vs. total researchers presented for indicator 1 in Key Figures 2001. Note that the three groups that emerge from Figure. 5 are again easily identifiable from this diagram. It is interesting that Ireland has a relative research population equal to that of the Netherlands with only half as much HERD as a fraction of GDP.

If HERD is now viewed as a fraction of GERD (Figure. 7), an interesting contrast appears. Here the high scoring countries show quite low relative investment values.
Thus a large research population for these countries is a result of substantial overall investment. The fraction that goes to higher-education expenditures is a relatively small part of this investment. Conversely, the low-scoring countries appear to spend a large fraction of the gross expenditure on RTD on the training process, but relatively less on the exploitation of this trained force in RTD, presumably due to low private investment.

It may be argued that the total research population is a result of long-term development, and should not be compared to recent investments. However, the trends observed appear to be quite robust, as they show up also when one considers the number of new PhDs. Figure. 8 and Figure. 9 show the values of indicator 2 as a function of HERD denoted as a fraction of GDP and GERD respectively. Again the reversal of the correlation line is seen, with a large fraction of the GERD used for educational expenditures by low scoring countries. An interesting feature here is that Norway now has moved from the top to the medium cluster. This may be ascribed to a researcher work-force where the PhD has not been the traditional route a large fraction of the research load being carried by engineers and researchers with intermediate university degrees. It illustrates how the interpretation of these data can depend on the socio-cultural conditions of the separate nations.

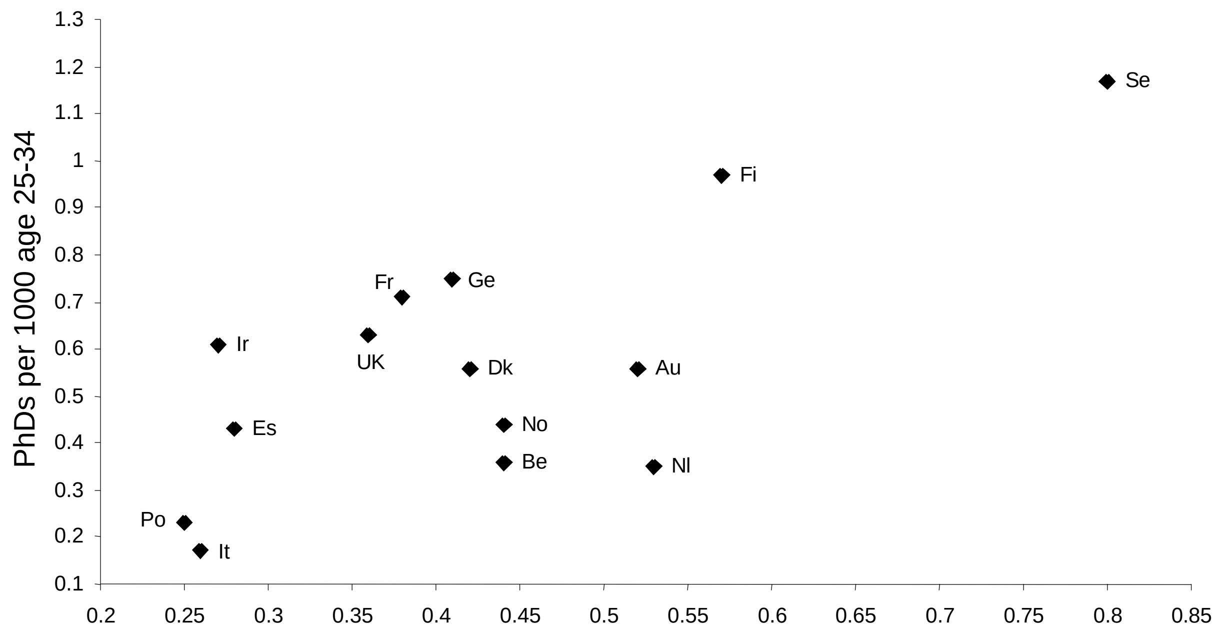

Figure. 8. Higher-education expenditure on R&D (HERD) in % of GDP.

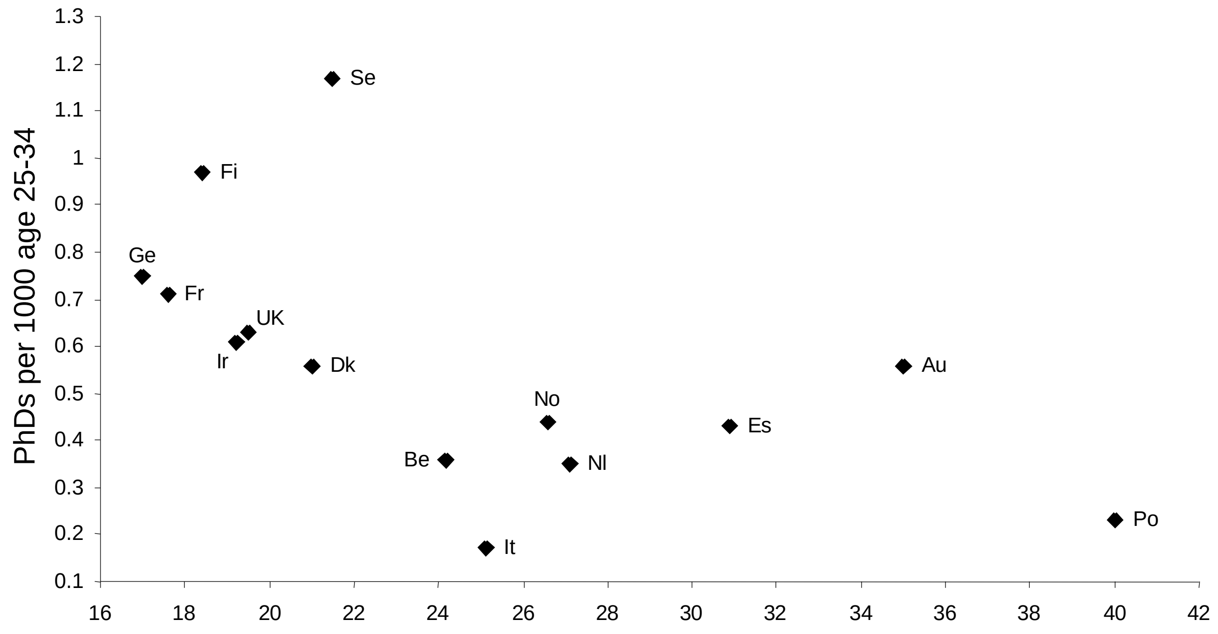

Figure. 9. Higher-education expenditure on R&D (HERD) in % of GERD.

4.5.2. Possible investments affecting the Human Resources for RTD.

The above analysis is admittedly rather preliminary, and any in-depth study of the effect of investments on HR for RTD must drill down through the data sets to display any relationships more clearly. Such data will have to cover also other types of investment, as well as taking a closer look at how the Human Resources should be defined in this particular connection. A brief list of investments that would be expected to contribute to the development and maintenance of Human Resources for RTD includes:

- Investments in the educational system
- Investments in life-long learning / training courses
- Investments covering infrastructure and running expenses in the RTD sector beyond the training aspect
- Investment in specific RTD projects
- Investment in work, environmental and social conditions
- Investments in increased awareness and promotion of science.

It is clear from this list that a very accurate accounting of all these contributors is not feasible at this time. The simplest investment to monitor is (probably) the educational system. Information about the cost of formal education across time will indicate changes in the basic investments in Human Resources, but only a limited amount of those investments will in the end be reflected in human resources for RTD. The task of singling out those contributions that go directly towards the Human Resources for RTD is not straightforward but there is likely to be a constant proportionality based on a simple head count. There might nevertheless be large transferability problems in such an approach – for a country where industry prefers to do a significant part of training of researchers in-house (e.g., France), some of this investment would be hidden.

For many countries there is also no sharp line between those investments in the university sector that are aimed at training, and those that are aimed solely at research. While this is a natural consequence of the von Humboldt model, it may obscure the effects of variations in university financing. A further complication is likely to arise in those cases where the university has independent funds – many European universities, often exclusively publicly funded and with strong restrictions on fundraising and commercial activities, feel that the comparison with USA universities with large private funds is not appropriate. And from a statistical perspective the comparison might seem invalid. Nevertheless the trends in such data will indicate trends in public willingness to invest in human resources.

Even more elusive are the contributions made to work, environmental and social conditions. In some extreme cases these are possible to discern, one example being the situation in Russia after the fall of the Soviet Union. Here conditions became so difficult for many researchers, that they left science and caused a considerable brain drain, both out of the sector and out of the country. As a consequence some foreign universities and agencies contributed to improved working conditions for Russian scientists in Russia in order to maintain the knowledge base and a core of Human Resources. However, in general we expect that it will be difficult to find statistically reliable data for this kind of investments in R&D.

Data for investment in increased awareness of science are not available at the moment although there is growing political attention to the role of citizen awareness of science. Included in this is the role general attitudes play in promoting science as an attractive field for youngsters, eventually motivating young students to enter higher education within the fields of science and technology.

In conclusion, it is found that the question of investment in Human Resources for RTD is a crucial area for understanding how these resources may be developed, especially considering the size of these investments, the need to mobilise an increasingly greater proportion of the intellectual resources of a country, and the long term strategy that is required. The data available at present as well as the scope of our work, do not allow further exploration of this issue, but it is recommended that it be the subject of further study in the continued development of the benchmarking process. It should be pointed out that in the two illustrative cases presented in Annexe 2, Finland and Bavaria, both regions emphasise that strategic investment in the development of Human Resources is a key contribution to success. At present these are the strongest messages.

4.5.3. Benchmarking consequence

Presently there are too little knowledge and data about the effect of investment on Human Resources for RTD, and benchmarking is premature, but a comprehensive analysis involving new data sets is clearly important.

4.5.4. Conclusions

- To capitalise on the training of Human Resources for RTD, it is necessary to increase national research intensity.

- The effect of various forms of investments on the development and deployment of Human Resources in RTD needs to be more deeply investigated but case studies point to a strong interconnection between investment and economic benefit.

5. Issues – Decision stages

The early development of a scientist goes through several distinct stages, each of which depends on a clear decision process, the outcome of which can be readily monitored. This chapter of our report focuses on benchmarking these stages and the influences that bear on the options being exercised. Since these decisions quickly become irreversible, it cannot be stressed too greatly how important the prevailing influences can be.

5.1. Schools

Summary: All data assembled thus far support the importance of the school experience in the choice of subsequent career – and science is doing poorly with declining take-up rates. In performance competitions, the PISA 2000 study already shows an ominous below-average picture for many European Member States. These observations are consistent with the widespread failure to attract and retain able scientists in the teaching profession, a situation that is likely to worsen on account of skewed age profiles and accelerated loss due to retirement. Clearly, this position cannot be reversed without substantial reform and improvement in the working conditions and remuneration of teachers, particularly in the sciences and mathematics.

5.1.1. Trends in students' choice of subjects

As pointed out above, it is desirable, almost essential that the career interest in science begins from an early age. Thus it is important to assess early uptake of scientific interests, which is most easily achieved by monitoring the proportion of school leavers taking final examinations in the main scientific subjects. Unfortunately, such data have not been made generally available although they do exist in some Member States. However, some trends can be ascertained by analysis of those groups going on to science courses at the tertiary level, and an analysis of this type is detailed later. If the back-extrapolation from those data is valid, they confirm the more anecdotal impressions voiced in the press – namely that despite interest in science at a very young age, this is not sustained into the later stages of secondary education. In general, the proportions remaining in the so called 'hard' sciences (chemistry, mathematics, physics) has declined by up to a third in the likes of Germany, The Netherlands and the UK whilst it is being maintained or even increasing in the newer sciences (biology, computer science, information science, earth and environmental sciences). The overall picture appears more encouraging in the likes of Portugal, Spain and Greece.

5.1.2. The changing role of the teacher

As indicated above, the availability and quality of teachers, a stimulating curriculum and the perceived worth of the scientist in society are essential to retaining the attractiveness of scientific education. We have already commented on the role of the curriculum in section 4.1.3 of the attractiveness of science and technology to young people.

However, for any curriculum to succeed, it is of vital and paramount importance to have good and dedicated teachers. The implementation of the new developments in education for the purpose of encouraging youngsters to consider science as a career is dependent on talented men and women both entering and remaining within the teaching profession. There is concern about the health of the teaching profession, not only from academia and the institutions of teacher training, but also from industry. Both employers' organisations (e.g., the German *Bundesvereinigung der Deutschen Arbeitsgeberverbände*) and trade unions (e.g., the European Trade Union Committee on Education) have put forward ideas for education in the 21^{st} century. The consensus emerging from this diverse interest in educational innovation is the call for a 'new type of teacher'.

Current thinking in education indicates that the future emphasis will be on 'learning' rather than 'teaching'. Teachers will have to progress beyond their present role of instructors and act more as 'facilitators', developing the necessary skills to become effective managers of a learning environment. In fact, if they are to fully harvest the benefits of the high-tech information age and the knowledge-based society, they have to be a part of a continuing learning process and become 'co-learners' in the learning environment. Phrases such as, teacher education for building a learning society and for developing competencies required for using information and communication technology in teaching-learning, may remain as mere rhetoric unless they get appropriately reflected both in the letter and the spirit of new teacher education programmes.

Unfortunately, the on-site conditions of schools in many countries appear to impede rather than facilitate the development of a new type of teacher. Classroom teachers lack the power and the position to change organisational structures, curriculum requirements or educational legislation. Also the re-education of teachers to utilise new technology frequently lags behind stated goals due to insufficient funding. In some cases, teachers finance this continued education themselves, but the result is that they feel little or no loyalty to the schools, and soon seek to apply their new skills in fundamentally more rewarding occupations.

5.1.3. Skilled teacher shortage

It is widely perceived that part of the problem of low interest in and take-up of science, and perhaps also declining comparable standards, lies in a shortage of inspirational teachers at the secondary school level – a shortage which is reflected in both quality and quantity. Many national systems face teacher shortages in particular subjects. Typically these subjects include mathematics and some sciences, where there has been a steady decline in the popularity of those subjects in schools, and technical subjects like information technology, where there is a strong demand for qualified people from other sectors of the economy. More worrying still is the age profile in some Member States (see below), which suggests an ominous outlook.

Based on limited harmonised data and public statements, it appears that there is already a significant shortage of adequately skilled teachers in at least some Member States. A few national programmes have been initiated in order to boost recruitment in shortage areas and topics. These take the forms of special recruitment initiatives both at home and abroad, financial inducements and altered qualification criteria. It is still too soon to be sure whether any meaningful and long-lasting improvement is seen, but the prospects are not encouraging according to reports to the European Trade Union Committee for Education.

- In France, from 2002 to 2006 an annual average of 16,900 teachers will leave for retirement, and the Ministry of Education considers that the annual need for new teachers for the period 2001-2008 will be about 14,650. The French *Syndicat National des Enseignements de Second Degré* concludes: 'When comparing the number of estimated departures and the number of appointments that have been scheduled, one can see that the system is not able to cover the needs.'

- Ireland has not provided statistics on this matter, but second-level schools are currently finding it difficult to get teachers in some subjects, including the sciences and mathematics. There is concern about the decline in the number of applicants with primary degrees in the sciences who wish to qualify as science teachers, particularly the small number of graduates in physics and chemistry.

- The Norwegian Teachers' Union's calculations show that there will be a significant undercoverage of qualified teachers at all levels if drastic action is not taken. The union provides detailed numbers of school children, students in teacher training, and necessary teachers up to 2005; in that year there will be an unsatisfied need of 20,000 teachers, according to their estimates.

