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Working Group on Innovation and Technology Policy

MOBILISING HUMAN RESOURCES FOR INNOVATION

**PROCEEDINGS FROM THE OECD WORKSHOP ON SCIENCE AND
TECHNOLOGY LABOUR MARKETS**

17 MAY 1999

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FOREWORD

This document contains information on trends and policies in the area of human resources in science and technology across OECD countries. The move towards the knowledge-based economy has placed human resources in science and technology at the forefront of policy debate. At their Ministerial meeting in June 1999, CSTP Ministers concluded that sufficient personnel mobility, improved education systems and better information flows in the economy are essential to meet the needs of the 21st century for highly skilled personnel. In doing so, Ministers recognised that science, technology and innovation policies have a role in both the generation of S&T skills and their deployment in the private and public sectors.

The analysis of human resources in science and technology has been carried out by the Working Group on Innovation and Technology Policy (TIP) of the OECD Committee for Scientific and Technological Policy (CSTP). The documents which follow were presented to the TIP Group at the Thematic Workshop on *Science and Technology Labour Markets: Current Trends and Challenges* held at the OECD on 17 May 1999. In addition to methodological information on classifying S&T personnel and measuring stocks and flows, the document provides OECD data on trends in supply and demand and the mobility of S&T personnel. This is supplemented by analytical country case studies that examine policy relevant issues such as shortages of IT workers, problems in the labour market for PhDs, and the international mobility of researchers. The document also provides information on recent policy measures in a number of Member countries to improve the contribution of S&T personnel to scientific discovery, innovation and growth.

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EXECUTIVE SUMMARY

The move towards the knowledge-based economy has placed human resources in science and technology at the forefront of policy debate. In 1998, the TIP Group undertook analyses of science and technology labour markets, following earlier work by the former Group on the Science System and statistical work by the NESTI. The work responded to a finding by the OECD's 1998 report on *Technology, Productivity and Job Creation: Best Policy Practices*, that technical progress is increasing demand for skilled labour and spurring an upgrading of skills across economies. This increase in demand is not being met equally in OECD countries; surpluses and shortages for certain types of S&T personnel point to slow adjustment of supply and labour market rigidities such as lack of flexibility and barriers to labour mobility. A waning interest in S&T among youth, under-representation of women in S&T education and employment, and the globalisation of the highly-skilled labour force pose other challenges to the ability of OECD countries to provide the right S&T skills for the knowledge-based economy.

In conjunction with its recent meeting in May 1999, the TIP Group held a Thematic Workshop on *Science and Technology Labour Markets: Current Trends and Challenges*. This executive summary reviews the main results and policy issues raised in the context of the TIP work on human resources in science and technology and the thematic workshop on S&T labour markets.

What is the role of S&T workers in the economy?

Human resources in science and technology are important for several reasons. First, investment in human capital is key to innovation and growth. As both the producers and users of knowledge and technology, men and women in science and technology are at the core of the technology-led economic expansion that is creating jobs and raising living standards in several OECD countries. Educated S&T workers are among the key services that the public sector provides to the private sector. The public benefits of spillovers generated by human capital are an important reason for governments to invest in public education and research training. As basic research becomes more important for technology and innovation, continued investment in S&T personnel is critical for exploiting the benefits of public research. The long-term sustainability of science and the innovation process will depend on an adequate and well-trained supply of new researchers and teachers as many older researchers and professors are about to leave the workforce.

Second, firm level evidence indicates that the share of S&T workers in firms, irrespective of firm size and sector, has an impact on the introduction of new products and processes. S&T personnel help firms appropriate and apply the knowledge from basic research into industrial applications and solve complex technological problems but also raise the overall learning capacity of firms. S&T personnel thus constitute a stock of intangible capital to the firm, as much of the returns to investment in innovation are only partially secured by the generation of new products, patents or other intellectual property rights.

Third, the movement of science and technology personnel between sectors, large and small firms, and across national borders is an important conduit for technology transfer. The skills developed by graduates in S&T provide substantial economic benefits to society as graduates move on carrying with them both codified and tacit knowledge. This knowledge is especially important in newly emerging and fast-moving areas of science and technology. In addition, co-operation in research and technology largely takes place

through people; scientists and researchers have long participated in national and international networks of experts. Barriers to mobility and co-operation could thus significantly weaken innovative capacity in OECD countries.

Fourth, mismatches in supply and demand for S&T personnel can have repercussions on the broader economy; shortages for information technology (IT) workers for example could result in wage pressure. Labour market imbalances for S&T personnel may thus contribute to unemployment, and an international “brain drain”.

Finally, human resources in science and technology are important because they constitute a source of entrepreneurs. Increasingly, academics and S&T graduates start up firms or participate in the creation of company spin-offs from the public research sector, thereby contributing to innovation, knowledge and technology transfer, industrial restructuring and job creation. Indeed, new technology-based firms are a growing source of jobs for the highly skilled as illustrated by evidence on employment growth of S&T personnel in SMEs. Weak incentives for self-employment and firm creation could suppress this entrepreneurial potential, however.

Main policy challenges

At their Ministerial meeting in June 1999, CSTP Ministers concluded that sufficient personnel mobility and better information flows in the economy are essential to meet the needs of the 21st century for highly skilled personnel. In doing so, Ministers recognised that science, technology and innovation policies have a role in both the generation of S&T skills and their deployment in the private and public sectors.

Making S&T education and training policies more responsive to changing demand

As technology increases demand for S&T workers, governments and businesses must find new ways to provide workers with the skills for the knowledge economy. An increase in temporary employment, the growing importance of IT skills, enhanced university-industry co-operation and the globalisation of skilled workers all mean that the conditions underlying the supply and demand for S&T workers have changed. In the new model of innovation, scientists and researchers can no longer be trained to work in laboratories isolated from societal and economic prerogatives.

Education and training policies have long focused on increasing the supply of higher education. Given the long lead times in supply and changing demand, this appears increasingly inadequate. Enhancing the *quality* of S&T education in order to improve the skills match between supply and demand and sustain the research enterprise is becoming equally, if not more, important. The debate on skills shortages also reveals that higher education can no longer be viewed as the exclusive source for S&T skills, especially IT. Industry and trade associations have a role to play as secondary education institutions. Duration of higher education is also an issue in several countries as long programmes can prevent early or easy exit from education to employment, increase lead times in supply, and result in skill mismatches.

Interdisciplinarity in education and research is becoming more important in both the public and private sectors but the S&T curriculum and training systems are slow to adjust. This is especially the case at PhD level where programmes are highly specialised. At the same time, interdisciplinarity leads to the emergence of new specialised disciplines so education policies must balance both specialisation and interdisciplinarity. The diffusion of IT and its application in S&T education and research (especially in new fields such as bio-informatics) means that S&T and non-S&T workers alike must increasingly be IT literate. Furthermore, since non-technical skills are also of growing importance, the curriculum should be

broadened to build interpersonal and networking skills, and expose S&T students to business and entrepreneurial skills.

Part of the solution to problems of skills shortages can be found in alternative sources of supply; non-S&T workers, older workers and women (who are under-represented in science and engineering fields) are a potential source. But improving the gender balance in S&T will require complementary efforts in education at the primary and secondary levels and in public and private research employment. This is particularly important in the IT field where employment and education tend to be male dominated in most OECD countries.

The experience of some types of S&T graduates in finding employment suggests that formal S&T qualifications are no guarantee for a successful and quick integration into the knowledge-based economy. They must be complemented with on-the-job training and lifelong learning. Lifelong learning measures should actively integrate science and technology, especially IT skills. This is becoming more important as technological change requires a continuous upgrading of skills.

Consequently, governments and firms have a stake in ensuring that workers, including the highly skilled, have incentives to invest in new skills. Governments can provide incentives for lifelong learning to firms and workers in the form of tax incentives and cost-sharing arrangements. Public partnerships between firms, government, and educational institutions can help address the issue of the risks and costs of training; SMEs are particularly vulnerable to such risks as few have resources to train workers and, under a tight labour market, may have even less incentive to do so.

One of the problems firms and education systems face in meeting skill requirements and training needs is lack of information on technological, industrial and research developments. Technology foresight exercises can complement occupational forecasts by creating a process that brings together firms, education planners and the research community to exchange information and identify potential new skill demands.

Adapting the science system to new demands

Despite the growth in employment of S&T personnel in the business sector, government and institutions for higher education remain key employers of S&T personnel. Science and education remain among the core tasks of government even in economies where the public sector is leaning more to the market. It is thus incumbent upon governments to ensure that there are incentive structures to attract, train and retain S&T personnel who will teach new generations of students and contribute to basic research that would not otherwise be carried out by the business sector.

In the past, public research employment was characterised by secure employment provisions and low employment turnover as well as concentrated age structures towards older workers. But increasing returns from public research requires greater openness and renewal of the public research enterprise. Universities and public research institutes, like firms, increasingly require the flexibility of *temporary employment* to access specific expertise from outside especially in the context of participation in research and technology partnerships with industry (e.g. contract research). Already, in some countries some of the basic characteristics of public sector employment, such as tenure systems and permanent employment, are giving way to more flexible arrangements. Many public science institutes have been privatised or have spun-off activities for commercial purposes and this is affecting employment relations, research prerogatives and skills.