- In Sweden, the estimated shortage of teachers in different levels is 9,000 in 2002, 8,500 in 2007, and 6,500 in 2012. There will be a long-term shortage of teachers in the upper secondary schools.

- Teacher shortage appears as a serious problem in the United Kingdom. Many schools rely on overseas staff from Australia, New Zealand, South Africa, Canada and recently Eastern Europe, in addition to all kinds of measures to cope with vacancies. There is under-recruitment to the training institutions.

Even allowing for the fact that these are trade-union numbers, emanating perhaps from sources with a vested interest, the overall picture is too bleak to be ignored. Some of the keys to understanding the situation must be sought in the demographic profile of the profession as illustrated in Table 10. There are nearly 4.5 million teachers in the EU in the primary and secondary levels taken together, about 3% of the total active working population in the EU, varying from 2% in Germany to 5% in Belgium. Gender is also an issue here. Primary and secondary teaching is predominantly a female profession in Europe (Table 10, right column), but the percentage of women in the teaching population decreases at higher levels of education (78% women in primary, 59% in lower secondary, 53% in upper secondary, less than 40% in tertiary education).

The changing nature of the teaching process also requires more flexibility. This in turn can only be achieved by reducing the high student to teacher ratios seen in some Member States. This has been recognised in some countries such as the UK but recognising the problem and solving it under the conditions outlined here is a major challenge.

Analysis of the distribution of teachers by age (Table 10, for selected countries) shows that in most European countries the proportion of teachers aged 40 and over is more than half of the teaching staff, both in primary and secondary levels. Ageing of the teaching workforce has several effects. First, it raises costs without resolving the problem of low entry salaries. Second, the need to adapt current teachers to meet the new challenges is likely to require resources. Finally, and most importantly, the future teacher supply is likely to be affected as proportionally more teachers retire in any given year. However, it is still preferable to retain competent teachers than over provide at the entry stage to compensate for future losses.

In primary schools, the proportion of older teachers (age 40 and over) is very high (and increasing) in Germany (78%), Sweden (74%), Italy (68%) and The Netherlands (65%), France (59%), Ireland (58%), Finland (58%) and Austria (53%). Moreover, the average proportion of teachers in primary education aged 50 or more years increased by 4% between 1996 and 1999. In Germany, The Netherlands and the United Kingdom, this proportion rose by more than 5%.

Table 10. Age distribution (%) and gender (% of women) of teachers, based on head count situation 1999 (for selected countries).

	Primary level			**Lower secondary level**			**Upper secondary level**				**All levels**
Country	40-49	50+	**Total 40+**	40-49	50+	**Total 40+**	40-49	50+	**Total 40+**		% women
Austria	38.0	15.3	**53.3**	43.2	16.8	**60.0**	40.5	24.6	**65.1**		62.0
Finland	28.4	30.0	**58.4**	31.4	32.6	**64.0**	34.4	34.5	**68.9**		66.2
France	37.6	21.1	**58.7**	30.8	32.6	**63.4**	31.5	31.2	**62.7**		61.4
Germany	38.1	40.4	**78.5**	40.7	45.7	**86.4**	39.9	30.8	**70.7**		57.3
Ireland	33.6	24.7	**58.5**	34.9	28.7	**63.6**					61.4
Italy	39.7	28.6	**68.3**	46.4	44.5	**90.9**	45.0	37.1	**82.1**		75.3
Netherlands	40.1	24.6	**64.7**				39.7	34.5	**74.2**		n.a.
Sweden	32.9	41.0	**73.9**	25.1	41.6	**66.7**	28.0	48.7	**76.7**		65.6
United Kingdom	36.9	22.5	**59.4**	38.6	21.9	**60.5**	38.5	21.8	**60.3**		61.4
All OECD	33.6	25.2	**58.8**	34.3	30.2	**64.5**	35.8	31.0	**66.8**		63.8

Source: OECD, 2001.
Ireland: Lower-secondary level includes upper-secondary and post-secondary non-tertiary level.
Netherlands: Primary level includes pre-primary level; upper-secondary level includes lower-secondary level.
Gender: % women for all levels (primary, secondary and tertiary).

In all countries, the teaching staff is older in secondary education than in primary. At secondary level, for example, the proportion of teachers in Italy aged 40 and over is 91% and 82% in lower- and upper-secondary education respectively, followed by Germany (86 and 71%), Sweden (67 and 77%) and The Netherlands (74% for both levels taken together). In lower-secondary education, the proportion of teachers aged 50 or more years rose by an average of 6% over the period 1996 to 1999. The increase exceeded 5% in Austria, France, Ireland and The Netherlands, and 10% in Germany and Italy. In all countries teachers aged 40 and over constitute more than 60% of staff in secondary schools (on average 65% at the lower secondary level, 67% at the upper secondary level). At the primary level this percentage is a little lower, on average 59%.

This position is not a comfortable one, especially as the pace of scientific change escalates inexorably. ‘Refresher’ training is therefore an important consideration and for this there has to be a system for teacher release which implies a need for short and long-term cover. It has many further implications for sustainability. The relatively advanced age of teachers in primary and secondary schools implies that many teachers will retire within the next ten years (Table 11).

Table 11. Teachers within 10 years of retirement (% of total number of teachers) in primary and secondary education (situation 1996/97)

Country	Primary Level	Secondary Level
Austria	11.2	13.0
Finland	18.6	22.8
France	10.8	18.3
Germany	18.8	21.6
Ireland	26.6	23.0
Italy	31.7	36.5
Netherlands	19.4	33.4
Sweden	14.6	24.5
United Kingdom	12.6	12.0
European Union	17.8	23.4

Source: Eurostat/Unesco, 2000.

Because of the age distribution, teachers approaching retirement are proportionally more numerous in secondary than in primary education which is alarming for science. In the majority of EU countries for which data are available, more than one teacher in five will be retired within ten years. Italy has the highest percentage – more than one in three teachers will have retired within ten years – and Italy also has the earliest retirement age. The opposite applies to Austria and the United Kingdom, with only about 12% of teachers being within the last ten years of their careers. Paradoxically, this is due in part to early retirement for various reasons but brings with it the headache of teacher shortages.

Thus, the outlook for a teacher population with a lopsided age distribution and its inherent rather high percentage of retirements in the near future is ominous. This situation should not really be a surprise; the first reports on the fact that the teaching profession is an ageing one date from the beginning of the 1980s, when specialists started to warn that this would lead to problems by the year 2000. The European Commission / Eurydice 1995 edition of ‘Key Data on Education in Europe’ made the following observation:

> *‘The ageing of the teaching profession is probably explained in part by the fall in pupil numbers during the 1980s. This was experienced in a majority of Member States. The 1960s having seen a very high birth rate and a vast*

recruitment of teachers by and large everywhere in the European Union. Consequently, the career advancement of staff in post since then has not been balanced by a significant recruitment of younger teachers. In the light of the present position, it is to be expected that a considerable proportion who were recruited in the 1960s will be departing on retirement in the next few years.'

Based on the statistics available in the 2000 edition of 'Key Data on Education in Europe' the position has not improved. This needs also to be seen in relation to two other factors that are likely to cause an even greater need of new teachers than mere replacement: increasing birth rates in many countries in the 1990s, and initiatives to reduce class sizes. Already the teaching profession must compete for staff from a shrinking pool of young talent, at a time when the attractiveness of school-level teaching as a career is declining. Teachers are typically being asked to do more work for less reward in a difficult learning environment. Salaries have fallen significantly compared with other professions while our knowledge-based societies are placing new demands on teachers' abilities. Faced with these problems, ensuring that there will be enough skilled teachers to educate all children becomes an issue of major importance to policymakers.

In his paper in the Dossier of Education International Magazine (May 2001), Robert Sikkes lists some current recipes for solving the teacher crisis. They include a range of limited measures to enhance recruitment and retention, but the reality is that they are unlikely to provide a long-term solution, only improvement of the status, remuneration and working conditions will do that.

5.1.4. Examples of good practice

It is hard to point to any really outstanding examples of good practice, partly because the various education systems differ widely, partly because this is an area of frequent changes and partly because many of the initiatives taken have only had a short time to work. The expert group has noted one interesting development in The Netherlands, where an offer of (paid) retraining has been made to engineers and researchers who want to change from (private) industry to teaching. This is a fairly recent initiative, and the results of the first year (2000-2001) only have been evaluated. However, this demonstrates a type of cross-sectoral thinking (and mobility) that will contribute a much needed flexibility to the future deployment of human resources. Sweden is paying particular attention to the conditions of service with the aim of making a teaching career professionally attractive and rewarding. The same is true to some extent of the UK. There is some statistical evidence to indicate, however, that retrained personnel of this type may not find it easy to find positions. Such inflexibility in recruitment would be disappointing.

To support attempts to improve science and mathematics teaching and learning in Germany a six-year priority program on 'The quality of schools: Acquisition of content specific and cross-curricular competencies in mathematics and science depending on in-school and out-of-school contexts' was launched by the German Science Foundation (DFG) in 2000. Currently, there are 23 projects from pedagogy, psychology, science and math education and sociology cooperating in the program. Apart from the proximal learning context (the learning situation), also the more distal contexts of learning are studied in the program. Teaching and learning science and mathematics are embedded in a particular school context and are influenced by it and there is also the broad context of the society schools are part of. Students' views of what mathematics and science are about and whether they are worth the effort rests also on the attitudes and beliefs of teachers, parents and the peers.

The results of the recent PISA 2000 survey of school children performance in mathematics and the sciences were not encouraging in that only Finland and the UK, for science, were amongst the high performers, whilst Germany, Spain, Italy, Portugal and Luxembourg were below average, some near the bottom of the ranking list. Clearly European schools are not performing well. Interestingly, the USA was only about average, emphasisng the advantages of scientific immigration from the likes of Japan, who were at the top. This PISA survey is recommended reading in that valuable points arise as to the importance of school in the performance (and probably subsequent career choices) of youngsters.

5.1.5. Implications for benchmarking

There are two main features of this situation, which may lend themselves to benchmarking. The first is the flow of pupils at the various school levels through the elective science and mathematics courses of the school system. The collection of the required statistics should be trivial, but the harmonization of the data for an international comparison is likely to be a severe challenge in view of the different school systems. The other is the quality of the science-teacher population. This would indicate the age profile as well as the qualifications. Again harmonization might be difficult, but in our view feasible.

5.1.6. Conclusions

- In many Member States, the recruitment base for science and technology is fragile, perhaps now inadequate to needs.

- Governments should play an active role in changing the working conditions so that teachers are given time and space for contemporary education and management of their schools.

- In many European countries, the educational system appears to be in difficulty due to a failure to recruit qualified teachers in science and technology. Salary and working conditions compared to other professions are key factors.

- In some countries the situation is further aggravated by a lopsided age profile, imminent mass retirement, and the effects of increased birth rates in the 90's. This growing crisis in teacher supply in many countries in Europe must be addressed as a matter of urgency.

Possible Political Actions

Decision Stage	Threat	Goal	Barriers	Levers
Science in secondary education	Proportion of pupils taking (particularly core) sciences falling	Increased involvement in Science	Lack of teacher attention for the individual student. Students from low-income families cannot afford lengthy education. Poor school infrastructure, facilities and staff:student ratios. Learning environment uninspiring, unmotivating or threatening. Lack of qualified and up-to-date teachers. Uninteresting / outdated science courses. Gender and social barriers. Poor status of science in society. Poor status and remuneration of scientists in society.	Increase teacher/student ratio. Provide economic support for students from low-income families. Improve school infrastructure. Extensive refresher and retraining programmes. Reform science curriculum.

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5.2. Undergraduate enrolment

Summary: The overall picture of undergraduate enrolment that emerges from this analysis is of a stagnant, in some cases even falling, proportion of the age-group undertaking degree training in the sciences. The situation is particularly worrying with respect to the core topics such as chemistry, physics and mathematics, but is also not encouraging in the industrially relevant engineering and (bio)technology sectors. Informatics alone look anything like buoyant. Again attractiveness, difficulty and the career prospects of the scientist appear to be key factors in the decision-making process.

The main recruitment pool for scientists and engineers is the higher-education sector. It is realised that there is a small element of recruitment directly from high school but this is usually into the technical stream – not evaluated in detail here – and is a very small and falling proportion of overall employment. Thus, the transition from the secondary to tertiary level of education is one of the crucial steps in the creation of the working scientific population.

5.2.1. Total undergraduate enrolment

The proportion of the relevant age group entering tertiary education has varied widely amongst different Member States but considerable changes in government policy (e.g., in Portugal and the UK) to increase this proportion, have taken place in recent years, with the consequence that something approaching parity across the Community can be anticipated by the end of the decade. However, other influences, particularly financial cost, threaten to destabilise this projection and may be especially significant for the science and engineering population. Any inhibition could be seriously detrimental since it may not be a coincidence that the percentage of the population in tertiary education in the EU-15 is less than 25%, whereas in the United States it is approaching 40%.

Not surprisingly, the proportion of students receiving university degrees is also lower in Europe than in the USA and Japan. Total undergraduate enrolment (UGE) across Europe shows a relatively static picture over time but one that masks different trends in individual Member States (Figure. 10). Portugal exhibits a strong rise in numbers with smaller increments in Spain, Sweden and the UK. The Netherlands seems to be exhibiting a slight recovery after a period of decline but the most worrying trend appears to be the sustained fall in Germany. For some Member States, such as Sweden and Finland, high university enrolments correlate with the high proportions of scientists in the workforce and the investment in R&D. Implications for other Member States can be drawn from this. Undergraduate numbers as a proportion of the overall population show some disparities ranging from over 2% (UK and Denmark) to 4% (Spain), The Netherlands is an exception where the proportion is as low as 1% but the latter percentage relates to students in traditional universities only rather than the whole tertiary higher-education sector. No data are available for Greece, Denmark and Finland.

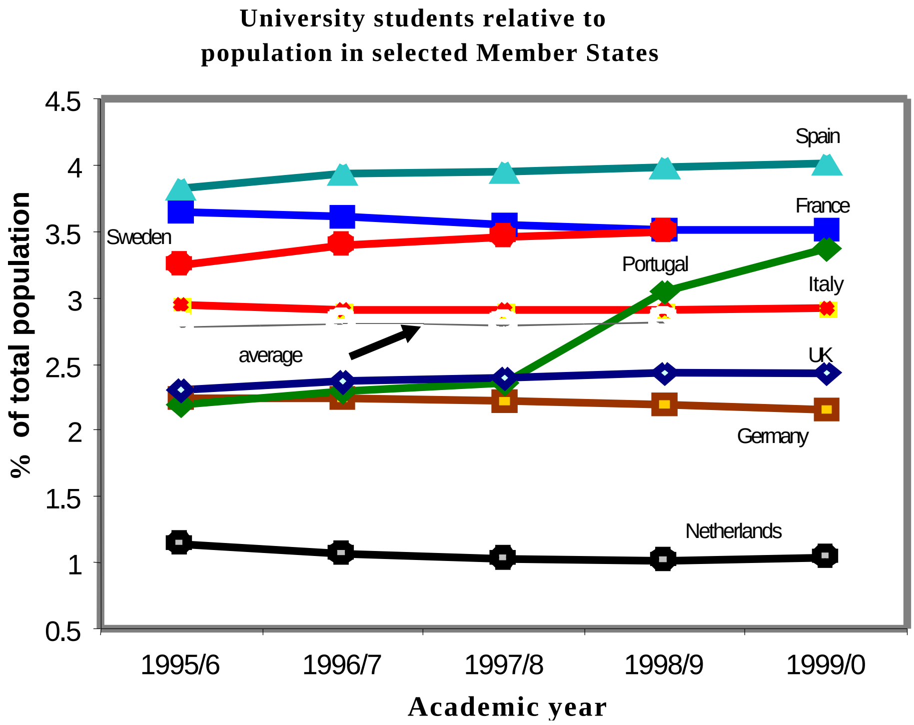

Figure. 10. Total Undergraduate enrolment (UGE) as a proportion of the population (FR - Université, including 1re, 2me, 3me cycles, STS, IUFM, and Ecoles; PT - total students; ES - ciclo corto and ciclo largo; DE - student enrolment; SE - undergraduates; UK - strictly undergraduates; IT - university students, 3-year diploma, or laurea, minimum 4 years; NL - total enrolment, only traditional universities).

5.2.2. UGE in science and technology

The high overall percentage in the USA is partly ameliorated in Europe by the higher proportion engaged in Science and Technology (35% vs. 26%). Breaking these global figures for Europe down somewhat (Figure. 11), there is clearly a very large divergence between the proportion of the UGE devoted to science and technology (as low as fewer than 25% in The Netherlands, Belgium and the UK to nearly 50% in Sweden). These proportions are changing at different rates, increasing faster in Sweden, Portugal and Spain, more slowly in France relatively static in The Netherlands and the UK, but actually falling in Italy and particularly in Germany (though the latter may have now 'bottomed-out'). Dissecting these data still further, this time for particular specialisms, there are again different trends emerging and differences in the Member States (Figure. 12). Enrolment in the natural sciences is rising somewhat in all but France, Italy and The Netherlands, with the latter actually registering declines. Germany is showing something of a recovery after a decline. The figures for the UK disguise that falls in chemistry, engineering, mathematics and physics are being compensated for by rises in biological and computer sciences. Thus, within the natural sciences, mathematics, physics and chemistry are under some pressure, whilst biological and computer sciences are more popular. Engineering and technology are even less buoyant with only France, Spain and Portugal exhibiting any real increase (Figure. 13). The decline in Germany is particularly marked.

Data for final-degree awards are very incomplete and require a considerable amount of study if only because of the different tertiary-education models. The 'drop-out' rates are low (less than 10%) for countries that have relatively tight completion schedules. Though not obvious, this may also be true of systems with more relaxed progression, but in this instance ways need to be found for analyzing the data over longer time frames. The adoption of the Bologna Convention may substantially aid this process. The gender issue is considered separately; general participation ratios for women are over 50%, but this may hide ethnic and social deficits.

The reasons for these declines particularly in the traditional sciences are not hard to determine. It has already been demonstrated that take up at school level has declined. Added to this are the perceptions that (i) the study of such subjects is much more difficult and time-demanding, and (ii) that the eventual rewards are less good, particularly in relation to the commitment, and there is a simple recipe for the declines seen. Only the more high-profile areas such as computer science and biotechnology are holding up but clearly even here, the supply is inadequate to anticipated need. Overall, the picture is not an optimistic one. As a postscript, it is considered that science education at all levels is essential to the national interests of the USA. How much more so must it be for Europe where natural resources are less available.

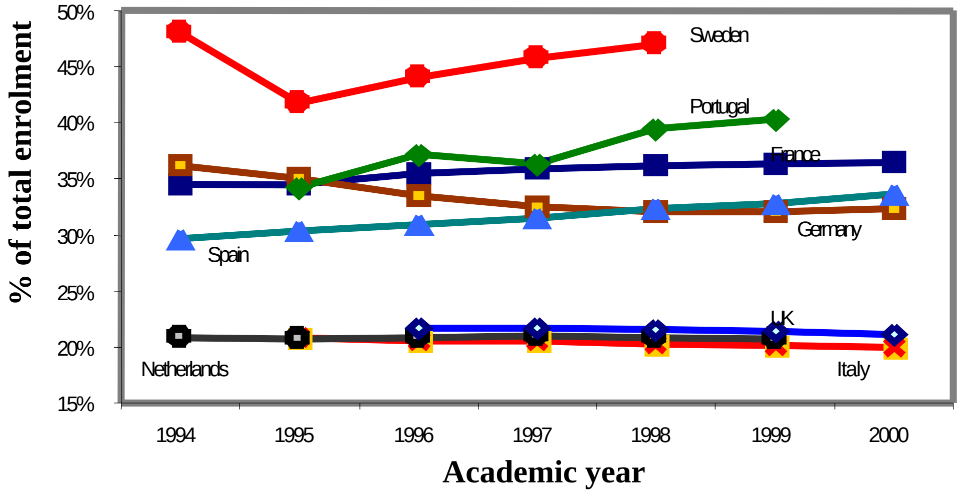

Figure. 11. Relative undergraduate enrolment (UGE) in Science, Engineering and Technology in selected Member States. (FR - STS, IUT, Ecoles d'Ingenieurs and Sciences; IT - Engineering, mathematical, physical and natural sciences; UK - Engineering and Technology, biological, physical, mathematical and computer sciences; ES - Arquitectura, Ingegneria, Ingegneria Tecnicas, and Ciencias esperimentales; NL - Engineering, Technology and natural sciences; DE - Engineering and natural sciences)

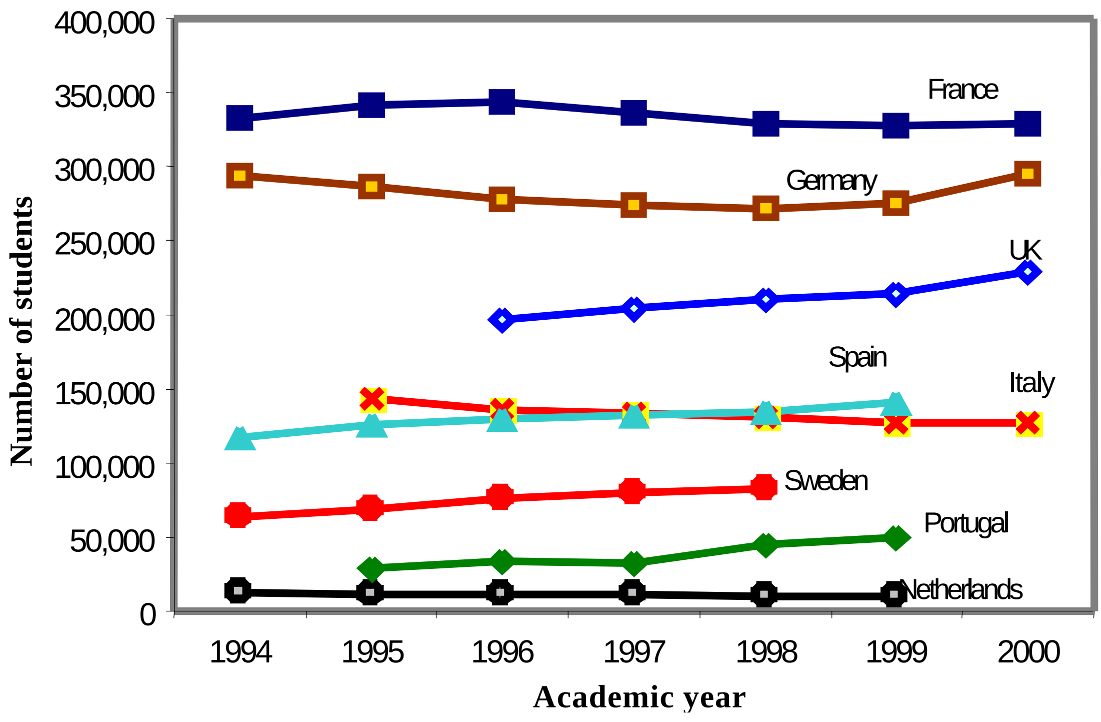

Figure. 12. Undergraduate enrolment in Natural Sciences in selected Member States.

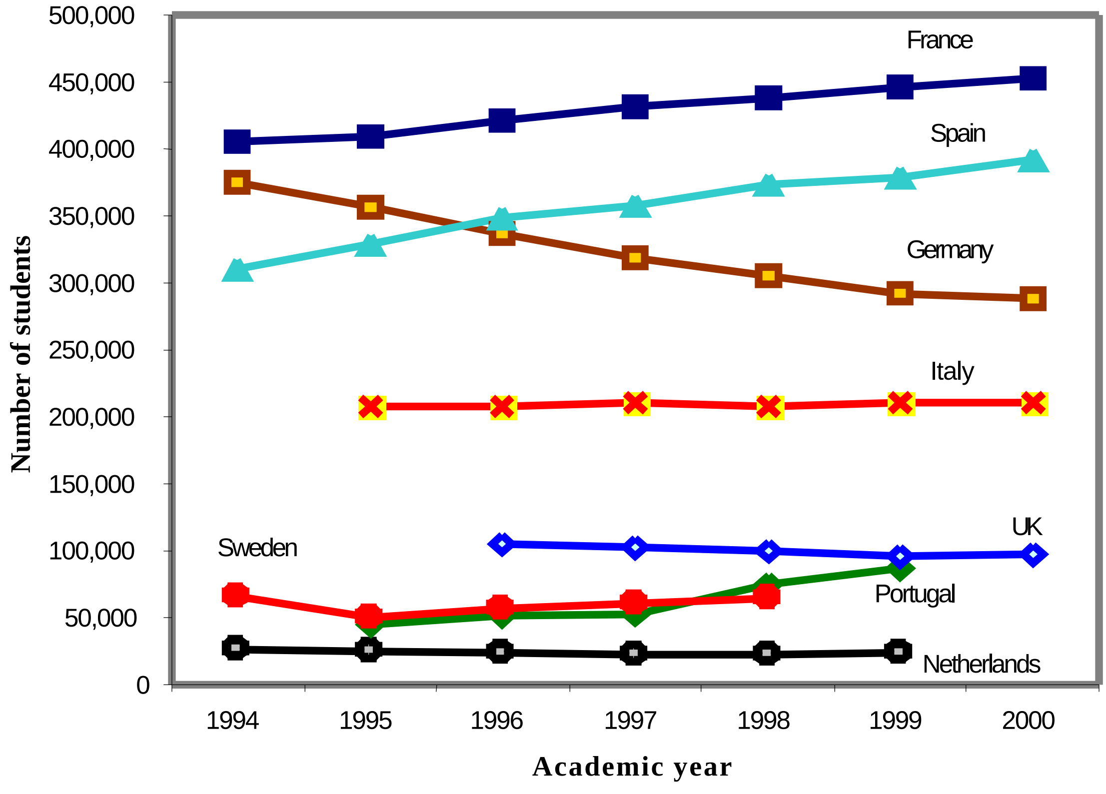

Figure. 13. Undergraduate enrolment (UGE) in engineering and technology in selected Member States. (ES - Tecnicas, D& I - Engineering; FR - IUT, STS and Ecoles d'Ingenieurs; PT, UK, & NL - Engineering and Technology, SE - Technology).

5.2.3. Implications for Benchmarking

The flow at this stage in the pipeline may be easily monitored by looking at undergraduate enrolment in S&T subjects. We have done this using unharmonised data, freely available. The further development of an indicator based on these data should be very feasible.

5.2.4. Conclusions

- Total undergraduate enrolment is generally static, only Portugal is exhibiting a significant increase.
- The proportion of students undertaking science and technology subjects is increasing only slightly or not at all, with serious declines in Italy and Germany.
- Special concerns exist for the continuing decline in popularity of chemistry, physics and mathematics, as well as for engineering and technology. Interest in Biotechnology areas may also have plateaued.
- The trends in Germany, Italy, The Netherlands and the UK look detrimental to sustaining the necessary innovative capacity.

Possible Political Actions

Decision Stage	**Threat**	**Goal**	**Barriers**	**Levers**
Science in tertiary education	Drop in quality and proportions of science undergraduates.	Increased uptake into scientific degrees	Subjects seen as difficult and time-demanding. Social and gender barriers. Economic returns and career possibilities not proportionate to commitment required. Education paths long and costly. Tertiary education conflicts with marriage and establishment of family.	Improve learning environment. Improve position of scientist in society. Provide financial / structural support. Provide introductory qualifier courses. Improve staff:student ratios.

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5.3. Postgraduate students: the decision to do a PhD project in S&T

Summary: The present production rate of PhDs is unlikely to be adequate to power a knowledge-based economy, particularly in the large Member States. This potential shortcoming is aggravated by a significant export of these Human Resources to other professions and countries. Better stipends at the training level, and competitive salaries and career opportunities thereafter are important factors in bringing supply and demand into equilibrium.

This decision stage is directly related to the proposed indicator 2 (Table 1), 'The number of new S&T PhDs in relation to the total population'. For the purposes of this analysis, a distinction was made between 'researchers' and 'technicians'. Although the boundary is a very imprecise one, the underlying concept is that the 'researcher' tended to make a more individually innovative contribution to the acquisition of new knowledge. (They also represent the majority of laboratory personnel. In the UK, for example, the relative proportions of researcher, technician and administrator in research is about 7:2:1). To achieve this, it is considered important, but not essential, to receive scientific research training of the kind provided by Masters and Doctoral schemes of study. Thus, an important indicator of the future viability and vitality of our knowledge-based society is the proportion of our population undertaking such studies. Particular emphasis was placed on PhDs in the science and technology sectors (Table 12), and this information appeared as indicator 2 (Table 1) of the Human Resources theme. Harmonised data on Masters enrolment across Europe are not available but are not expected to significantly alter the conclusions arising from evaluation of the PhD information.

5.3.1. New S&T PhDs

From Table 12 it is clear that the potential number of PhD qualifiers supplied to the scientific market, as a proportion of the relevant age group, is being sustained, taking the European Community as a whole. Overall, there are significant variations between Member States but care must be taken to compare like with like. The 'classical' PhD is relatively new to Italy, for example, where research scientists often go through the *laurea* route and may not represented in these figures. There are positive growth rates in Germany, Finland, Sweden and the UK. Surprisingly, these proportions (0.36 to 1.17%) are higher than in the USA (0.47%) and Japan (0.24%), even though the latter two nations have a higher average number of researchers in the workforce (0.53% vs. 0.74% and 0.89%, respectively). It is perhaps also relevant here to review briefly the proportion of non-domiciled PhD students. Figures for 1998-99 (OECD 2002) indicates that Belgium, Denmark, France and the UK possess a very high proportion (20 to > 30%) of foreign students enrolled on PhD programmes. In the case of the UK, this accounts for much of the increase since until 1999 the number of government funded (the vast majority) UK domiciled PhD students has steadily declined from the early 1990's. This high proportion of incoming talent may be regarded as a healthy situation if these students remain on a more permanent basis but the fragile reality is that the majority are destined to leave (see First Destination data for France Section 5.4). Thus, there is little net ‘brain gain’.

Table 12. Total new science and technology PhDs per 1000 population aged 25 - 34 years.

Country	**1995**	**1996**	**1997**	**1998**	**1999**
Belgium	0.37	0.38	0.38	0.38	0.36
Denmark	0.49	0.42	0.53	0.53	0.56
Germany	0.61	0.64	0.68	0.72	0.75
Spain	NA	NA	NA	NA	0.43
France	NA	NA	0.77	0.71	0.71
Ireland	0.41	0.55	0.55	NA	NA
Italy (2)	0.13	0.13	0.13	0.11	0.14
Netherlands	0.36	0.38	0.36	0.36	0.35
Austria	0.44	0.5	0.58	0.55	0.56
Portugal	0.19	0.23	0.21	0.21	0.23
Finland	0.6	0.55	0.61	0.99	0.97
Sweden	0.88	0.99	1.04	1.08	1.17
United Kingdom	NA	0.54	0.63	0.73	0.78

All data for 1995 and 1996 refer to the ISCED76 definition of Science and Technology PhDs.
All data for 1997 refer to ISCED97 definition of Science and Technology PhDs with the exception of Austria and Sweden which refer to the ISCED76 definition.
All data for 1998 and 1999 refer to the ISCED97 definition of Science and Technology PhDs.
Italy: derived from data not yet approved or amended by the Italian Statistical Office.
NA = not available as yet.