These developments raise new challenges. The special tenure and pension arrangements in universities and public laboratories may act as disincentives to mobility. At the same time, tenure has been promoted as a way to reward academic achievement and allow scientists *independence* in research. Consequently, other

incentives, including sharing in the commercial returns of public research and possibilities for academic entrepreneurship, must be constructed if researchers are to continue to pursue research and teaching in the public sector. As intermediaries between researchers and public employers, public employee unions and professional associations have an important role to play in the new employment arrangements and incentives structures that are emerging.

Leveraging human resources in S&T to enhance science and industry relationships

Innovation in firms and advances in science increasingly depend on the intensity and quality of interactions between the public research base (government laboratories and university research) and the business sector. Across OECD countries and at national and regional levels, policies have been implemented to commercialise public research. This does not happen automatically and human resources are an integral part of technology transfer and commercialisation strategies. Policies that aim to enhance industry-research interactions therefore often focus on improving mobility of S&T workers. Mobility not only benefits firms and universities, but can benefit researchers themselves in terms of increasing human capital and building personal and research networks. There are concerns in many OECD countries that barriers to researcher mobility can weaken the pace of scientific discovery and innovation.

Preliminary results from the OECD's work on *Benchmarking Industry-Science Relationships* suggests that regulatory barriers are generally low in most OECD countries but that non-regulatory barriers and weak incentive systems restrict mobility of public sector researchers. But while mobility is important, too much mobility may have longer-term repercussions on both demand and supply for S&T labour. Frequent job changes involve a loss of job-specific skills and transaction costs for workers and employers. Higher turnover could act as a disincentive for training of S&T workers. Mobility is also skewed towards younger researchers as the propensity to change jobs, or sectors decreases with age.

Reforms in the science system that allow academics to co-operate with industry in the framework of public/private partnerships can enhance mobility and flows of tacit knowledge. These may include improving the portability of public sector pensions, allowing public researchers to advance their careers while working for industry or better recognizing joint publication with industry. Financial incentives that reward mobility and co-operation with industry such as IPR sharing and equity participation in spin-offs can also improve knowledge flows and provide practical training.

Yet universities are increasingly concerned that greater industry involvement, including mobility of researchers, may redirect their mission away from fundamental research and teaching. If academics engage in industrial projects or firms, there is less time for teaching and basic research. But the two may be reconciled if academics with practical experience continue to teach and prepare students for industrial and public research.

Moreover, networking and inter-firm collaboration may complement or substitute for external mobility and may actually be preferable from the knowledge perspective. The policy implication is that while internal and external mobility should be encouraged through the removal of regulatory and non-regulatory barriers, alternatives to physical mobility such as networking and "virtual mobility" should also be explored.

Enhancing framework conditions for the business sector to strengthen the contribution of S&T personnel to innovation

Framework conditions in the business sector play an important role in providing incentives for students to pursue education in science and technology in the first place, and once in the labour market, in moderating the match between supply and demand. In the face of changing demand for skills or in the event of

shortages, limited flexibility in wage-setting arrangements may reduce incentives for S&T workers and may lead to increased international mobility. The *OECD Jobs Study* outlined reforms in the areas of wage flexibility and overall labour mobility which can aid firms and workers to better respond to technology-induced changes in labour market demand. These broader labour market reforms are often essential in meeting the more narrow demand for S&T personnel.

Framework conditions can influence the investment by firms in hiring and training skilled workers. Organisations and workers have a greater incentive to invest in training if employment relations are relatively stable and predictable. Because higher education and training, especially in S&T, has significant private benefits, firms and individuals may have to absorb a larger part of costs. This requires clear market signals for both workers and firms to invest in training. But market failures may prevent firms, especially SMEs, from hiring and training research and technical personnel. S&T policies may thus have an additional role in encouraging human capital and training investments in small firms.

Without business conditions that facilitate the creation of business start-ups, the contribution of investment in science and technology to innovation and growth will remain limited. New technology-based firms are significant employers of S&T personnel and key actors in the innovation process. At the general level these conditions include well-functioning venture capital markets, regulatory reform to enable greater entry and exit (business start-ups and closures) and, more broadly, a business climate that rewards risk and new undertakings. If incentives for self-employment and firm creation are weak, this could lead to weak or depressed demand for S&T personnel. Finally, the degree of openness in the economy also matters and policies towards the permanent and temporary immigration of foreign high skilled workers play a role in helping the business sector adjust to demand shocks. From the workshop discussions, it emerged that countries whose higher education and research systems are internationalised in general succeed better in increasing the pool of foreign S&T workers. Yet countries would be shortsighted to rely too much on foreign S&T students and personnel as a source of additional supply as it no substitute for national efforts to train future generations of scientists and technology personnel.

Concluding remarks and further work

The move towards the knowledge-based economy is characterised by increasing demand but also changes in the types of skills and qualifications required. The expansion of IT across economic sectors, including services, will continue to fuel the demand for S&T workers. On the supply side, there have been dramatic increases in the number of higher education graduates, especially in “catching-up” countries, but there are signs that the share of S&T graduates may be falling or stagnating in some countries. Some categories of S&T graduates are having trouble entering the labour market as they lack the right skills even whilst industry reports shortages for S&T personnel in knowledge intensive sectors. The slowness of supply systems to adjust means that partnerships between government, industry and education providers are necessary to speed the labour market entry.

The OECD's work on S&T labour markets and the presentations at the TIP Group Workshop underscore the important role that science, technology and innovation policies have in improving the match between supply and demand and enhancing the contribution of S&T personnel to scientific discovery, innovation and economic performance. Policies to promote S&T education and training must focus more on quality issues. Information technology skills should be integrated at all levels of education and lifelong learning. A number of countries such as Finland, the United States, Ireland and Denmark are taking the lead in investing in IT education to address potential shortages. Technology foresight policies can also help business and governments identify growth areas in science and technology that may have implications on skills demand and education.

Because a large share of S&T personnel are trained and work in the public sector, technology and innovation policies must ensure the science system can attract and retain researchers. This will require adapting the regulatory framework in the public research sector to the new employment demands for flexibility, mobility and growing university-industry interactions. While reducing barriers to mobility, especially non-regulatory barriers, remains an important challenge in many countries, the presentation by Miles and Tomlinson highlights the limits to and the costs of mobility as well as the importance of fostering alternatives to physical mobility for technology transfer and co-operation.

Education and employment policies in research should capitalise on industry-science relationships by adjusting curricula and rules so that staff with industry experience can contribute to teaching and research. Capturing the teaching and public research benefits from industry-science interactions will also require adjustments to incentives systems. One way is to improve the rewards to academics from participating in industrial projects (e.g. through incentives for joint publications, sharing the rewards in joint patenting). Financing of higher education research can also be a mechanism for strengthening teaching and research missions in areas of importance to industry and society.

Governments play a key role in developing the framework conditions for the business sector but also the specific policies in the science system that encourage the entrepreneurial potential of S&T personnel. In other words, policy cannot only focus on supply but must address market failures on the demand side as well. Improving the mechanisms for research commercialisation and conditions for company spin-offs and business start-ups is necessary for generating new demand for S&T personnel, especially in SMEs, and enhancing their contribution to innovation and growth.

Data issues, including problems in classifying S&T workers, continue to limit analysis. The TIP workshop highlighted the potential for better exploitation and use of national data. Although most data are not gathered with the specific objective of analysing human resources in S&T, they provide a powerful political tool. In many cases, as illustrated in the Spanish presentation by Canibano and Sanchez, only minor modifications to the existing questionnaires could enormously improve the analytical capacity of the data. Focusing on specific issues and groups might yield more results than attempting to measure stocks and flows of the entire S&T population. The importance of maintaining flexibility in taxonomies and data collection was also stressed at the workshop. Statistical agencies and policy makers must recognise the diversity within S&T human resources. The relationship between educational qualifications and occupation is often quite loose. In addition, there are many barriers to substitution; a specialist in molecular biology is not easily replaced by a chemical engineer.

As we move into the 21st century, addressing the issues above is of vital importance to innovation and the economic competitiveness of OECD economies. While OECD countries have succeeded in raising education attainment levels, especially in science and technology, the knowledge-based economy is exerting new demands for flexibility in the education and employment of human resources in S&T. In the near future, other developments such as the ageing of the workforce will pose additional challenges to policy makers.

The OECD will follow-up its work on human resources in science and technology in the context of the work by the TIP Group on *Innovation and Growth* and *Benchmarking Industry-Science Relationships*. The latter project will deepen analyses on the regulatory frameworks and policies that govern researcher employment, mobility and their interactions with industry, whether it is in the commercialisation of research or the creation of spin-off firms. The OECD's Working Party on the Information Economy will be revisiting the issue of IT workers in its *Information Technology Outlook 2000*.

As regards further methodological and data work, the OECD's NIS Focus Group on Human Resources Mobility is continuing its work on mobility for an extended group of countries and a study of international mobility. The Group of National of Experts on Science and Technology Indicators (NESTI) is continuing work on the mobility of human resources and will prepare a final report, with statistics from France, the United Kingdom, the United States and the European Union, by the end of 1999.