At face value, therefore, the potential supply of trained capital in Europe as a whole is not falling but nor is it rising at rates which may be required. Data are not available as to how the distribution of PhD graduates amongst the specialisms is changing but there are clearly deficits in certain areas – physics, mathematics, (bio)information science, biotechnology and some technological areas. However, there is well-established anecdotal comment, which suggests that (i) PhD vacancies are increasingly hard to fill, (ii) the quality of applicants is declining, (iii) a widespread and severe shortage of postdoctoral candidates exists in the academic sector, (iv) the number of postdoctoral appointments of the period in a research grant is rising, and (v) migration out of science in Europe is high.

How then can these various factors be reconciled? Possible scenarios are as follows:

- The gap between researcher production and presence in the USA workforce is met by migration to the USA from other countries, Europe being a net provider.
- A significant proportion of the PhD population in European Member States is not domiciled in Europe and will not remain in the European workforce.
- A significant number of PhD graduates leave science for other occupations.

Clearly, the overall picture here is a complicated interplay between different factors but current evidence suggests that the third factor is dominant. The fact that Europe is exporting PhD graduates to the USA or other professions could be viewed as a sign of overproduction. However, it is more likely to be a result of restrictions at the outlet of the pipeline model. If the private and public sectors do not create the attractive opportunities required to compete within the knowledge-based economy, then net export from science will occur as a result of under-hiring and under-investment rather than overproduction. Again, as the profession, particularly in the European Public Sector, is seen as unrewarding (especially in Germany, The Netherlands and the UK), then a flight to more attractive options, especially of the more able students, is inevitable. Thus the question of scientist production at the level of PhD must be intimately tied up with the economic considerations and models that form the basis of the national strategy for a knowledge-based economy. It should also be kept in mind that PhD students contribute significantly to the nation's intellectual productivity during their degree work, and that the training of PhDs may be seen as a knowledge industry in itself.

5.3.2. Quality

Whilst the majority of data so far presented are quantitative in nature, there is also a major qualitative element which has a significant impact where fundamental advances and innovation are key factors. Statistical evidence for this is hard to assemble. In order to ascertain whether there has been a qualitative change in the population of students undergoing graduate training in S&T, a new set of data is required. One appropriate indicator is to assess the proportion of high-achieving undergraduates undertaking PhD studies. The data can also come in the form of the aggregate or average entry qualifications (e.g., degree classification). For some Member States such information has been collated and could be studied if made available.

In its absence, there has to be a reliance on anecdotal observations. These tend to suggest that in some Member States (e.g., Germany, The Netherlands, and the UK) the proportion of the very best science undergraduates entering research (e.g., PhD) training has been falling. In Germany, for example, the number of applicants/fellowships in natural sciences *Graduiertenkollegs* has dropped from nearly 2.5 in 1998 to under 1 in 2001, which is also likely to lead to a decline in standards. In the same vein, the UK Research Council statistics also show a slow decline in take-up by the best students even though the numbers recruited are no greater than in the early/mid 1990's. However, these trends appear to be less true for many other Community Partners, where those showing the greatest propensity for migration to other types of employment or to other countries may not be among the best. At present it is too early to tell whether we are seeing the beginning of a trend where those most able to do research in S&T to a large extent choose not to, something which could have serious consequences for the competitive edge that Europe depends on for a knowledge-dependent economy.

5.3.3. Examples of Good Practice

From the data gathered for indicator 2 (Table 1), Finland and Sweden again appear as didactic examples. Finland, in particular, has invested substantially in national PhD programmes. It is worth pointing out that in the pipeline analogy, there is an obvious connection between volume flow (degrees) and output (researchers in the workplace). Taken together with previous remarks on financing and industrial structure, this suggests that to make substantial improvements in knowledge-driven areas, it is essential to provide the human resources for both growth and entrepreneurship.

5.3.4. Implications for Benchmarking

The proposed indicator 2 (Table 1) seems to be well justified. Monitoring the production of PhD graduates is clearly important to allow the nation's capacity for mobilising its intellectual resources to be assessed. However, the overall relative number may not be sensitive enough to catch unwanted developments in crucial areas, and it is therefore necessary to monitor the dynamics behind these numbers, especially in the context of mobility.

5.3.5. Conclusions

- The production of PhD scientists should at least be sustained and in some Member States certainly enhanced. This may require some reform in the PhD training programmes.

- There is a need for further data describing the dynamics of training, deployment and mobility of PhD students.

- From the data gathered on indicator 2 (Table 1) and other data, there appears to be a direct correlation between PhD production, investment in PhD programmes and PhDs in the workforce, with Finland as a prime example.

Possible Political Actions

Decision Stage	Threat	Goal	Barriers	Levers
Postgraduate training for research	Best students not continuing in science or research. Numbers not sufficient for projected need.	Enhance quality of student and training in science and technology	Recruitment base inadequate. Research training daunting Commitment not justified by rewards. Supervision and support from senior scientists too limited. Equipment not up-to-date or professionally supported. Quality research time-consuming. Financially disadvantageous. Research training is difficult to combine with normal family life.	Improve financing of PhD students. Improve level and maintenance of scientific equipment/labs. Limit dilution of student time on less-relevant activities. Strengthen international / industry ties. Set minimum full time study (4 years?). Reward 'good' PhD outcomes. Better family support structures. Better student:staff ratios.

5.3.6 References

Key Figures 2000, EC 2000, EUR 19396
OECD Education and MSTI Databases, 2002.

5.4. First Destinations

Summary: Monitoring the first destinations of both undergraduates and graduates is a good indicator of the attractiveness of a career in scientific research. The current climate as judged by this factor is not a good one; up to 40% of graduates at PhD level in some countries immediately forsake a career in research science in Europe. The main reasons appear to be lack of opportunity and inferior rewards for high commitment.

For society to capitalise on the investment in training a young person in S&T, it is desirable that the training be put to use through work in areas closely related to the training. Many countries have some statistics for the progress of S&T personnel (mostly at the PhD level), but an overall evaluation of the situation in Europe is very difficult on the basis of the available data. In an attempt to elucidate this rather important career step we have therefore had to rely mostly on national data of somewhat disparate character.

5.4.1. Undergraduate Level Exit

From data now becoming available (e.g., the UK), there are indications of a large number of undergraduates leaving the pipeline after (or even before) their first degree. Only a small minority of these remain in scientific research, many at a more technical level, the rest opt for a variety of other professions, particularly in management and finance, some involving further training. Surveys suggest that remuneration and long-term career prospects are key motivators. Thus the PhD option has a great deal of competition, and may explain why so many of the most able students do not continue in science or school teaching. Much of the output at undergraduate level, because of their numerate, analytical and deductive skills are valuable in a number of professional sectors. They should not, therefore, be regarded as other than a positive influence on society. Indeed, there is a case for a more pervasive spread of scientists throughout the varied workforce.

5.4.2. Postgraduate-level exit

Movement from the major research training phase to first employment represents a crucial career choice. An assessment of the first destinations of PhD graduates is a revealing indicator of the attractiveness of a career in scientific research. At this stage, it should be borne in mind that some industries hire few PhDs, preferring instead in-house training of research staff. Other industries are heavily reliant upon the inflow of PhDs for sustaining their research and innovation. Data are available from some Member States, which allow an assessment of the situation at this stage.

France: Interpretation of the data presented in Table 13 shows that the situation in France is qualitatively similar to that seen for the UK, The Netherlands and possibly also Germany but the loss is less severe in that perhaps less than 30% of all PhD graduands are not found in bona fide research occupations in France two years after graduation. The figure is imprecise in that the nature of the positions in the private sector in particular are not specified, clearly some are not in research.

Table 13. Destinations 18 months after obtaining PhD in the sciences – France

	1997	1998
Total	***7192***	***6916***
Post Doc/University	2781	2023
Higher Education	408	924
Public Research Institution	423	491
Private Sector	1278	1748
Administration	290	309
2° Education	119	158
Temp unemployed	968	295
Repatriation	578	566
Unknown	347	402

Table 14. Percentage of PhDs employed in Academia and R&D, according to PhD subject and cohort - Germany.

		1979/80			**1984/85**			**1989/90**		
		A	**R&D**	**T**	**A**	**R&D**	**T**	**A**	**R&D**	**T**
Year 1	**Biology**	50	27	77	50	32	82	40	30	70
	El. Eng	24	59	83	13	62	75	2	60	62
	Mathematics	72	17	89	47	29	76	53	19	72
Year 5	**Biology**	34	30	64	33	34	67	37	25	62
	El. Eng	18	58	76	10	58	68	12	56	68
	Mathematics	56	20	76	37	32	69	41	27	68
Year 10 *9	**Biology**	27	23	50	31	26	57	31	29*	60
	El. Eng	26	44	70	20	42	62	18	47	65
	Mathematics	43	19	62	40	28	68	42	20	62

PhDs graduating in 1979/80, 84/85, 89/90 working in Academia or in R&D (non academic) 1, 5 and 10 (*9 for 1989/90 graduands) after graduating in biology, electrical engineering and mathematics. Source: J. Enders & L. Bornmann (2001), own calculations.

The Netherlands: Recent surveys in the Netherlands indicate that 41% of recent graduates are not in science, 30% are at a Dutch University and 29% are in industry or abroad.

Germany: A study carried out by Enders & Bornmann of PhDs graduating in 1979/80, 1984/85 and 1989/90 in biology, electrical engineering and mathematics reveals that the numbers entering academic and non-academic research and development, initially very high, had begun to show a marked decline – 77 to 70%, 83 to 62% and 89 to 72%, respectively – by 1989/90 compared to 1979/80 (Table 14). Although less complete, more recent data suggest that this decline has continued throughout the 1990s. The Enders survey illustrates, moreover, that first destinations after having achieved a PhD degree seem to be crucial for the future development of careers. This is especially due to the very limited mobility (Table 15) between the different sectors of employment (public, private and academia, Enders & Bornmann, 2001, p. 115ff.).

Table 15. Mobility between sectors (in %) - Germany.

Type of mobility	Biology	Electrical Engineering	Mathematics
academia only	30	7	38
public sector only	10	5	3
private sector only	28	64	32
academia -> public sector	5	1	3
academia -> private sector	11	14	17
public sector -> academia	4	1	2
public sector -> private sector	5	2	1
private sector -> academia	3	8	4
private sector -> public sector	5	1	1

UK: The trend can be picked up with data from the UK Scientific Research Councils which sponsor the majority of UK research students (Table 16). At first sight, it would appear that a relatively constant percentage (nearly 60%) of graduates enter research-related academic or private employment in the UK (18% or so register as unemployed, about 10% go overseas). Of these 60%, a declining proportion take up fixed-term academic posts, synonymous with postdoctoral research positions. In contrast, a rising proportion enter the private sector. Thus, there would appear to be a stable overall position, albeit indicative of a relative decline in academic activity. However, the true reality lies in the observation that there is a rising proportion of the private sector take up which is not related to science and technology. The standard industrial classification of employer statistics for 1998, for example, would suggest that greater than half of those in the private sector are engaged in managerial, production or financial pursuits unconnected with research. Thus, the decline in public-sector take up represents a real and increasing loss of human resources in scientific innovation. A survey by the Research Councils in 2000/01 revealed that only 52% of UK PhD graduates in S&T continue on in *bona fide* scientific research after their PhDs.

The loss rate in other Member States, while still significant, may not be as large as seen above, at least as revealed by the numbers remaining in the public sector. In Denmark, 49% and 37% of PhD graduates in natural sciences and engineering, respectively, are to be found in the public sector, one assumes mostly in the research area. However, of these going into the private sector only 60% and 48%, respectively, continued to work on R&D, with 16% and 13% combining research and education. These figures would suggest that up to 15-20% of Danish PhD graduates in science and engineering might not continue in research. The Scandinavian countries in general seem to be more successful at retaining their doctoral scientists and there may be examples of good practice to be obtained. In Denmark, however, and possibly also true of some other Scandinavian countries, this higher retention may in part be due to lower production.

Table 16. First Destinations of UK Research Council Funded PhD Graduates in Science (including the Environment) and Technology, 1994 to 1997.

	1994	**1995**	**1996**[r]	**1997**
PhD leavers	**3166**	**3386**	**3201**	**3392**
Known destinations - total	**2109**	**2730**	**2580**	**2712**
of which	**per cent**	**per cent**	**per cent**	**per cent**
permanent academic appointment	5	8	5	5
fixed-term academic appointment	29	25	21	22
further training (excluding teaching)	5	5	4	5
school teaching or teacher training	3	2	2	2
private sector, industry or commerce	22	26	33	30
government or other public sector	5	4	5	6
other employment	4	3	2	3
not employed	19	18	18	16
overseas	10	9	9	11
Source: Research Councils				
Notes:				
1 Figures for BBSRC are for ex-AFRC students only.				
2 For NERC, the figures for overseas indicate leavers already allocated a category but who are working overseas.				
3 The years given are those in which funding for the MSc finished, i.e., one year after the start date.				

4 The years given are those in which funding for the PhD finished, i.e., three years after the start date.
r = revised.

One of the critical and very widely experienced consequences of postdoctoral drop-out is the considerable difficulty experienced in at least the UK, The Netherlands and Germany, in recruiting fixed-term research scientists by Universities. This is evident in extended grant life-times. In Germany, for example, principal investigators are reluctant to withdraw research money they had been granted due to difficulties in finding research personnel willing to work on fixed-term contracts. This had induced DFG's Board to set up a panel of experts early in 1999 to find out which stages of the pipeline was leaking excessively.

Recruitment to permanent positions in academia has rarely been a problem in the past and in certain Member States, e.g., Spain and Portugal there is still a pool of high-quality applicants. But there are disconcerting signals beginning to appear in the likes of the UK and The Netherlands where high-quality applications are falling (and in some specialisms no appointments can be made) whilst a period of high retirement rate is on the horizon. A survey in The Netherlands for example, suggests that there may be recruitment crises in the near furure. The situation is especially severe in subjects facing large retirement rates such as computer science in Germany. By 2010 approximately 50% of all computer science university chairs in German universities will need replacements. Who then will teach the teachers and researchers?

5.4.3. Implications for benchmarking

The first employment of a PhD graduate is in most cases decisive for the rest of his or her career. Many nations have data available for these choices, although at different levels. The development of an indicator on this basis would be very useful. It is essential that it be gender-disaggregated. This indicator should also be extended to profile the career development of such scientists over the highly important formative next decade to evaluate whether the returns from a career in scientific research are sufficient to retain the human resources needed for a knowledge-reliant society.

5.4.4. Conclusion

- Based on a survey of four countries it appears that remaining in research (public or private) is the preferred route for most scientists after their PhD studies, but there is an unacceptably high drop-out rate, particularly in the UK and The Netherlands. This may be partly due to the lack of attraction of the public sector which is still the preferred destination in Denmark, France and Germany.

Possible Political Actions

Decision Stage	Threat	Goal	Barriers	Levers
Remaining in research?	Brain drain to other occupations or countries.	Retention of a larger majority of PhD graduates in research.	Lack of satisfactory job opportunities. Poor salary returns considering quality and commitment required. Career advancement difficult on a research track. Obstacles to mobility. Employment problems for two-scientist families. Long-term ageist attitudes.	Improve salaries of researchers. Increase job opportunities for young researchers. Implement measures to strengthen mobility and return. Implement special consideration for two-scientist families.