BACKGROUND REPORT: AN ANALYSIS OF S&T LABOUR MARKETS IN OECD COUNTRIES

by

Mario Cervantes, *Science and Technology Policy Division, OECD*

Introduction

The continued development of human capital and upskilling of the labour force is critical for sustaining innovation and economic growth in the OECD area. Member countries have justifiably focused their active labour market policies, together with education and training measures, towards improving the employability of lower and unskilled workers as recommended by the *OECD Jobs Study*. But what about the highly skilled, especially science and technology personnel? Imbalances in the supply and demand of skilled labour may stifle the innovation performance of firms if not addressed. The move towards the knowledge-based economy is transforming the supply and demand for human resources in science and technology in firms and across sectors and borders. On the demand-side, this transformation is characterised by increasing demand but also changes in the types of skills and qualifications required, notably the rising importance of combining up-to-date technical and non-technical skills (e.g. managerial, interpersonal, and entrepreneurial skills) as well as flexibility in employment. On the supply side there have been dramatic increases in the number of higher education graduates, especially in "catching-up" countries, but there are signs that the share of S&T graduates may be falling or stagnating in some countries. Some categories of S&T graduates are also having trouble entering the labour market even whilst industry reports shortages for S&T personnel in knowledge intensive sectors or that skilled workers lack the "right" skills. This background report analyses the existing data on supply and demand for S&T personnel in OECD countries in order to draw out the implications for policy.

Categorisation of S&T personnel

The OECD *Frascati Manual* and the OECD *Canberra Manual on the Measurement of Human Resources Devoted to Science and Technology* form the core of a statistical framework to categorise, collect and analyse data on science and technology personnel at the international level. While educational and activity-based classifications have long been in use, these are now joined by efforts to systematically collect and analyse data on where science and technology personnel are employed by occupation or sector. In the simplest formulation, there are four ways to classify science and technology workers: i) by qualification, ii) by activity, iii) by sector and iv) by occupation (see Box 1).

Box 1. Categories of science and technology personnel

By qualification: Science and technology workers can be classified according to their qualifications, specifically by their level of educational attainment and field of study. These qualification-based classifications are the major source of information on the supply of science and technology personnel. The *International Standard Classification of Education* (ISCED) provides the standard categories. According to the Canberra Manual, the main ISCED qualification or educational levels recommended for categorising the science and technology labour force are: ISCED Level 5 or holders of non-university tertiary level degrees (which includes vocational and technical degree programmes); and ISCED Levels 6 and 7 or holders of basic university degrees up through university PhDs. This may change somewhat as the Revised ISCED 1997 classifications are introduced. The Canberra Manual recommends five main ISCED fields of study covering graduates in science and technology: natural sciences, engineering and technology, medical sciences, agricultural sciences and the social sciences.

By activity: The OECD's Frascati Manual defines *Researchers* as scientists and engineers employed in research and development activities. For those countries that compile data by qualification only, data on university *graduates* are used as a proxy. *R&D personnel* are all persons employed directly in R&D as well as those providing direct services such as R&D managers, administrators and clerical staff. Even though this measure includes workers who are not scientists, it does have advantages over considering researchers in isolation: technical and support staff are often critical to the performance of researchers as a unit. R&D personnel can be broken down by level of education or by broad occupation; i.e. professionals, technicians and other supporting staff. R&D personnel are expressed in terms of full-time equivalent (FTE); thus, more people may be involved in this activity than are counted by this measure.

By sector: At the broadest level, personnel can be classified as working in the government, higher education or business enterprise sectors. Within the business enterprise sector, S&T personnel can be classified according to the industry in which they are employed, for example, manufacturing, mining, services, agriculture, etc. The basis for comparison among countries is the *International Standard Industrial Classification* (ISIC-Rev 3) developed by the United Nations. In the countries of the European Union, the NACE-Rev 1 classification has been made reasonably consistent with ISIC-Rev 3. In the United States and Canada, the SIC categories are not generally comparable except at an aggregate level and must be translated into the ISIC standard for cross-country comparisons by national statistical agencies. Within manufacturing, the OECD has developed a categorisation of sectors by their research and development intensity, based on the ratio of indirect and direct R&D expenditures to production. Manufacturing sectors are divided into four broad groups: high-technology (e.g. aircraft); medium-high technology (e.g. motor vehicles); medium-low technology (e.g. shipbuilding); and low-technology (e.g. textiles). Although science and technology personnel can be employed in any sector, it can be assumed there is a higher concentration of these workers in the higher-technology sectors.

By occupation: S&T personnel can be classified according to occupational categories derived from the *International Standard Classification of Occupations* (ISCO) as defined by the International Labour Office (ILO). According to the Canberra Manual, the relevant ISCO occupations for S&T are as follows: Group 2 Professionals (ISCO 21: Physical, Mathematical and Engineering Science Professionals; ISCO 22: Life Science and Health Professions); Group 3 Technicians and Associate Professionals (ISCO 31: Physical and Engineering Science Associate Professionals); and some subcategories of Group 1 Legislators, Senior Officials and Managers (i.e. ISCO 122, 123 and 131). At present the Canberra definition of HRST includes persons who are employed in an S&T *occupation* (e.g. general managers) but who may lack tertiary level education which raises some methodological challenges. As a result, recent analysis has tended towards eliminating all or most categories of managers (e.g. general managers).

Source: OECD

Most meaningful analyses of trends in science and technology labour markets combine one or more classifications, for example, qualification and occupation. This is used to identify the qualifications and skills needed for different types of jobs. Combining data on workers by occupation and industrial sector indicates what types of workers are being employed in different industries, e.g. computer programmers in

the chemical industries. However, as yet, such approaches are not totally harmonised across OECD countries and efforts continue to refine the categorisation of science and technology personnel.

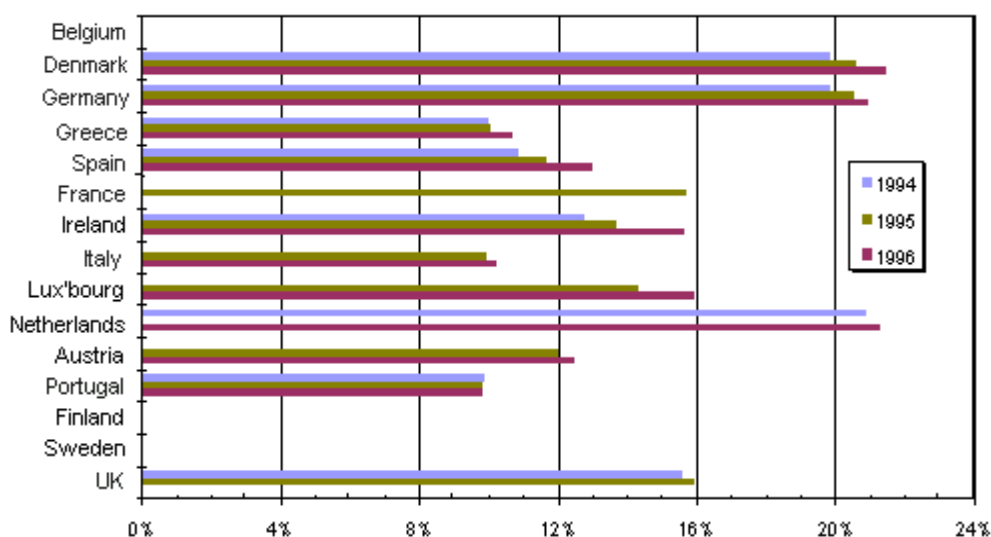
Categories of S&T personnel and "skilled workers"

Recent concern about shortages of some fast-developing fields such as information technology, environmental technology and biotechnology has raised the question of measuring the stock of skills, given that strict occupational categories are unlikely to capture the jobs that are in demand. The term "skill" refers to the qualifications needed to perform certain tasks in the labour market according to occupational classifications. The OECD uses the ISCO-88 classification as a proxy for categorising occupations by four broad skill levels (*white collar high skill* through *blue collar low skill*). Of these, the category most pertinent to science and technology is the white collar high skill. While analysis of skill levels can provide information on trends in the overall upskilling of employment by sectors it cannot give an indication of demand of specific categories of S&T personnel (e.g. molecular biologists, systems analysts) but it does tell us whether the skill intensities of sectors most likely to employ such S&T personnel are changing.

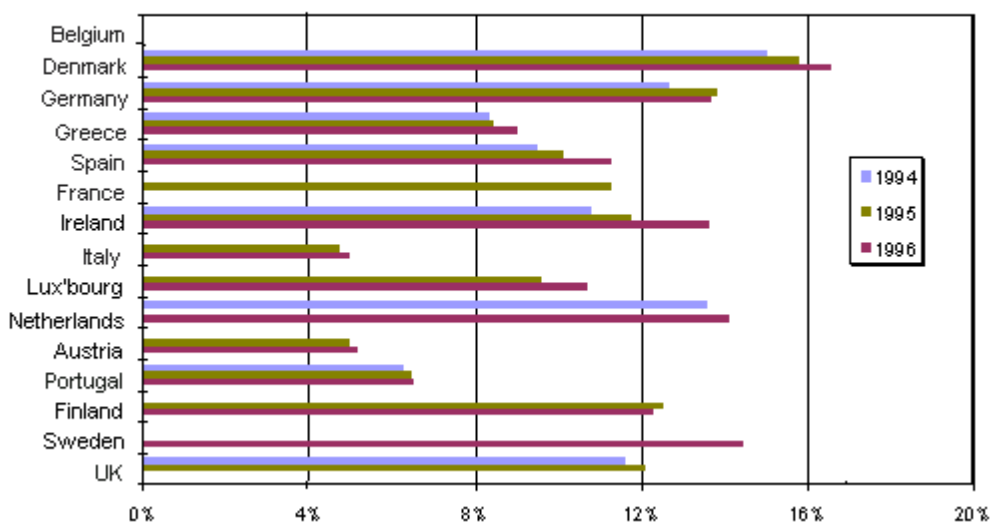
What are the size and characteristics of the S&T population in OECD countries?