5.4.5. References

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5.5. Career Progression

Summary: Little attention is paid to the mid- to late-career development of research scientists – indeed there is evidence of prejudicial treatment, even unemployment. This is a waste of valuable Human Resource and experience.

Almost all focus so far has been on the introduction, recruitment and retention of young scientists into research science. Whilst this is understandable, it has been to the exclusion of any serious consideration of longer-term career development.

In the case study of the first 10 years of their working careers in Germany (Table 14) it is noticeable that the proportions of scientists in academia fall (except for electrical engineers) while those in other sectors remain relatively unchanged, indicating a distinct trend away from research and development. This would appear to be symptomatic of the increasing unattractiveness due to lower remuneration than in managerial positions or lack of availability of long-term positions in research and development.

These are important and meaningful data which echo individual experience throughout the sector. If similar surveys could be carried out on a widespread and comprehensive fashion, it would be very revealing of the ability of science and technology to retain, as distinct from attract, trained scientists. The current suggestions appear to be that, whether due to salary, career progression, or other job-related factors, scientific research does not seem able even to retain its entrants during their first ten years of employment.

Interestingly, the German mobility trends indicate a move from academia in all areas except for electrical engineering where the trend for these cohorts are, atypically, in the other direction. Thus, mobility trend towards academia for electrical engineers in later phases of their careers may be explained by rising unemployment rates for 45+ year old engineers. (See Figure. 14). This is an unusual phenomenon and unclear how representative of other Member States.

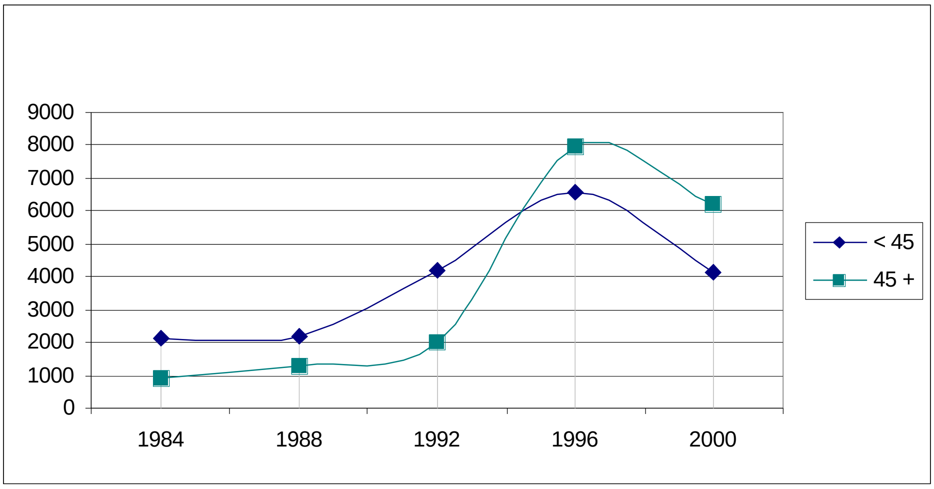

Figure. 14. Unemployed electrical engineers by age*.

* Before 1996 data only for former Western Germany.
Source: *Zentralstelle für Arbeitsvermittlung (ZAV), Arbeitsmarkt-Information 4/1998, Qualifizierte Fach- und Führungskräfte: Elektroingenieurinnen und Elektroingenieure.*

However, it does raise the spectre of the research scientist in mid or late career. There are no good data readily available, but there are numerous examples in all areas of science of:

1. Overt inducement into administrative, bureaucratic or managerial roles as a consequence of the financial and organisation structure of the institution. Or in simpler words: at some stage, there are no more rungs on the research-career ladder, and further advancement requires a change of role.
2. Pressurised use of early retirement schemes.
3. Fiscal rules which require early retirement due to pension-fund accumulation.
4. Prejudices on ageism and scientific creativity.
5. Lack of retraining provision.

6. Societal attitudes towards career changes and reorientation.
7. Directed cost-cutting.

An interesting consequence of some of these attitudes may lie in the data shown below (Table 17) for Germany. Here is an example of a significant unemployment rate amongst highly skilled workers in computer sciences, mathematics, mechanical engineering and physics, even though there is a demonstrable shortage of such skills in the workforce. This picture may be true of other Member States. Clearly, effective policy instruments of some kind are required.

Table 17. Unemployment Levels in Germany of Skilled Workers.

Science field	Year*	Unemployed aged 45+	Total number of unemployed
Physics	1999	1400	2600
Mechanical Eng.	1998	12075	17500
Mathematics	1998	767	1374
Computer Sciences	1998	982	2128

* Latest year for which data have been available.
Source: *Zentralstelle für Arbeitsvermittlung (ZAV), Arbeitsmarkt-Information No. 7/1999, No. 2/2000, No. 5/2000 Qualifizierte Fach- und Führungskräfte*, own calculations, data only for Germany.

The sum total of all these effects is that there has been, and still is a growing section of the scientific community (usually post-50 years old) who are diverted or prevented from pursuing a continuing involvement in active scientific research. There is nevertheless a small but growing realisation in some countries that these practices of the past could be as disruptive to individual and national well-being as failure to recruit at an early stage. Indeed, the issue of brain drain or wastage is as germane here as in earlier career development. Japan and the USA have long recognised the contribution made by senior scientists to their society – in the USA, for example, compulsory retirement is no longer acceptable in the public sector.

A few specific examples of the problems and solutions are provided below as illustrations of current attitudes.

- Inspirational experienced scientists would be valuable as teachers at the high-school level but there are substantial barriers and attitudes which inhibit such career reorientation amongst which are:
    - Retraining provision and interim financial support is almost non-existent. A successful scheme in The Netherlands should be constructively considered.
    - Lack of more flexible attitude towards appropriate qualifications.
    - Ageist attitudes, financial restrictions and hierarchical sensitivity to recruiting the middle-aged scientist.

- Similar prejudices can be seen in the private sector where training of the middle-aged for new careers is thought to be ‘wasteful’ even though ‘job-hopping’ in this age group is much more infrequent and hence the cost-benefit to the trainer much greater.

- Reluctance to recognise financially the worth of an active research scientist relative to a 'manager'. This is as true in the public sector as in the private one. In the worst cases, this may result in a structure with 'too many chiefs and too few Indians'.

5.5.1. Implications for Benchmarking

Because the part of the population active in RTD is expected to increase and play a crucial part in the knowledge-based economy, the mid-career scientist will emerge as an important resource, particularly if the downturn that is now well-established in the training of researchers in the 'hard' sciences lasts for some time. It is possible to make a case for an indicator monitoring how well a nation is using this particular resource. One possibility is to monitor the drop-out rates from both the public and private sectors. To our knowledge, there are little firm data on this subject, demonstrating how its importance is down-valued.

5.5.2. Conclusion

- Premature disablement of the scientist in mid-career is an example of a brain drain which is counterproductive in the setting of a knowledge-based economy. The successful nation has to meet the challenge of utilising this resource to its fullest extent, if necessary by facilitating re-orientation and redeployment.

Possible Political Actions

Decision Stage	**Threat**	**Goal**	**Barriers**	**Levers**
A career in academia?	Fall in quality and number of public sector scientists ('who teaches the Teachers')	Recruitment and retention of high quality scientists in academia.	Uncompetitive and inflexible academic salary. Hierarchical and fixed employment structures. Dominance of short-term and external funding mentality. Mobility obstacles. Poor working practices and conditions. Bureaucratic culture.	Establish new positions of a university researcher (non-teaching). Establish intermediate tenure-track positions with reasonable job-security. Provide ample start-up funding. Establish support networks for new appointees. Open jobs to international applications. Sensible infrastructure support. Mobility measures. Twin-hire policies for two-scientist families.

5.5.3. References

Zentralstelle für Arbeitsvermittlung (ZAV), Arbeitsmarkt-Information, Qualifizierte Fach- und Führungskräfte Elektroingenieurinnen und Elektroingenieure, No. 4/1998.
Zentralstelle für Arbeitsvermittlung (ZAV), Arbeitsmarkt-Information, Qualifizierte Fach- und Führungskräfte Maschinenbauingenieurinnen und Maschinenbauingenieure, No. 2/1999.

Zentralstelle für Arbeitsvermittlung (ZAV), Arbeitsmarkt-Information, Qualifizierte Fach- und Führungskräfte Mathematikerinnen und Mathematiker, No. 6/1999.
Zentralstelle für Arbeitsvermittlung (ZAV), Arbeitsmarkt-Information, Qualifizierte Fach- und Führungskräfte Informatikerinnen und Informatiker, No. 2/2000.
Zentralstelle für Arbeitsvermittlung (ZAV), Arbeitsmarkt-Information, Qualifizierte Fach- und Führungskräfte Physikerinnen und Physiker, No. 5/2000.

5.6. Life-long learning

Summary: There are numerous previsions of life-long learning (LLL) as the major new mode of knowledge acquirement, in many cases strongly coupled with distance learning. At present, the main impact of LLL appears to be directed towards secondary and tertiary education and less towards high-level research training. There is clearly room within LLL for systems to facilitate ‘refreshment’ and ‘retraining’ of researchers, particularly as the pace of research developments accelerates still further. This is likely to act as a driver for substantial alterations in the overall training and retraining processes.

The movement towards what is somewhat loosely termed life-long learning (LLL) has been one of the main areas of attention for pedagogical development over the last decade. Although LLL does not appear as a decision point along the linear development pipeline, it will in the future represent an increasingly important training possibility that may be chosen by more and more persons eager to improve their skills. Most nations, in Europe as well as elsewhere in Western civilization, have instigated or support efforts in this field, and the EU position is outlined in a Commission Communication ‘Making a European Area of Lifelong Learning a Reality’, Com (2001, 678, final). The volume of activity in the field worldwide is easily demonstrated by doing a search on the Internet, this yields approximately 500,000 hits for the keyword Life-long Learning. The multitude of entries produced by such a search also displays the diversity of activities under the LLL umbrella, making it a rather difficult area to survey. There can, however, be no doubt that LLL will emerge as a major factor in developing the knowledge potential of the modern nations, and in the opinion of some pedagogues this will become the major and dominating mode of training and development of intellectual resources.

Despite all this activity, LLL must still be regarded as a movement in the making, and little is known about its consequences and effects. Particularly in the context of tertiary and higher education where the training paths normally are of considerable duration, we have few concrete evaluations of the impact of LLL except in specialist areas such as informatics where the advantages are very clear. There is abundant quantitative information on course offering, teaching and participation (see e.g., Life-long learning: the contribution of education systems in the Member States of the European Union, Eurydice Survey 2, ISBN 2-87116-294-8), but the consequences and possible advantages of this activity for the various sectors of society appears to be largely undocumented.

The purpose of the present section is to discuss the possible consequences of LLL for the development of Human Resources in research and technical development (RTD), seen in the context of the terms of reference for the expert group on Benchmarking the Human Resource area. The main focus has been on what is seen as the agents for front-line RTD, the research scientist trained at the PhD level. This is an area that appears to be peripheral to the main thrust of the LLL effort (except for areas of informatics), much of which aims at vocational or remedial training for early school leavers up through secondary education. It is therefore convenient to structure this discussion in two parts – the first dealing with how training within the vocational and pre-tertiary education level may affect Human Resources in the activities required to promote RTD, while the second examines the situation of training at the tertiary and post-tertiary level within the LLL framework. No attempts will be made to drive the LLL concept in any particular direction, drawing rather on those aspects that we find relevant for the training sectors discussed.

5.6.1. LLL up through secondary school

Pure vocational training within an LLL framework will primarily aim at improving the skills (competences and ultimately qualifications) of the working population. There will necessarily be a more or less general knowledge component to this, in particular as much modern equipment requires an extensive background knowledge for efficient use. One example is the introduction of advanced information technology into many work situations. It is probably reasonable to expect that these increased skills will have little significant first-order impact on RTD, and that this impact will be mainly in improved process technologies and instrumentation. However, an overall increase in the skills at the production and implementation level will be important for a rapid exploitation of new developments and technologies, as well as for bringing new products to market rapidly at a time when product ageing and competition for market priority appear to accelerate.

That part of the LLL effort which aims to provide a larger segment of the population with more or less formalised schooling up through the level of secondary education, may have its main impact on the increase of the base of skills and competence in the work force. Again, we expect few direct effects from this effort on the Human Resources for RTD. The number of people emerging from this is likely to be small, and we expect that the majority of those who do go on to tertiary education will end up in the category of highly skilled support staff. But a general raising of the level of education in a nation may have the positive effect of imparting greater interest for and understanding of science and technology, and a resultant increased propensity towards higher education for younger generations. Thus a second-order effect could be enhanced recruitment and motivation for tertiary education and research careers.

5.6.2. LLL at tertiary education and beyond

Proceeding now to tertiary and post-tertiary education, there again two major aspects are discussed – training at the tertiary level, and the situation of the fully trained researcher. There is no shortage of university-level courses within the world-wide framework of life-long training. These range from the possibility to enter a regular university for parts or all of a regular course schedule to the offering of distance learning either by established elite institutions or by a number of institutions specialising in distance learning. Admission requirements may range from none to ordinary entrance requirements for the university offering the course. There is a tendency to regard LLL students as a separate category, and in many countries efforts are under way to derive entrance schemes which also credit work and practical experience in addition to formal educational background. This is in the spirit of the Bologna declaration, which proposes that the lowest level of tertiary education should reflect the knowledge and competences required, rather than time of study.

However, most of the courses offered at this level are in areas or of a character that will not easily tie into a research-training track. Much of the offerings are in economy, law and computer science – frequently targeting short-duration training in areas where employment opportunities are expected to be good. With the market mechanism being one of the motivators here, it is no surprise that the main thrust of activity is in this direction.

For science subjects there is the additional complication that most of these require extensive laboratory and/or field work, both of which are expensive to run and very hard to fit into a distance-learning scheme (again the exception is informatics). Still, the system should be prepared for the exceptional case where somebody has followed a non-traditional path and develops interests towards research. One example is from a recent a posting to the news group science.physics.research:

> *'How does an enthusiastic non-academic get into research in the UK? I have a degree from the Open University that has a heavy smattering of quantum physics and I am keen to expand this knowledge. Can anyone point to a web page, amateur research group or university that have places for people such as myself to assist in research?'*

Needless to say, the answers to this have been somewhat guarded. However, if LLL is to become the major educational path of the future, the research departments should be able to accommodate students emerging along the more untraditional paths.

The opening up of tertiary education that accompanies the LLL movement may also have other benefits. One is the possibility of providing training opportunities to late-bloomers. Examples of this might be women who complete a first degree, devote some years to homemaking and childraising, and then when the family situation becomes less intensive, can come back for training at the PhD level. Another group which might benefit from this are those who spend some time working after a first degree (for instance to pay off student loans), and then decide to come back for further training later. Within the LLL mode of thinking, the research departments and institutions must become more open to these channels of recruitment. One problem with this is that training at the PhD level is time-consuming, and frequently expensive. It therefore becomes important that the investment in training is amortised over a reasonably long research career.