As part of the joint OECD/Eurostat project on developing new indicators for science and technology, progress has been made in building internationally comparable indicators on *Human Resources in Science and Technology (HRST)*. This indicator concerns persons in the labour force who have an S&T occupation or have completed tertiary education. Data from the Community Labour Force Surveys compiled by Eurostat suggest that the stock of S&T personnel represents between 15% and 20% of the population in Denmark, Germany, France, Ireland, Luxembourg, the Netherlands and the United Kingdom (Figure 1). In 1996 the stock of the S&T personnel defined according solely to level of tertiary education (ISCED 5-7) was over 10% of the total population for most of the countries surveyed and significantly higher in France, Germany, Ireland, the Netherlands, Sweden and Denmark (over 16%) (Figure 2).

**Figure 1. Human Resources in Science and
(as a percentage of total population)**



**Figure 2. HRST with a third level education
(as a percentage of total population)**

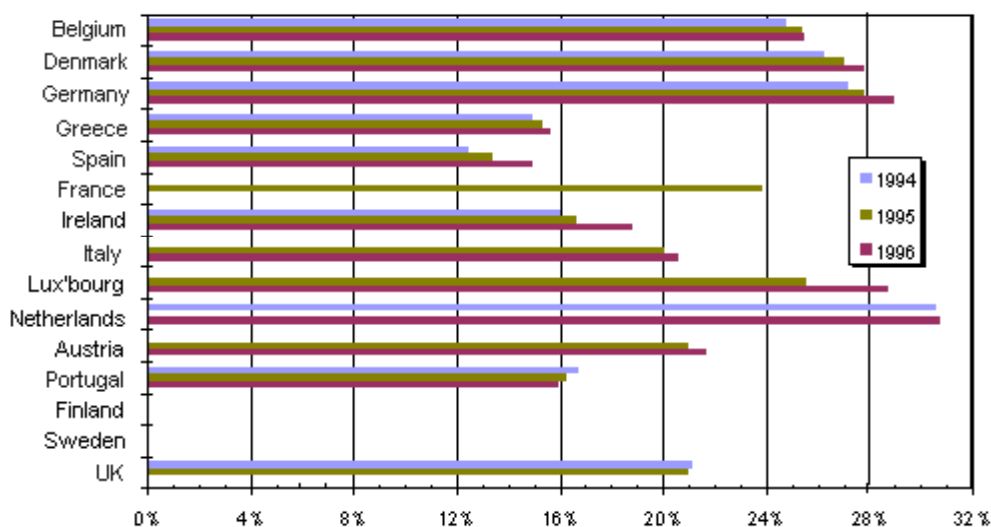


Source: Figures 1 and 2: Eurostat, 1998a.

What is the share of S&T personnel employed and unemployed?

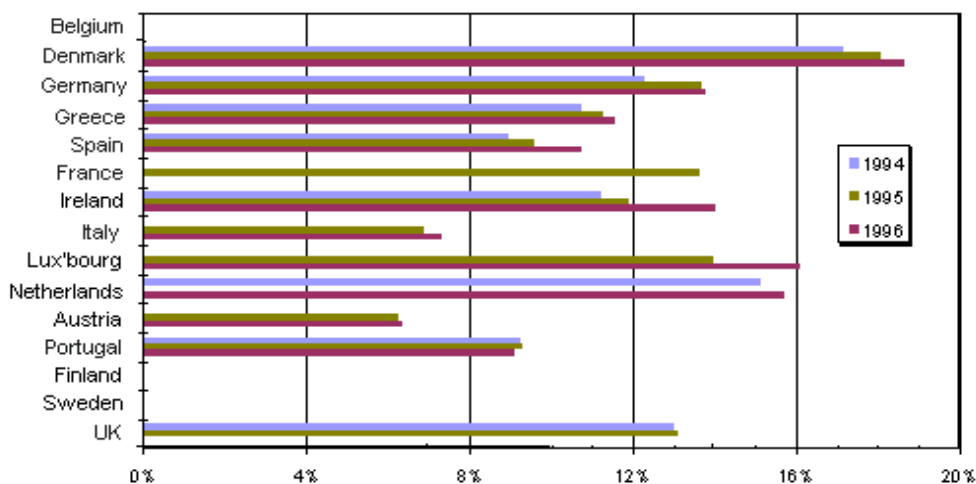
Figure 3 shows that persons working in an S&T occupation (defined as ISCO 2 and 3) accounted for 20-30% of the labour force (i.e. only those employed or not employed but actively seeking work) in the EU countries surveyed. In addition, the "core" of the S&T population, those having attained tertiary level education *and* working in an S&T occupation varies significantly across countries, with less than 8% of the labour force in Italy and Austria and up to 12% in Germany and Denmark (Figure 4). However, if one only considers the share of ISCO 2 occupations with tertiary education, there is a clear correlation between professional occupations and the level of education; 68% of Italian and 84% of German professionals had completed tertiary education. Consequently, the low overall shares of "core" S&T personnel in the labour force of a number of countries suggests that the match between initial qualifications and occupation is less consistent in ISCO 3 occupations. In other words, more people working in technician and related occupations have not completed tertiary level education.

Figure 3. Persons employed in an S&T occupation - HRSTO
(as a % of the labour force)



Source: Eurostat, 1998b.

Figure 4. HRST with third level education and employed in an S&T occupation - HRSTC (as a percentage of the labour force)

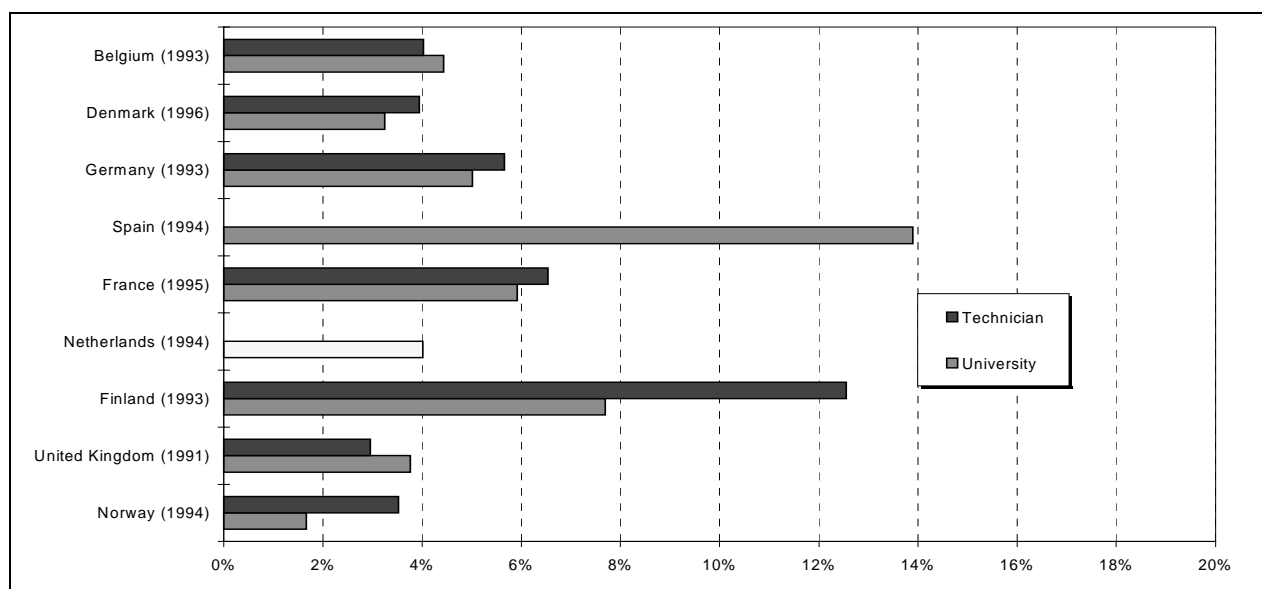


Source: Eurostat, 1998b.

Figure 5 indicates the share of S&T workers with tertiary level education (i.e. technicians and university-level graduates) that were unemployed at the time of the surveys in selected European countries. With the exception of Finland, the proportion of technicians classified as unemployed differed only slightly from that of workers with university degrees in science and technology. The total unemployment rate for technicians and workers with university degrees in science and technology in 1993 was slightly over 5% in Germany but more than 13% for technicians in Finland. In 1995, French technicians had a slightly higher unemployment rate than French workers with university degrees in science and technology. Figure 6 shows the share of S&T workers with university level qualifications who were unemployed in selected European countries. University degree holders in social sciences and humanities had higher unemployment rates than graduates in S&T (engineering and technology; natural, medical, and agricultural sciences) in Belgium,

Spain, France, and the United Kingdom. The high rate for Spain parallels the high unemployment rates for youth and the total labour force at the time.

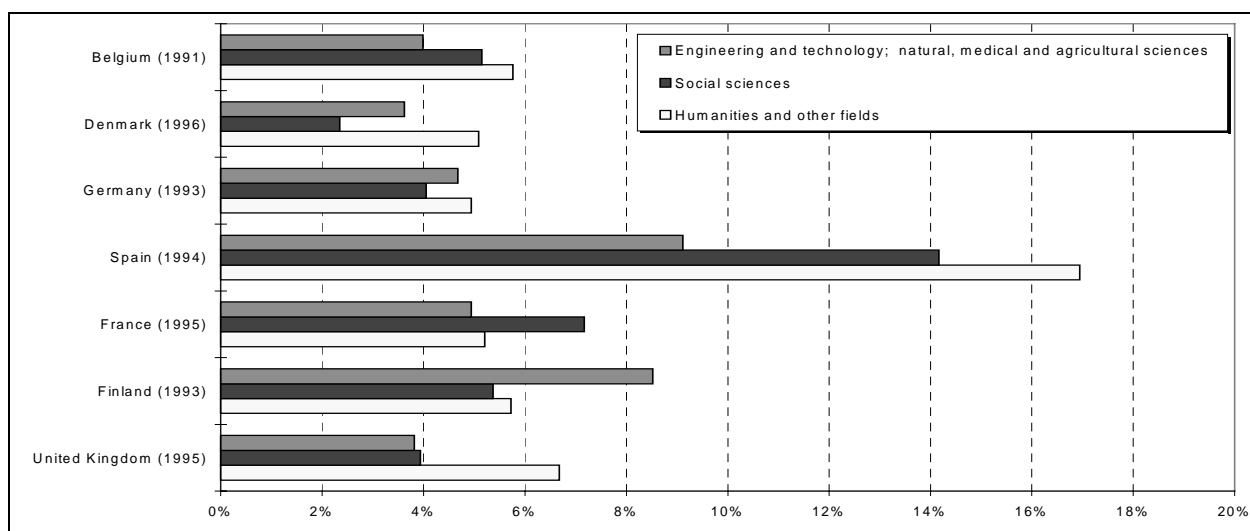
Figure 5. Share of HRST with tertiary education and unemployed,¹ various years



1. Data has been adjusted to remove those aged over 60. For the Netherlands, a breakdown of data is unavailable. Data for Spain includes only university HRST.

Source: Eurostat, 1998b.

Figure 6. Share of HRST with university level education and unemployed, various years



Source: Eurostat, 1998b.

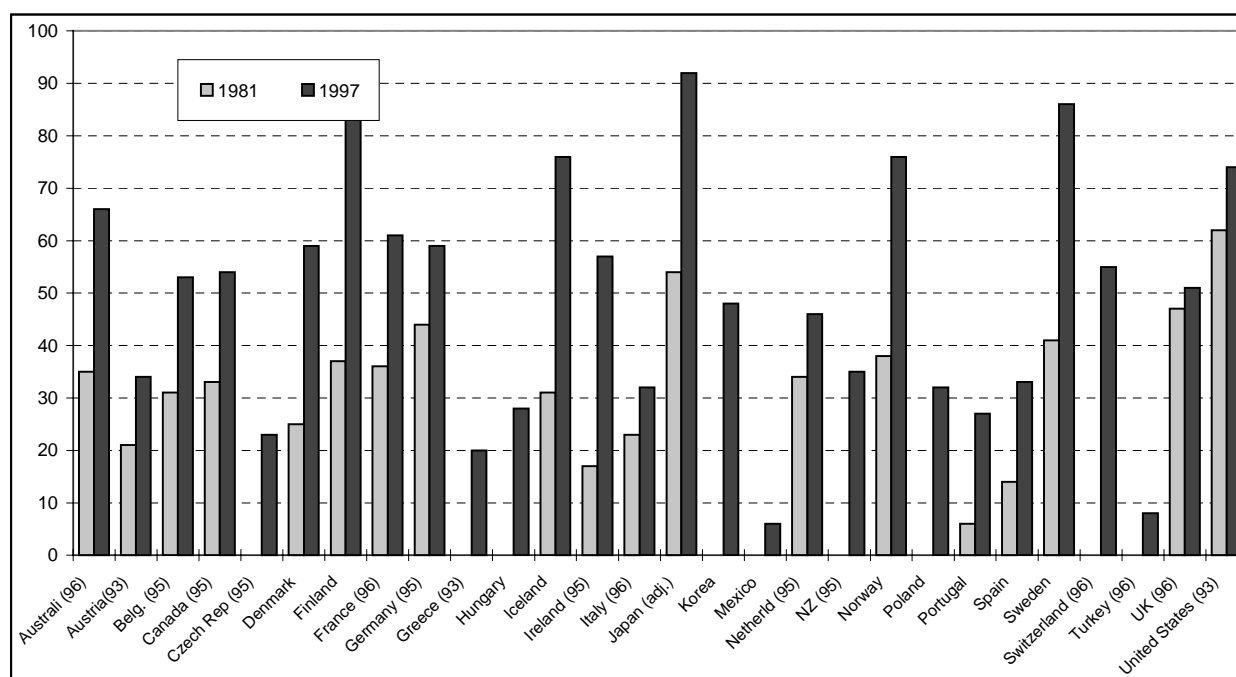
Growing demand for researchers and research personnel in the business sectors

International labour force data on the stocks of S&T personnel in employment prior to 1994 are not comparable with earlier surveys. It is thus not possible to construct a time series for employment demand

for S&T personnel as defined above. On the other hand, R&D surveys provide information on demand for *Researchers* and *Research personnel* (both subsets of the HRST population) since the early 1980s. There has been a continuous growth in the number of researchers since the early 1980s, although the growth rate slowed in the early 1990s, primarily due to lower expenditures on research and development in the United States. In a number of countries, there has been a decline in the number of researchers over the past five years, notably in the Czech Republic and Hungary, which is associated with a restructuring of their science systems. However, preliminary national data suggest this trend in the Czech Republic is being reversed. As regards the share of researchers in the labour force, all OECD countries for which data are available recorded strong increases between 1981 and 1997 (Figure 7). Finland for example nearly doubled the number of researchers as a share of the labour force. Australia, Japan, Norway and Sweden have made dramatic increases while larger European countries notably Germany, Italy and the United Kingdom made smaller gains in the 1980s and 1990s. This indicator also reflects strong progress in employment of researchers made by smaller economies such as Denmark, Iceland, Portugal, Spain and Greece. Since the late 1980s, the total number of *Research personnel* per 10 000 labour force has grown steadily in the OECD area. Spain, Belgium, France and Japan experienced strong growth during this period, while there was a small decline in the United Kingdom. Ireland, garnering the fruits of investment in technology and human capital, has seen strong annual growth in R&D personnel since 1987.

Most *researchers* in Japan, the United Kingdom, Germany and the United States are employed in the business sector, which has continued to increase since the mid-1980s (Figure 8). Germany, however, experienced a drop in the mid-1990s both in the number and share of researchers working in the business and government sectors. Japanese researchers are mainly employed in the business sector with a decreasing share working in higher education and government. The number of researchers in the US business sector-- which employs around 80% of US researchers -- also experienced a small drop but this is currently on the upswing as increases in R&D expenditures and the economic expansion increase demand. Employment in the French business and higher education sectors expanded in absolute numbers, but the overall distribution has remained broadly stable with slightly more researchers in business followed by the higher education and government sectors. In Australia and in a few European countries including Italy and Spain, researcher employment has been greater in the public research sector since the mid-1980s.

Figure 7. Number of researchers per 10 000 labour force in 1981 and 1997 (or closest year)



Source: OECD, STI databases, May 1999.