5.6.3. LLL and the practicing researcher

There is also the question of what LLL has to offer the fully trained PhD, frequently a practicing scientist either in private enterprise, in academia or in a government research laboratory. Browsing through the offerings in the catalogues of various universities, there does not appear to be much aimed at this segment of the population. The reasons are probably simple. First of all, the market is too small, specialised and expensive to be of interest to most LLL providers. Secondly, this group is to a large extent expected to provide their own continuing education. While this certainly functions in the ideal case, there are many instances where access to a LLL network aimed at this group also would be profitable. Research scientists working alone or in small groups, isolated from larger, more comprehensive research environments may have problems staying abreast of developments. There is also the problem of scientific burn-out which may be expected to become more widespread in an expanded research sector as envisioned by the European Research Area. And there is the question of efficient mechanism for technology transfer, and the frequent accusation of too little communication between the universities and private enterprise. Furthermore, there is an important, but frequently forgotten segment of PhDs that are not practicing directly in research, but who are in administrative positions crucially connected to the same research. For this group, the gap between their degree training and the forefront of present research will become increasingly large, and their work situation may be such that updating knowledge is difficult, even if their work ideally requires that they stay abreast of current developments.

Thus, there appear to be several areas where the LLL philosophy could be applied also to the practicing PhD-trained researcher. It is not likely that market forces will be a strong motivation here, although some universities have a fair success in selling knowledge-update courses to private enterprise. We witness today the emergence of university agencies charged with this specific task. However, there is probably further benefit to be derived in the area of investment in Human Resources by rethinking the entire research career in the perspective of LLL. This would also include the retraining of those who leave RTD, be it because of burn-out, career stagnation, or economic restructuring. While these persons might no longer contribute directly to RTD, they possess valuable competence that should be put to use elsewhere in the knowledge system, for instance in teaching or research administration. Mechanisms for such restructuring of research career paths might profitably be cast as part of an LLL approach.

Finally, it is important to consider also that part of the life-long training that the researcher receives as on-the-job development. With present innovation frequencies, some high-technology companies estimate that up to 50% of their income five years hence will come from technology that does not exist today. This trend of rapid development has two main consequences for the training process. Firstly, mastering these new technologies will require continuous updating of skills and knowledge. Secondly, institutions of higher learning may lag behind some or most of this developmental front, and thus an important aspect of the research training will be to enhance the researchers' ability to further expand his or her knowledge base. Within this framework, there is a wide spectrum of training paths, ranging from self-study, via more or less formalised courses offered by equipment manufacturers or consulting companies, to further basic studies within the normal course offerings of universities. In this process, the borderline between work experience and formal training may become more diffuse, and lose much of its meaning.

5.6.4. The research community and the LLL challenge

In summing up, LLL at present does not appear to play a role that will have a major, direct, short term impact on Human Resources in RTD. In a somewhat longer time perspective, it is possible to envisage that the opportunities that LLL offers should be taken seriously and exploited by the RTD community. This applies particularly to the training process which needs to be restructured if LLL becomes a dominant mode of knowledge transmission in the future. But it also applies to how the research community sees itself and its possibilities within a LLL framework. There is no reason why the research sector should not use LLL opportunities to their full advantage. Conversely, if the research community ignores the changes taking place at political and societal level as regards the developments of a more coherent LLL framework, scientists may well wake up one day to the realisation that they have missed some important trains.

5.6.5. Benchmarking consequences

At present there is no easy way to include LLL in benchmarking beyond the already numerous benchmarking efforts being undertaken in this area by most nations.

5.6.6. Conclusions

- LLL in its present form has a low impact on the development of Human Resources for RTD.
- There are a number of areas where LLL can be exploited, even today, for a better training and deployment of Human Resources for RTD.
- The development of Human Resources for RTD must over a reasonably short time period come to terms with LLL as a major new mode of learning, and with the consequences this has for the traditional linear ‘learn first – then research’ model.

6. Benchmarking and indicator recommendations

Throughout the text, comments have been made on the benchmarking process relative to the issues discussed. In the following, the original five indicators (Table 1), are revisited and consideration given to new indicators that appear as natural consequences of these studies. Before going into details, the distinction between benchmark indicators and the (research) data required for fully exploring and understanding a phenomenon or a process should be emphasised. The indicators by necessity have to be at an overview level, often appearing as a result of the interplay of several complex factors. Sometimes they are also influenced by needs in other areas, such as the influence of economic fluctuations on the development of Human Resources. Thus, the indicator represents a projection onto one specific axis of a process that takes place in rather complex multidimensional space. One is easily tempted, therefore, to refine these indicators to display more of the complexity contained within them. If this process goes too far, however, the value of the indicator as an operational tool (as opposed to a research instrument) is reduced. Thus, a balance must be found between the two extremes of the crude one-point description and the full multidimensional picture. Ultimately, the choice is left to the user of the data and their interpretation. However, the expert group would like to emphasise that using the indicators without at the same time having access to the full picture is likely to lead to great difficulties in interpretation and strategic planning. Thus, while operational indicators have their uses in a (comparative) benchmarking process, these must be followed by more comprehensive studies of the area being benchmarked, otherwise the result will be a little like trying to steer a ship over large distances, using only a radar without access to a map or a compass.

It is important to make these remarks because the field under examination is rather rich in data, and the possibilities for gathering all kinds of statistics are very good. The challenge of finding the right point of balance between indicators and research data has not been an easy one, and for any indicator presented below, it is easy to find further and interesting refinements. In what follows, the original five indicators (Table 1) formulated by the High-Level Group are discussed. Thereafter, suggestions are made for four possible additional indicators in a suggested order priority. It would have been very easy to extend the list of proposed indicators much further, there is virtue in keeping the list short at this point.

6.1. Number of researchers in relation to the total workforce (HLG indicator 1)

The group considers this to be a robust and relevant indicator. There are a number of possibilities for refining it to provide a more detailed picture of dynamic situations, but much of that may be obtained from other indicators dealing with specific factors. However, it is suggested that this indicator should be gender-disaggregated. The reason is that the proposed indicator 4 is of limited value (see below), one obvious weakness being its failure to account for female researchers' participation in the private sector.

6.2. Number of new science and technology PhDs as a proportion of the corresponding age group (HLG indicator 2)

The group considers this to be a robust and relevant indicator, in line with the suggestion of monitoring the changes at important decision stages. In actual application, it will be necessary to account for the cultural differences between nations which prefer PhDs for industrial research, and those where industry prefers in-house training, thus the time-development of this indicator should be seen in the light of indicator 1.There may also be differences between subjects and industrial sectors.

Again, it is suggested that this indicator be gender-disaggregated, as it will be of obvious concern to a nation if one sex turns out to be underrepresented. This could be indicative of barriers to training or pipeline leaks, and this is sufficiently important to monitor at the indicator level, rather than in the baseline data.

6.3. Number of young researchers recruited in universities and public research centres in relation to the total number of researchers (HLG indicator 3)

This indicator would hopefully monitor the renewal rate in the population of researchers. In line with previous remarks, this also should be gender-disaggregated. However, there may be possible interpretative problems in the application of this indicator. One can think of cases, for example, where this indicator would show a positive trend for the wrong reasons. One such scenario would be a forcible retirement of older researchers due to economic cut-backs which would give new hirings an unrealistically high weight, whilst disguising the fact that the total number of researchers is actually declining. Another weakness of this indicator is that it does not measure the entry of young researchers into private enterprise, and thus at best gives only half of the picture of the renewal process in the research population. Thus, this indicator should be supplemented with similar data for the private sector. In addition a decision should be reached on how to treat short-term postdoctoral positions. These are important both for recruitment and for mobility, and should be included. Since they are not permanent positions, they only indirectly affect the renewal rate for the researcher population.

6.4. Proportion of women in the total number of researchers in universities and public research centres (HLG indicator 4)

The group is somewhat doubtful as to the value of this rather restrictive indicator. As pointed out under 6.1, it only tells part of the story, no information about women going into the private sector is obtained. The latter data may be somewhat harder to collect, but should still be feasible with modern socio-statistical methods. Of equal concern is the fact that this indicator could show positive values for the wrong reasons. A worst-case scenario would be where universities and public research centres are not able to compete on salaries, offering low-paying or part-time positions which only women will accept. The ratio of women would increase, but the state of public research (and tertiary education) could be rather fragile. On the other hand, it is of great interest to monitor the gender balance in tertiary education and public research. As such the indicator might serve a purpose, but its real value can only be ascertained by comparison with time-development of the researcher population in this sector, amalgamated with data on the nature of the positions women are recruited to. Thus one can think of (extreme) structures where the women do all the instruction and the men do all the research. The expert group is rather concerned as to the value of this indicator as a measure of the success of a national research policy.

6.5. Proportion of researchers from other countries amongst researchers in universities and public research centres (HLG indicator 5)

The importance and complexity of the mobility issue in connection with Human Resources in RTD has already been commented on. This indicator, as proposed, would presumably provide some measure of policy efficiency in this area. One objection here, however, is the lack of private-enterprise data which are very important in this connection. Thus, it is private enterprise in Germany that has campaigned for special mechanisms to facilitate employment of foreign IT specialists. Another weakness of this indicator is that it does not fully account for the dynamics of the mobility problem. Such 'brain-gain' data must be supplemented with data showing the corresponding migration of non-domiciled scientists over time. The lack of rigour on the 'brain-gain' issue has already been mentioned. It is unlikely, however, that any European Nation can in the long run depend on the continual import of talent. Thus it becomes an indicator of science-policy strength to be able to recruit efficiently among its own graduates. The recommendation is, therefore, that this indicator be expanded to include the private sector, and that it should be seen in relation to the export of talent, whether this be made into a separate indicator, or another aspect of this one. Finally, during the work, the expert group became aware of the technical difficulties involved in collecting these particular sorts of statistics, due to the fact that some nations do not register the nationality of students and researchers. The solution might be to use regular surveys, rather than national statistics, to monitor this information domain. This would have the additional advantage of allowing a more complete monitoring of flow, giving a better overall picture of the brain drain, gain and circulation in the European Research Area.

6.6. The proportion of students taking S&T courses at the level of secondary school *(proposed new indicator)*

The level of secondary education has not traditionally been the domain of national science policies. However, as pointed out above, the recruitment base for future researchers is critically dependent on maintaining a sufficient flow of students through the science courses at this level. These data should be readily available, and harmonisation should not prove a major obstacle in the light of emerging conventions.

6.7. The proportion of new students enrolling in S&T courses at the level of tertiary education *(proposed new indicator)*

This indicator is also concerned with the recruitment base. It would serve as a measure of the interest in S&T subjects in the incoming student population. It is noticeable that many students today leave before completing a formal degree because they are offered attractive jobs in certain industries (frequently at salaries higher than those of their university professors). Finally, for those countries where industry does in-house training of researchers, the recruitment base at this level is very important and unrepresented in some of the data compilations.

6.8. The proportion of mid-career researchers that have changed to other fields of work over the previous five years *(proposed new indicator)*

This indicator would monitor a number of interesting factors. It would give a measure of how well the nation is able to maintain this segment of the workforce, whether there are long-term career possibilities and deficits, and whether salaries are competitive with other sectors. For this purpose, a mid-career scientist could conveniently be classified as someone with 15 years postdoctoral research experience, or the equivalent thereof for in-house trained researchers. It is probably easier (and less controversial) to develop and harmonise this form of indicator rather than monitoring the salaries of researchers relative to their non-research peer group, interesting though this latter information might be. Some Member States already have some relevant data in this field.

6.9. The number of new teachers qualified in science, mathematics and technology which take employment in secondary schools per year, relative to the total population *(proposed new indicator)*

Again this indicator is concerned with recruitment. It would serve as a measure of the renewal process in teaching staff in schools which provide the raw material for the scientific population. No final decision was made as to whether this should be computed relative to the total population; alternatives could be relative to the size of the student population in secondary schools, or relative to the amount of student hours taught in these subjects. Each have their advantages. The problem with these alternatives, however, is that they can be manipulated, e.g., by lowering the number of hours taught in the sciences, the indicator would rise, but science would be worse off.

6.10. Proportion of EU researchers employed in other countries disaggregated by country of origin and destination *(proposed new indicator)*

As noted in section 6.5, the ‘brain-gain indicator’ (Indicator 5 – Proportion of researchers from other countries amongst researchers in universities and public research centres) should be supplemented with data showing the corresponding brain drain. Thus, if indicator 5 is employed as originally suggested, a supplementary indicator which describes the outflow segment of brain circulation should be considered. Without it, interpretations of ‘gain’ are highly suspect. This new indicator would need to show the major destination countries for EU researchers, preferably disaggregated by country of origin. A distinction between public and private sector employment would also be useful, for reasons similar to those outlined in 6.1 above. Gender disaggregation should also be included. The above remarks about the difficulties of monitoring this type of demographic movements, would, of course also apply to this new indicator.

7. Conclusions and policy recommendations

As stated many times already, the acquisition and deployment of scientific knowledge is one of the major keys to innovation and competitive advantage. This report addresses the essential ingredient in this process – Human Capital. The expert group appreciates, however, that while the roles of research scientists and engineers are central to new products, processes and their development, individuals with scientific training, knowledge and perspective have a valuable part to play in a variety of different fields. Thus a broad scientific background is desirable in itself, and it appears as a formidable challenge to schools and the educational system to provide this background to a broadest possible student population.

In this perspective, scientific education appears as a process delivering value to society at a variety of points. Using again the pipeline analogy, it becomes clear that restrictions or inducements affecting the flow through this pipeline, either intentionally or unintentionally, will have feedback effects on the delivery of usefully trained individuals. In some instances the overall effect may be beneficial, in other cases detrimental.

It is the impression of the expert group that the present volume flow through the pipeline is inadequate to the needs of our society and the competitive demands of our world. In many, though not all Member States, it is argued that the proportion of the age group with scientific awareness through learning, teaching and training is not growing, indeed appears to be falling, at a time when the technological demands of our society are increasing remorselessly. The origins of the general problem are often traced to the schools and early media exposure, but there are also important aspects of policy and/or neglect later on in the educational process which serve to divert the flow, produce haemorrhaging leaks or lead to feedback inhibition. The total effect may be that both the quantity (i.e., the volume flow) and the quality (in general) of the human resource undertaking research science and engineering will be inadequate to the needs, particularly in the future. Put in blunt terms, the intellectual and personal rewards from training and commitment to this area of endeavour are now probably neither sufficiently attractive nor competitive with other activities or other societies to generate the level of involvement likely to be necessary for the success and well-being of the European Economy. To develop a pipeline of opportunity, rather than one of frustration, may require a wave of reform sweeping through the system rather than piecemeal solutions that have characterised the past. It is with this background that we offer our recommendations and some suggestions for possible policy measures.

Although the original terms of reference were concerned exclusively with the benchmarking process, the expert group was later asked also to formulate some suggestions for policy measures that could be applied to this sector, in the light of our discoveries.

To begin, support is given to measures already proposed within the areas of mobility and gender balance (see, e.g., ‘Women and science: The gender dimension as a leverage for reforming sciences – European Commission, 15.05.2001’ and ‘Communication from the Commission to the Council and the European Parliament: A Mobility Strategy for the European Research Area – European Commission, 20.06.2001’. As pointed out previously, care has been taken not to duplicate work carried out by the groups involved in these efforts. In the process of these considerations, however, it is obvious that disadvantaged minorities exist in our society.

As a background to these recommendations, it is doubtful that Europe today is poised to increase the levels of both public- and private-sector investment needed to compete with its main competitors despite commitments to that effect. The present policies may not even be sufficient to close pre-existing deficits. Increased investment is essential if our human capital is not to opt for careers outside of innovation and research, or depart for societies with greater opportunity and potential. The solution of attracting replacements from even further afield runs the risk of being short-sighted and of storing up future problems. This does not appear to be a very sensible alternative to retaining or enticing back scientists in which the society has already invested. Clearly Europe has to make itself as attractive as its competitors if it wishes to be the world leader in knowledge generation. The recent adoption of the 3% of GDP target for investment in research is, therefore, highly welcome. This 3% should, however, be distributed to both the training and provision of human capital and to the research effort itself. Experience in a few Member States has already demonstrated the efficacy of an integrated approach.