Figure 8. Number of researchers by sector of employment, 1985, 1990, 1997 or nearest years available

Expressed in thousands of full time equivalent

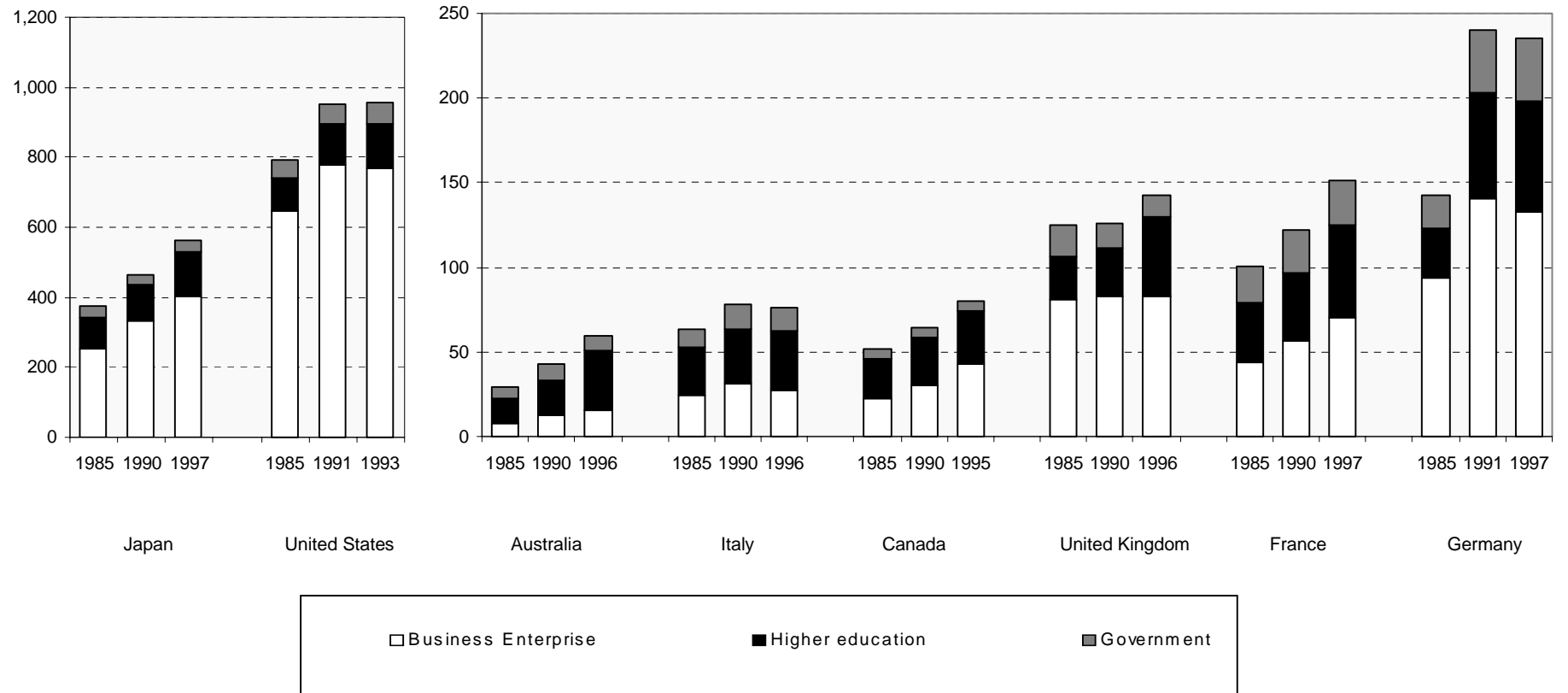
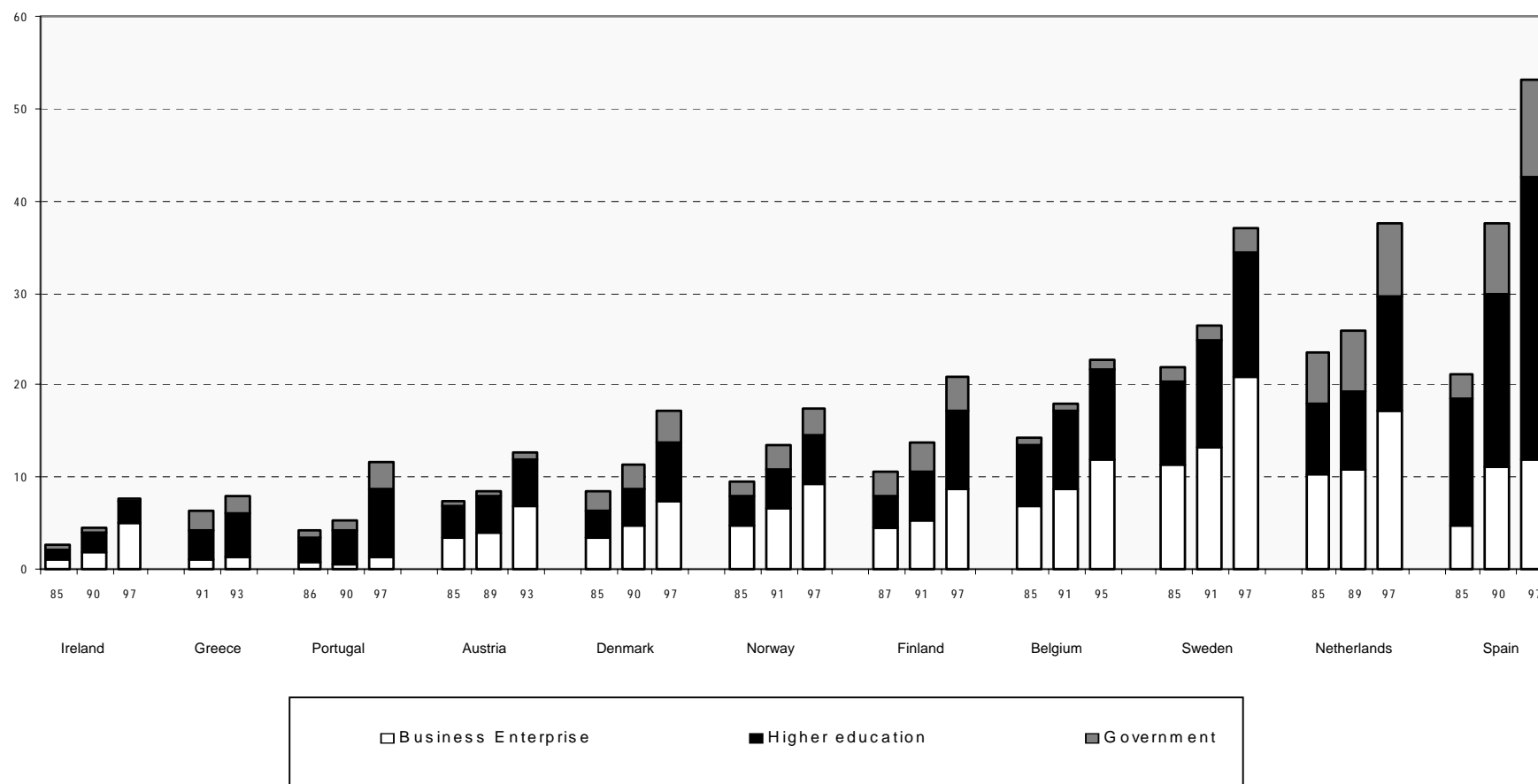


Figure 8 (cont'd). Number of researchers by sector of employment, 1985, 1990, 1997 or nearest years available

Expressed in thousands of full time equivalent



Source: OECD, R&D databases (STI, EAS Division), October 1999.

Growing demand for S&T personnel: evidence from industry and service sectors

While the above indicators tell us there is growing demand for *researchers* in the business sector, they do not tell us which specific occupations and industries are using scientific personnel more intensely. An analysis of census data on employment growth by S&T occupation and industry according to a more restrictive definition of S&T personnel limited to scientists, engineers and technicians (ISCO 21-22; 31-32), shows employment grew faster for S&T personnel than for all other occupational categories in manufacturing and market services during the 1980s (Figure 9). This holds true even in low and medium-low technology sectors, confirming the overall employment shift towards higher skilled workers. While in Italy and Japan, employment growth in the high technology manufacturing segment was positive for all occupations, in France only science and technology occupations expanded in high-technology industries on average between 1982 and 1990. Another observation is that in several countries, low-technology industries, while continuing to decrease overall employment, expanded their use of scientific labour at a faster rate than firms in medium-high technology industries. In relative terms, science and technology occupations still represent a very small share of total occupations in low technology industries, which are dominated by lower skilled jobs. But as low technology sectors increase their use of technology, demand for skilled workers will increase.