The policy suggestions made here are aligned to the concept of key decision stages. This is because these stages are undoubtedly crucial cross-roads in the development of human resources for RTD. These are also points where very specific levers may be applied in order to achieve quite concrete results. The suggestions have been tabulated at appropriate points in the text, listing the goals and targets at the various decision stages, as well as barriers involved and possible political levers (see also Annexe 1). The decision stages correspond to those earlier, with one exception – a special point concerned with deciding on an academic career has been added since it is clear that high-quality research and education at the tertiary level does require a highly competent corps of academic staff. The example of the slide in the school teaching profession should be a salutary lesson.

Despite a tabular display of an *à la carte* menu of policy recommendations as apparently separate measures, it is important to emphasise again the totality of the vision as illustrated by the pipeline analogy. The effect of one specific measure may be negated by shortcomings elsewhere in the system. Thus, choices from the menu should only be made on the basis of a thorough overall analysis of the consequences. Below is listed the stages involved with a few comments.

7.1. Science in secondary education

In many European countries the recruitment base for science and technology is perceived as inadequate – too few students study these subjects in secondary schools, and the overall level of knowledge is too low. The goal of measures applied at this stage would be to increase the general level of knowledge/competence in the population and in particular in the areas of science, mathematics and technology.

7.2. Science in tertiary education

There has been a shift from elite education towards mass education at the tertiary level throughout Europe over the last decades. This trend is forecast to continue. However, some students perceive the traditional institutions of tertiary education as unexciting, outdated or unfriendly, offering courses of questionable relevance to future careers. It is worth pointing out too that employers also comment that students are not sufficiently well prepared for the flexibility and skills required in modern employment. Whilst the various demands placed on tertiary education look unrealistically demanding particularly in the current economic climate, nevertheless, the goal would be to increase or maintain an ample supply of high-level competence for the workforce through increased attractiveness of tertiary education. In many European countries, enrolment in traditional science and technology education at the tertiary level has decreased. Even where increasing, recruitment to those subjects is often perceived as too weak to provide an adequate basis for a competitive knowledge-dependent society. The aim must be to increase relevant science and technology competence at the level of tertiary education.

7.3. Postgraduate training for research

The PhD or its equivalent provides the basic qualification for a research scientist in Europe. Many countries are experiencing a lack of candidates for this training. Even countries which are able to fill their PhD programs worry that these may not attract the most able students who frequently opt for faster paths to better-paying jobs. It therefore becomes a goal to strengthen research training in science and technology.

7.4. Remaining in research

The young PhD has the choice of pursuing research in the private sector, the public sector, or entering a non-scientific activity. If research opportunities are not attractive in the home country, the PhD may choose to pursue a career in another country (brain drain). The goal, for Europe, therefore is to retain a larger majority of PhD graduates in domestic research activities, either in the private or the public sector.

7.5. Choosing a career in academia

Universities are usually expected to form the vanguard of innovation and advanced training, based on high-quality basic and applied research. If universities are to fulfil the Humboldian ideal of combining top research with training of students and future researchers, it becomes essential to attract some of the best research scientists. Today, advertisements for university positions in many countries attract decreasing numbers of well-qualified applicants, and with harder competition for the talent, the universities may find themselves recruiting below the desired standard. Added to this, the conditions of employment and decreasing staff:student ratios are proving damaging to academic research performance and the attractiveness of the profession. It must be a goal, therefore, to create conditions which attract top quality candidates for university positions and in numbers sufficient to fulfil their primary goals.

7.6. Career development

Individual scientific creativity may be limited, and scientists can slow down or suffer burn-out when pressures are excessive, as seems to be the case now (again the analogy is the experience of teachers in schools). On the other hand, many scientists have productive careers till late in their working lives. In addition to carrying out research, the experienced older scientists can also serve as mentors (and sources of inspiration), providing an introduction and connection to international networks for younger colleagues. It, therefore, becomes important that researchers at any point in time can find positions where their talents and capabilities are best exploited, and where they do not block the advancement of new talent. It is thus a challenge to deploy existing research capacity in science and technology in an optimal manner.

8. Epilogue

This report is an attempt to elucidate some of the problems connected with mobilising Human Resources for RTD in a competitive knowledge-based economy and to determine how a nation's policies for dealing with these problems may be benchmarked. With the resources and time available to the expert group, there has had to be a limit to the scope of the discussions. The lack of available data on several important areas has also imposed further limitations. Future work on benchmarking will hopefully be able to reach beyond some of these deficits.

Above, a number of critical areas for future development have been suggested. The two most challenging ones are the brain-circulation problem, and the connection between investment and Human Resources for RTD. In both of these areas there is a real need for better knowledge of the underlying socio-economic mechanisms if a nation is to successfully meet the demands of a knowledge-based economy. There is also the challenge of statistics and data gathering. Whilst this exercise originally foresaw collection and harmonisation of official statistics as the main tool, future needs may also require surveys and other forms of data gathering. In this respect, it will be important to establish effective collaboration between the various agencies involved in data-collection, not only to avoid duplication of effort, but also to provide the users with simple interfaces and accesses to unique and unambiguous information. On an overall level, the perceived financial starvation of the sector will undoubtedly have to be addressed.

The main focus has been on the S&T sector, since this has so far been the principal supply route for Human Resources. To the extent that industry follows the currently competitive development lines of information technology, micro- and nanotechnology and biotechnology, S&T competence will be at a high premium. It should be pointed out, however, that there is a great challenge in also mobilising the non-S&T sectors in knowledge-based industry. Examples from information technology show that potential profits in exploitation of the technology may far exceed the profit in producing it. Thus concepts such as 'infotainment' and 'edutainment' are a challenge to both non-S&T talent and to the traditional S&T groupings. The fact that the non-S&T sectors may have little experience in working within an industry-oriented RTD framework will represent a further challenge.

At an even more basic level are the challenges of interaction brought on by increased globalisation. While the deplorable situation within S&T subjects in many school systems has been given at least some attention, the future demands in some non-S&T subjects are equally large. Language proficiency, for example, will be of prime importance in a common European knowledge industry with high mobility and it is not clear that present school systems are up to this challenge. The importance of a balanced development of the intellectual resources of a nation is emphasised.

Finally, the time perspectives involved in developing Human Resources for RTD should be clearly appreciated by the policy makers. In the Bologna model (3 + 2 + 3), it takes 8 years to complete the university track through to PhD level, and if secondary schooling is included, 12 to 14 years of continuous training are the norm. It is not easy to see how the acquisition of knowledge at this level can be made very much more efficient without losing an essential practical component. Thus the nations that want to develop competence along these lines must be prepared to take a long-term perspective and invest for a considerable time before they can harvest the product. In the same way, one should not expect to see the results of benchmarking efforts in the very short-term. It should be part of a continuous learning process; only then will these exercises produce real results and not just statistics.

Annexe 1. Summary of barriers, levers and targets at the different decision stages within a scientific career (see also Section 5).

	Decision Stage	Threat	Goal	Barriers	Levers	Target
1	Science in secondary education.	Proportion of pupils taking (particularly 'hard') sciences falling.	Increased involvement in Science.	• Lack of teacher attention for the individual student. • Students from low-income families cannot afford lengthy education. • Poor school infrastructure, facilities and staff:student ratios. • Learning environment uninspiring, unmotivating or threatening. • Lack of qualified and up-to-date teachers. • Uninteresting / outdated science courses. • Gender and social barriers. • Poor status of science in society. • Poor status and remuneration of scientists in society.	• Increase teacher/student ratio. • Provide economic support for students from low-income families. • Improve school infrastructure. • Extensive refresher and retraining programmes. • Reform science curriculum.	• Reduce drop out rate in science before and during secondary school by X% in Y years.

Annexe 1. Summary of barriers, levers and targets at the different decision stages (continued).

2	Science in tertiary education	Drop in quality and proportions of science undergraduates.	Increased uptake into scientific degrees.	• Subjects seen as difficult and time-demanding • Social and gender barriers. • Economic returns and career possibilities not proportionate to commitment required. • Education paths long and costly • Tertiary education conflicts with marriage and establishment of family.	• Improve learning environment. • Improve position of scientist in society. • Provide financial / structural support. • Provide introductory qualifier courses. • Improve staff:student ratios.	• Increase enrolment in scientific tertiary education by X% in Y years. • Reduce drop-out rate from tertiary education by X% in Y years.

Annexe 1. Summary of barriers, levers and targets at the different decision stages (continued).						
3	Postgraduate training for research.	Best students not continuing in science or research. Numbers not sufficient for projected need.	Enhance quality of student and training in science and technology.	• Recruitment base inadequate. • Research training daunting. • Commitment not justified by rewards. • Supervision and support from senior scientists too limited. • Equipment not up-to-date or professionally supported. • Quality research time-consuming. • Financially disadvantageous. • Research training is difficult to combine with normal family life.	• Improve financing of PhD students. • Improve level and maintenance of scientific equipment/labs. • Limit dilution of student time on less-relevant activities. • Strengthen international / industry ties. • Set minimum full time study (4 years?). • Reward 'good' PhD outcomes. • Better family support structures. • Better student:staff ratios.	• Increase applications and quality in PhD programs by X% in Y years. • Increase number of graduates from PhD programs by X% in Y years.

Annexe 1. Summary of barriers, levers and targets at the different decision stages (continued).						
4	Remaining in research?	Brain drain to other occupations or countries.	Retention of a larger majority of PhD graduates in research.	• Lack of satisfactory job opportunities. • Poor salary returns considering quality and commitment required. • Career advancement difficult on a research track. • Obstacles to mobility. • Employment problems for two-scientist families. • Long-term ageist attitudes.	• Improve salaries of researchers. • Increase job opportunities for young researchers. • Implement measures to strengthen mobility and return. • Implement special consideration for two-scientist families.	• X% of PhD graduates should be employed in research activities 5 years after graduation.

Annexe 1. Summary of barriers, levers and targets at the different decision stages (continued).						
5	A career in academia?	Fall in quality and number of public sector scientists ('who teaches the teachers').	Recruitment and retention of high quality scientists in academia.	• Uncompetitive and inflexible academic salary. • Hierarchical and fixed employment structures. • Dominance of short-term and external funding mentality. • Mobility obstacles. • Poor working practices and conditions. • Bureaucratic culture.	• Establish new positions of a university researcher (non-teaching). • Establish intermediate tenure-track positions with reasonable job-security. • Provide ample start-up funding. • Establish support networks for new appointees. • Open jobs to international applications. • Sensible infrastructure support. • Mobility measures. • Twin-hire policies for two-scientist families.	• Increase the number of top qualified applications for academic positions in science and technology by X% in Y years.
6	Career development	Deficit of senior scientists.	Maximising Research Potential.	• Inflexible employment structures. • Limited retraining for experienced scientists. • Administrative overload. • Mobility barriers. • Gender barriers. • Ageism. • Employment prejudice.	• Increase opportunities for career advancement based solely on research activities. (public & private sectors) • Flexible career development. • Major retraining Initiatives. • More flexible working schedules. • Flexible retirement / semi-retirement mechanisms.	• Reduce unemployment and induced early retirement by X% in Y years

Annexe 2. Two illustrative cases – Finland and Bavaria.

A2.1. Introduction

The expert group has chosen to work primarily with the statistical data available from various sources, as previously described in the section on methodology. However, in examining these various statistics, one cannot fail to notice the position of Finland as a country that consistently scores highly with regard to various parameters. The group has deliberately not carried out special analyses on a single-country basis; the approach has been to take a comparative view of activities and results across a broader spectrum of Member States. It is interesting, nevertheless, to include a description of the Finnish case as an illustration of some of the points made in this analysis. Similarly, in a regional perspective, the German state of Bavaria has emerged as a strong performer in the field of knowledge-based industry and enterprise. As parts of the economic-political issues in Europe are formulated at the regional level, it is interesting to include also an overview of the development in Bavaria.

The two sections below do not constitute case studies, and therefore the term 'illustrative cases' has been chosen for this annexe. The descriptions are mainly laudatory, and most of the statements made have not been validated, nor have possible negative aspects of these apparent success stories been investigated. Partly for these reasons, these two illustrations cannot be unambiguously flagged as 'best practice', but also partly because the transferability of these practices and their results between countries has not been demonstrated. The extreme view may be formulated as '*We know that the Finnish strategy worked for Finland in the 90's*' (Eric Arnold, TIP Workshop, Vienna, April 2002). Still, it is interesting that many of the practices in these two examples align quite closely with recommendations drawn from a more general analysis.

The section on Finland has been adapted (with minor changes) from a memorandum prepared by Eva Ikonen of the Finnish Academy. For Bavaria, the overview is based on an article by Steven Erlanger (International Herald Tribune, 16.02.02), generously supplemented by information from position papers prepared by the Bavarian ministry. The group takes this opportunity to thank those who have helped with this part of the report.

A2.2. Improving human resources in RTD – The Finnish strategy

A2.2.1. The Finnish education system

Finland has experienced a rapid growth in the total number of researchers. At the same time the career opportunities of professional researchers, and women and young researchers in particular, have been developed.

In 1999, the Finnish government adopted The Development Plan for Education and Research for 1999-2004. The government programme highlights know-how and knowledge which equitably benefit the regions of the country. The Plan states that researcher training should be developed to fulfil the needs of the society. The target is 1,400 new PhDs per year by the end of the planning period.

During the period 1999-2004, the Finnish education system will focus on:

- ensuring the basic right to study
- safeguarding the financial foundation of education
- information technology in teaching and research
- international cooperation
- lifelong learning
- further development of research activities
- evaluation
- basic and continuing education for teachers.

The Finnish higher-education system is divided into two sectors: universities and polytechnics. A network of twenty public universities covers the entire country. The Finnish universities have strengthened their links with society, and many universities have reformed their strategies on undergraduate education, researcher training and research activities. There was an increase in external funding in 2000, bringing it up to 35% of overall funding for the universities.

Universities will continue to increase their international cooperation and foreign-language instruction. The project for a national virtual university intends to link national and international university education. Part of the international cooperation is in the form of student-exchange programmes between partner universities, often within EU programmes. About 5,000 undergraduates a year pursue part of their studies abroad. At the same time, almost 3,500 foreign students are studying for degrees at Finnish universities, of these 1,200 are postgraduate students. Most of them came from European countries, with the second largest contingent coming from Asia. In 2000, about 12% of all Finnish researchers and teachers worked for at least two weeks at foreign institutions of higher education.

The annual enrolment in universities is about 20,000, which corresponds to 30% of the age group. Young people in Finland are well motivated towards university education. In 2000, almost 110,000 applications were received by the universities. Nearly 64,000 applicants took entrance examinations, and approximately 26,800 were accepted. The number of university students and university degrees has increased during the 1990's (Table A1). Thus at least at the moment, the recruitment base for research work is good in Finland, except in fields like IT, where the demand for experts and researchers is very high. A majority of all Master's degrees are taken in engineering, humanities, educational sciences, natural sciences, economics and business administration, and social sciences. The annual number of doctoral degrees more than doubled in Finland during the 1990s. In 2001 there were 1,203 new doctorate degrees (Table A1) with women being awarded 44.5% of the degrees in 2001, compared to 33% in the early 1990s. In 1999, the total number of new PhDs per thousand people aged 25 to 34 years was 0.97 in Finland, which is the second highest figure among the OECD countries.

In 1995 a system of graduate schools (researcher schools) was established in Finland to supplement traditional postgraduate education. The Finnish graduate school system is based on networks of research teams and cooperation in doctoral training. Some of the graduate schools comprise a single discipline, some one university, while others are fairly extensive national networks. Universities have also established graduate schools of their own. The aim of the graduate school system is to intensify doctoral education so that it is possible to obtain a doctorate in four years after a master's level degree and that the age of new PhDs would be around 30 or less. Support for one graduate school is for a four-year period. This funding is based on selected qualified proposals. The Ministry of Education and the Academy of Finland have annually allocated a total of FIM 25-35 million (1 Euro is about 6 FIM) to the graduate school system. In 2002 there are 108 graduate schools funded by the Ministry and the Academy.

In 1995 the first 67 graduate schools started with 722 four-year research students positions. The graduate school system has been enlarged in several stages since 1995. In 2002, the number of graduate schools is 108 having 1426 graduate-school positions for four years. Full-time research students in the graduate schools are employed by the relevant universities with special funding from the Ministry of Education. A national steering committee has been established to function as an advisory body for the system.

Table A1. Finnish degree production for the period 1990 – 2001.

Year	Total, university students	Total, postgraduate students	Total, Master degree	Total, Doctoral degree	Master degree, females (%)	Doctoral degree, females (%)
1990	110 700	13 363	8 423	490	54,1	31,6
1991	115 573	11 839	8 410	524	54,7	32,6
1992	122 200	13 359	8 713	527	55,0	30,6
1993	126 100	14 218	9 439	647	55,1	36,6
1994	128 267	14 730	9 615	698	56,4	36,2
1995	135 107	15 927	9 819	765	56,0	37,1
1996	138 173	16 674	10 611	851	57,5	40,2
1997	142 818	18 056	10 893	934	57,2	40,1
1998	147 263	18 958	11 343	988	57,5	39,7
1999	151 900	19 842	11 856	1 165	56,1	43,3
2000	157 195	20 537	11 515	1 156	58,3	45,2
2001	162 785	21 008	11 581	1 203	58,0	44,5

The creation of the graduate-school system was well-timed, since it started when the need for a highly educated workforce was growing rapidly. The employment prospects for new PhDs from the graduate schools are excellent. More than half of them find work outside the Finnish universities or public research institutes. In the 1990s an average of 1.4% of the PhDs did not find jobs within two years of their dissertation. The overall unemployment rate in Finland was 8.1% in December 2001.

A2.2.2. Infrastructures

In the knowledge-based economy, universities, research environments, laboratories and institutions of higher education, together with infrastructure facilities, are core elements of the science system. The Finnish technological infrastructure was rated by the IMD (International Institute for Management Development) as the third best in the world, after the USA and Sweden. In the scientific infrastructure index, Finland came sixth.

A change in the structure of production towards information-intensive and technology-intensive fields has accelerated markedly during the past few years. According to a report from the UN development organisation UNDP, Finland is technologically the most advanced country in the world. Two criteria which contribute to Finland's position ahead of the USA, which came second, were Internet penetration and the population's above-average knowledge base.

The Finnish research infrastructures are mostly connected to university campus areas. Universities have established joint regional or national institutes or networks between laboratories. Some of the new institutes have a multidisciplinary character. Also the State Research Institutes have increased their cooperation with university laboratories and plan to place their new facilities in university campus areas.

A2.2.3. Cooperation with business

A survey conducted among Finnish company directors shows that they regard science and technology, together with education, as the key factors of economic success. In the past few years companies have also begun to show great interest in academic research and in recruiting highly educated staff. International competition and a faster phase of technological development have led to new concepts in the R&D strategy of Finnish companies. They are now actively seeking cooperation with producers of new knowledge and working near or inside the university campus areas.

Finnish higher-education institutions have continually intensified their cooperation with business and industry. External financing made up over 48% of university research funding in 1999. The share of external funding is highest in the faculties and universities of technology. Funding from domestic and foreign companies represented over 10% of all external higher education income. According to innovation surveys conducted in the EU countries, 40% of Finnish innovative enterprises had contacts with higher education institutions.

In 2000, a total of 68,800 employees were working in research and development in Finland. The number of R&D personnel increased by a little less than 3% from the year before. Women accounted for one third of all R&D personnel. The proportion of women was clearly larger in the public sector (47%) and in the university sector (43%) than in business enterprises (21%).

A2.2.4. International cooperation

The Finnish science and technology community is well integrated into EU research programmes and other international cooperation schemes. Finland is a member of several major international research organisations, such as ESA, CERN and EMBL, and Finnish researchers participate actively in many smaller world-wide and European research organisations and research programmes.

Participation of foreign students in researcher training courses has been an efficient tool in training Finnish students for international scientific collaboration. The participation of young Finnish postgraduate students in summer schools and courses organised by international scientific organisations and other universities abroad has increased during the last twenty years. Finnish undergraduate students have used student-exchange programmes between partner universities. All these activities have been important elements in international collaboration in university education and researcher training.

A2.2.5. Research and development expenditure 3.6% of GDP in 2001

The volume of Finland's R&D expenditure is fairly small when compared to those of larger OECD countries. However, as a fraction of GDP it is among the highest. It has been growing steadily, and went up particularly rapidly in the latter part of the 1990s. The main reason for this is that R&D investment in the private business sector increased faster than expected. The main contribution came from the electronics industry.

Due to the absolute volume of research funding and research output in an international comparison, a careful allocation of research funding has been essential. One of the most important ways of improving the quality of research in Finland, has been to increase the share of competitive research funding. This has been done by allocating a larger share of public research funds through the Academy of Finland and the National Technology Agency, Tekes. One-third of all government R&D funding is allocated through Tekes to business companies. The implementation of the national R&D policy is based on a broad autonomy of funding organisations, universities and research institutions. This makes it easy to respond to emerging scientific and technological needs.

The national research and technology programmes, the national programme for Centres of Excellence in research, together with networks between private and public research units, have increased quality, performance and results in the whole national innovation system. The national research and technology programmes consist of several connected projects. Programmes are initiated in topical research problems, important research fields and new fields and disciplines generated by published research. The main aim of the programmes is to promote interdisciplinarity, multidiciplinarity, internationalisation and researcher networking and to intensify researcher training. The new programmes launched by the Academy of Finland, jointly with other funding organisations, will have partners from other countries. In 2001, the Academy of Finland had 23 programmes. In 2002 five new programmes will be started, all having funding cooperation between different countries

The research programmes are set up for a fixed term, usually for three years. The national technology programmes may have shorter terms. In 2000, there were 56 technology programmes, of which 14 were closing and 8 starting. Nearly 2,400 businesses and 800 research institutes participated in these in 2000.

The aim of the national Centres of Excellence programmes (there are two: 2000-2005 and 2002-2007) is to promote high-standard, creative and efficient research and educational environments which have the potential for generating world-class research. The funding for one unit is for a six-year period. Finland participates also in the first Nordic Centres of Excellence pilot programme which will be opened for application early in 2002.

In 2001, the R&D share of the GDP reached 3.6% from only 1.5% in the mid 1980s. Total nominal R&D expenditure doubled from FIM 10 billion to 20 billion in 1998. At the same time, research expenditure in private companies increased from FIM 5.8 billion to 15.5 billion. In 2000, EUR 4.4 billion (FIM 26.3 billion) was spent on research and development in Finland. The expenditure rose in real terms by over 10% from the year before. The growth of R&D expenditure continued through 2001, when it is estimated to be EUR 5.0 billion.

A2.2.6. Success criteria and some key factors

In the last twenty years, Finnish science and technology policy has been progressing from discrete scrutiny to a more comprehensive approach, in which the producers and users of knowledge are regarded as an entity. One of the most important factors is the political consensus on goals for science policy, investments in education and in R&D. Long-term and systematic efforts combined with the structural changes of education and business sectors have been key factors for the success.

New knowledge is produced by universities and polytechnics, research institutes and business enterprises, among others. The foremost users of knowledge are enterprises, private citizens, policy-makers and administrators responsible for societal development. Cooperation between producers and users has rapidly increased in Finland.

The competitiveness of Finland and the performance of its innovation system were evaluated in several surveys published during 2001. The World Economic Forum rated Finland the best, both in its growth competitiveness ranking and in its current competitiveness ranking. In 2001 Finland overtook the USA in growth competitiveness, rising to the top from the sixth place (2000). In the WEF technological advancement index, Finland came third.

In the Finnish system, science policy is the responsibility of the Ministry of Education; the most important research financing organisation is the Academy of Finland. Publicly funded research is mainly conducted in universities and research institutes. Technology policy is the responsibility of the Ministry of Trade and Industry. The responsibility for measures geared to develop and disseminate new technological knowledge have been assigned to agencies in the Ministry’s sector. The most important organisation financing technological R&D is the National Technology Agency (Tekes).

Key success factors in Finland – a summary

i	Political consensus on science and technology policy (in the Science and Technology Policy Council chaired by the Prime Minister)
ii	Well-functioning system of planning, decision-making and funding for research
iii	Large amount and rapid growth of R&D investments in last 15 years
iv	High-level information-technology infrastructure
v	Active research cooperation in the country and within the EU
vi	Cooperation in researcher training between universities, and to some extent also with companies
vii	Large investments in education and a full regional coverage by the university system
viii	Highly educated young people and motivated students both at the graduate and the undergraduate level
ix	Wide range of high-quality education in engineering
x	Well-qualified teachers
xi	Focusing on the quality of scientific research
xii	Profitability of R&D investments (e.g., patents)
xiii	Close cooperation between the different actors (ministries, science and technology funders, universities and research institutes) in the public and private sector and between sectors in research
xiv	Active internationalisation

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A2.3. A regional response to the knowledge-based economy
The development in Bavaria

A2.3.1. Background

Of the 16 German states, Bavaria consistently ranks first or second in growth rate and living standards, and among the lowest in unemployment (less than 6%, compared with the German average of more than 9%). Essential factors are considered to be the strong partnership with businessmen and managers, and the efforts to create a modern network between politics and the economy.

The lack of old industry – iron, coal and steel – forced Bavaria to become a high-technology centre. Today, Siemens dominates the field of computers for medical equipment. Still, the real strength of the economy lies in the many medium-sized companies, often privately held by families, each employing 200 to 500 people. The government has concentrated on the education system, starting a system of 'clusters' for associate industries to grow near specialised schools that could train their employees. Large sums have been spent on better roads, rail connections and modern airports.

To finance this, the government privatised state companies, raising more than $ 4.5 billion. New clusters have been created for environmental technology in Augsburg and for medical technology around Nuremberg. A new cluster for biotechnology in and around Martinsried is envisaged. A good example of the Bavarian model is the medical cluster. In Erlangen, near Nuremberg, Siemens has its medical-instruments headquarters, and its buildings dominate the town. Every fifth worker in a town of more than 100,000 works in the field of health care, and there is a quality university that trains potential staff members.

Basic success factors are the general orientation towards and a positive climate for research particularly at a basic level. Bavaria's institutions of higher education (11 universities, 17 technical colleges of higher education at 19 sites, and 5 art colleges provide a broad offer for education) are well equipped by German standards. Other contributing factors are a success-oriented appointment policy and a firm commitment to placing the main emphasis on specific fields at the universities together with support for the large number of excellent research institutions covering a wide spectrum of disciplines ranging from Natural Sciences and Health Research to Historical Sciences.

At the same time, the Bavarian system of higher education has undergone structural reforms aimed at the improvement of teaching, promotion of performance and competition between and within universities. The reforms also target increased professionalism in the administration of the universities, strengthening of autonomy and self-responsibility of these centres of learning, increased internationalisation and strengthening of the economy of university hospitals.

The biggest problem remains the search for excellent people. 'We need engineers,' said Ulrich Kripps, a Siemens manager, 'and we need them from anywhere.'

A2.3.2. Instruments of the Bavarian research policy

- Collaborative Research Centres (*Sonderforschungsbereiche*)

A Collaborative Research Centre (CRC) is approved by the *Deutsche Forschungsgemeinschaft* (DFG) on the basis of a strict peer-review system with very high-quality demands. Consequently it constitutes a special mark of quality for the research done at the successful university. In 2001 CRCs and technology transfer were supported by 663 million DEM (1 EUR is about 2 DEM). The number of CRCs established at Bavarian universities has continuously increased, reaching 53 in 2001. Of this number, 16 are at the Ludwig-Maximilian-University of Munich (presently the German university with the largest number of CRCs), 13 at the Technical University of Munich, 11 at the Erlangen-Nuremberg University, 9 at the Würzburg University, 2 at the Bayreuth University and one each at the Augsburg and Regensburg Universities.

- Bavarian Research Foundation

The Bavarian Research Foundation was established by the government in 1990 with the objective of strengthening Bavaria in the field of high technology by fast and flexible promotion of applied research. The Bavarian Research Foundation funds projects with a promising future, which are carried out in close collaboration between Academia and Industry.

- Bavarian Research Conglomerates (*Forschungsverbünde*)

The installation of Bavarian Research Conglomerates has emerged as an effective instrument for supporting interdisciplinary as well as interuniversity research. By June 2001, 29 such Conglomerates were installed in fields with a promising future. Within such Conglomerates, scientists from different disciplines and from different universities – together with partners from industry – carry out joint research and development in a specific field for a limited duration of time. In particular, emphasis is placed on specific themes in the area of information and communication technology, new materials, biotechnology and medical provisions.

- The Bavarian long-term program ‘New Materials’

The Ministry of Finances funds measures for improving infrastructures at the universities with the objective of supporting research and development in the area of new materials. A prerequisite for applicants is the formation of ‘clusters’ involving different chairs and departments.

- Technology transfer and support for start-ups

Technology transfer from the universities towards industry constitutes an instrument for developing, safeguarding and extending the competitiveness and technological leadership of enterprises. For improving the exchange of information in this area, universities have generated points of technology transfer. These points establish contacts with industry and raise awareness among the staff of the universities (students, professors and assistants / lecturers). Several projects are aimed at giving optimal advice for future entrepreneurs and generating a network among the start-up activities of universities.

A2.3.3. BioRegion Munich – an example of competitive establishment of a knowledge-based development cluster

A total of 17 regions in Germany are competing for designation as BioRegion which brings with it financing under the National Biotechnology program. Special awards were given to three regions:

- BioRegion Munich
- BioRegion Rheinland
- BioRegion Rhine-Neckar-Triangle,

with additional awards for the BioRegion Jena and others.

The main objective is that these funds should mobilise additional private capital. Although pursuing different concepts, these three BioRegions are given substantial opportunities to push structural changes to meet international standards and, thereby, create new jobs with real futures.

The Munich region is characterised by a very high concentration of research centres in biotechnology. The large number of patents and cooperative ventures involving companies from Germany and from abroad, the recent start-ups of companies as well as the large number of research initiatives in gene-technology provide strong evidence for the power of research institutes within the field of modern biotechnology. A special position is occupied by the Centre for Innovation and start-up of enterprises in Martinsried, which opened in 1995. A consequence of this initiative is the large sum of risk capital made available for new enterprises in biotechnology.

A2.3.4. The Rudolf-Virchow-Centre for Experimental Biomedicine at the University of Würzburg – a DFG Research Centre

The *Deutsche Forschungsgemeinschaft* (DFG) has reviewed proposals for a Research Centre for Experimental Biomedicine. Three sites have been selected – Bremen, Karlsruhe and Würzburg. The Rudolf-Virchow-Centre will be funded by the DFG for the next four years with a presumption of extension to 12 years.

The Würzburg centre is characterised by new concepts, integrating new structural reforms into the German research landscape. This includes the award of short-term research professorships, allowing researchers with a particularly high profile to receive a budget and positions for a limited period, with great freedom of action. Following a ‘Graduate School’ model for structured doctorate training in biomedicine, a new Bachelor/Master course is being offered at the University of Würzburg.

A.2.3.5. References

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