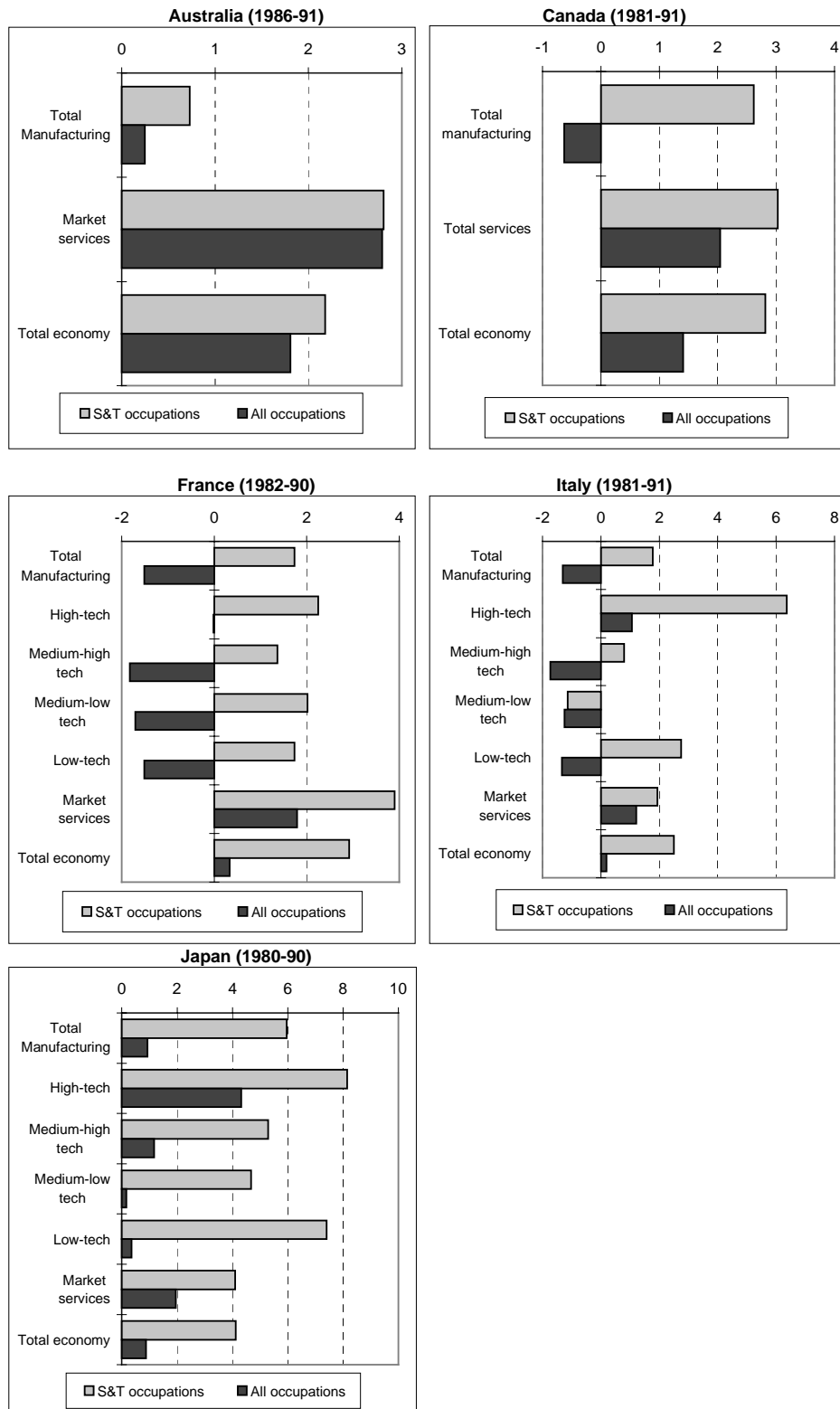
Expansion of service sectors increases demand for S&T personnel

In the 1980s and early 1990s, employment growth of S&T personnel in services outpaced the general shift of employment from manufacturing towards the services in OECD countries. While recent data at the OECD-wide level is unavailable, many of the fastest growing services sectors, such as software and telecommunication services, employ a large number of science and technology workers. Survey data on mobility in Norway show that the business service sector recruits and supplies skilled labour to a broader number of sectors branches than any other sector (OECD, 1999a). In the US, the computer and data processing services sector is among the fastest growing segments of the US economy, employing the largest number of software workers of all industrial sectors in 1996 (Johnson and Bobo, 1998).

The expansion of electronic commerce and related knowledge-intensive business services will increase demand for S&T personnel in services. In the United States, three service sectors -- transportation, communications and utilities; wholesale trade; and retail trade -- already account for over 80% of employed scientists and engineers in services.

Further evidence of the potential growth of S&T personnel in services emerges from OECD data on the increasing share of services in total business R&D. One third of business R&D in Australia, Canada, Denmark and Norway, is performed in services. This figure is around 20% for Italy, the Netherlands, the US and the UK (OECD, 1999b). Because continued growth in services R&D increases demand for S&T workers, education and training curricula will have to adapt to prepare S&T graduates for the services sector where closer customer interactions require non-technical skills as well.

Figure 9. Employment growth of S&T¹ and all occupations, by industry
Compound annual growth rate over period in percentage



1. S&T occupations are defined as ISCO-88 groups 21, 22, 31 and 32.
Source: OECD Secretariat estimations from national data.

The impact of information and communication technologies on demand for S&T personnel

What impact is technology, in particular information technologies, having on the quantity and quality of the skilled labour force, in particular for S&T personnel? Is growing demand for example in the IT producer industries combined with demand from IT-user industries (e.g. financial services, retailing and distribution, electronic commerce, etc.) outstripping supply of S&T personnel with IT skills? Research at the firm-level in several OECD countries suggests technology adoption and employment are positively related whereby increased use of technology leads to greater demand for skilled workers relative to the unskilled. At the sectoral and economy-wide level, the effects of technology are much more diffuse and indirect but as illustrated in Figure 9 above, technology is accelerating the upskilling of the OECD area labour force (OECD, 1999). As regards the impact of IT on the demand for S&T personnel, Table 1 shows the strong increase in employment in the United States, Canada, France and Finland of software and computer-related services professionals, a small but important group of S&T personnel. In Europe, although there has been a stagnation or decline in growth in IT employment (more broadly defined), the demand for IT skills in the software and applications industries is also increasing. But reports of shortages of S&T personnel with IT expertise (i.e. computer scientists and engineers, systems analysts and computer programmers) would seem to suggest demand is outstripping supply. Indeed, a recent OECD report on the economic impact of electronic commerce cited estimates of shortages for IT skills in Germany (60 000), Canada (20-30 000) the UK (20 000) the United States (400 000) with a worldwide estimated shortage of 600 000 IT jobs (OECD, 1999).

While some shortages are related to short-term demand factors such as the *Year 2000* conversion problem, the question of IT skill shortage is much more complex because demand for "IT skills" extends beyond demand for S&T personnel with specific IT skills (e.g. *Year 2000* specialists). In other words, skilled individuals *without* qualifications in IT strictly defined are working in IT-related occupations. Already in 1995, according to data from the US National Science Foundation SESTAT database, only slightly over 40% of workers in computer software engineering had a university level degree in engineering. Many IT professionals come from non-computer science backgrounds, notably engineering and mathematics, others still come from non-university tertiary education. Of course, there is a clear demand side effect where in a tight labour market it becomes necessary for firms to invest in training individuals without "formal" qualifications in science and technology. S&T workers attracted by demand and high paying jobs also move into IT jobs, but this could be at the expense of other technical fields including public research. In some countries where labour markets are not functioning well, skills shortages may also be the result of the *underemployment* of S&T personnel.

Table 1. Employment growth in software and related software and computer-related employment-services

	United States	Canada	Japan	France	Finland
1992	838,334	72,024	488,469	151,347	16,200
1993	894,256	79,021	445,662	147,881	17,000
1994	955,094	99,056	424,867	153,329	16,500
1995	1,083,977	123,312	407,396	158,544	17,400
1996	1,233,263	NA	NA	NA	NA

Source: OECD and ITAA1998b.

As software and other sectors draw more and more workers from non-IT fields to fill demand, the match between qualifications (degree level/field) and occupational categories will become increasingly blurred. The impact of demand for IT skills will also be felt in user sectors. Some 75% of US software workers for example already work in non-software industry segments. As information technologies become more standardised and pervasive, a sort of democratisation of IT skills occurs in user-sectors so that learning certain IT skills can be achieved in a relatively short time and increasingly outside the domain of tertiary education institutions. This raises several policy implications. First, while S&T personnel are critical for the creation and development of the IT sectors, there is a growing demand for IT skills in users sectors which recruit a variety of S&T and non-S&T personnel. One implication is that increasing the supply of "computer scientists" may not automatically solve the IT "skills" shortage issue. What is needed then is the continual upskilling of workers and adjustments in education systems so that they provide graduates with the necessary (generic) skills for adapting to ever-changing IT skill requirements. Second, these effects of IT on the labour market for S&T personnel imply a greater role for public/private partnerships in upgrading the existing skilled labour force. However, this raises other issues too, as training in IT skills entails higher costs relative to training in non-technical skills for education institutions, firms, and individuals. In many ways, while the impact of IT on skills and labour force appear confined to key knowledge intensive sectors, they may signal further changes to come for all S&T workers and more broadly for all high skilled workers.

Indeed, higher education can no longer be viewed as the exclusive source for IT skills. Industry and trade associations have a role to play as do lower level educational establishments, including institutions for secondary education. While the debate on the shortage of IT workers remains open, a principal benefit is that it has raised awareness among policy makers about the challenges that lie ahead in the education and training of workers for the knowledge economy.

The end of traditional employment for S&T personnel?

Globalisation and enhanced competition place greater demands on flexibility and regulatory reform in product and labour markets. As a key component of R&D investment, the allocation of S&T personnel is not immune to these pressures. As firms restructure R&D departments and increase outsourcing, temporary work arrangements are on the rise. In the United States, technical staff accounted for 14% of all temporary contract staff in 1996, an increase of over 4% since 1992. This externalisation of the labour market for S&T personnel reflects the needs of firms for more flexible forms of employment in order to resolve short-term human capital needs and to respond to changing market demands. In addition, structural factors such as the concentration and mergers in knowledge-intensive industries (e.g. biotechnology and semiconductors) could increase demand for temporary employment of S&T personnel. The risk of failure for start-up companies and the loss of capital associated with delays or technical setbacks may also prompt demand for temporary staff who work only as long as the company needs them. For S&T personnel, particularly new graduates, temporary employment is also a way to gain experience in a variety of areas. For employers, temporary contracts allow the screening and training of future permanent staff.

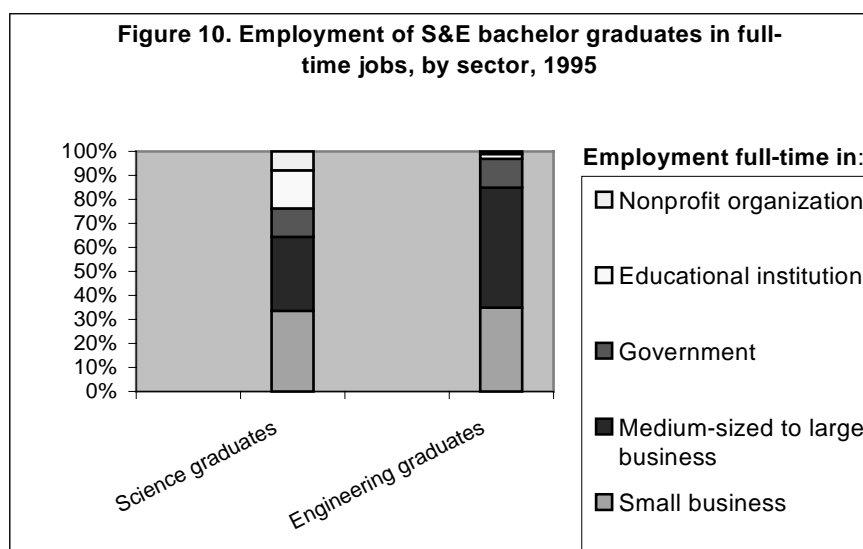
A 1998 survey of 5 000 R&D performers in North America found that almost 50% of the companies surveyed indicated that they use the services of professional contract staff. In addition, data from one of the largest temporary scientific staffing agencies in North America shows that temporary R&D staff is particularly important in sectors such as pharmaceuticals and cosmetics, biotechnology, clinical research and food and beverages (*R&D Magazine*, 1998). In the IT field, a survey by Coopers and Lybrand showed 75% of IT firms surveyed were using consultants and temporary contract employees to fill the shortage of IT workers and to respond to *Year 2000* conversion problems. The trend in temporary employment has implications for companies that must balance filling short-term needs with attracting and retaining quality employees. The increase in hiring foreign S&T personnel in areas such as software development also

appears on the rise in the US, according to anecdotal evidence and data on visa applications, even if this mainly concerns larger firms (ITAA, 1998a).

Changes in the private sector are also having an impact on employment in the public research sector. In some OECD countries, there has been an increase in the privatisation of research institutes and government laboratories or of state-owned firms with large research departments (e.g. telecommunications) which is having an impact on the allocation of S&T labour. As industry-public research linkages increase, public research organisations, like firms, increasingly rely on the flexibility of temporary employment to access specific expertise. In Japan, for example, a large number of young S&T personnel in the public research sector are employed in non-tenured posts or part-time positions. This trend towards more flexible employment arrangements in the public research sector is also observed in the United Kingdom and the United States where there has been an increase in graduates entering non-tenure and temporary academic employment. Labour market conditions play a role but these trends most likely reflect university requirements for flexibility, mobility, and the lowering of high costs associated with tenured employment.

SMES and demand for S&T personnel

What role do small and medium-sized firms play in the employment of S&T personnel? Data from the United States National Science Foundation show SMEs are a main employer of recent graduates in science and engineering. As a group, small business hire as many recent S&E graduates as do larger ones, while engineering graduates tend to find work in medium to larger-size firms. As might be expected, a slightly greater share of science graduates find employment outside industry (i.e. government, education, non-profit organisations) than do engineers even if most recent science and engineering graduates find employment in the private sector (Figure 10). Insofar as knowledge-intensive SMEs are closely tied to the rapidly growth sectors such as biotechnology, telecommunications, and computer software-related technologies, it is likely that small businesses will continue to play an important role as employers of S&T staff. Indeed, the continued creation of new firms and jobs in knowledge intensive sectors such software and biotechnology depends heavily on an adequate supply of scientific and technological personnel and its matching to market demand through flexibility and mobility in labour markets. One implication is that if employment generation through the formation of new innovative firms is weak, this could lead to weak or depressed demand for S&T personnel. For example, in countries where S&T employment is concentrated in the public sector, cutbacks and weak firm creation in the industrial sector might result in higher unemployment or *underemployment*. More research is needed to better understand the relation between S&T labour and innovative SMEs. In the future, industry data on employment could be analysed to examine whether any significant employment changes have taken place in small high tech firms (even if this data would only provide a picture of the situation in a given year and not capture the dynamics of job creation/destruction).



- The survey included recent college graduates who had received their degrees between July 1, 1992 and June 30, 1994 and were surveyed in April 1995. Medium-size to large businesses are defined as for-profit firms with 500 or more employees. Small businesses are for-profit firms with less than 500 employees and self-employment individuals.

Source: National Science Foundation/Issue Brief May, 1999.

ADEQUACY OF THE SUPPLY OF S&T PERSONNEL

Trends in the supply of new S&T graduates

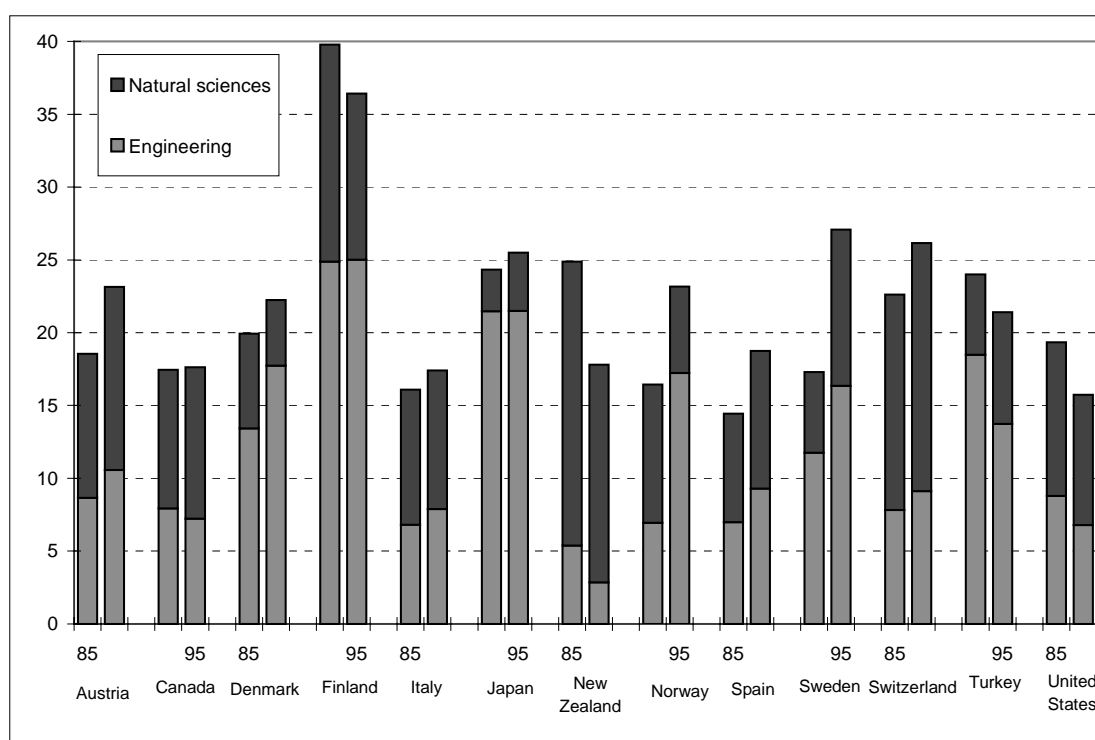
How effective are educational systems in ensuring an adequate supply of S&T personnel in OECD countries? An adequate supply both in quantitative and qualitative terms (i.e. the right skills) is crucial for firms to innovate. But the supply of S&T personnel is driven by several factors including higher education policies (e.g. funding, access issues), demographic patterns as well as wages. Because of the lead-times associated with training and educating people in science and technology, there may be a considerable time lag between the point when a shortage or surplus of workers in a certain field appears and the corresponding supply response. Firms that encounter bottlenecks in the supply of S&T personnel face higher costs in investing in innovation. A well-functioning labour market would give strong price (wages) signals that there is a shortage in certain S&T occupations, and firms and workers would have an incentive to invest more in relevant training. From a purely quantitative perspective, OECD countries have made significant strides in increasing the number of graduates in science and technology, especially in "catching-up" countries such as Korea but also in Portugal, Spain and Greece.

But differences remain and Finland, Sweden, Switzerland, Japan and Norway lead the OECD area in the production of science and engineering graduates as a *share* of total graduates. Figure 11 shows that in recent years, the share of science and engineering graduates as a percentage of all university graduates has fallen in the United States, Finland, Turkey and New Zealand (even if it increased in absolute numbers)

implying that the number of graduates in other fields (e.g. law, business administration, etc.) is growing faster¹. Survey data from the United States show for example that the number of doctoral graduates in natural sciences and engineering reached an all time high in 1995 with engineering PhDs graduates increasing by close to 23% since 1990. However, there is a concern that falling doctoral enrolment rates could signal a reversal of this trend in the near future. Declining shares of graduates in S&T relative to other fields suggests that demand signals may not be strong enough to attract students to enrol in science and technology courses and this could raise the risk of shortages. While wages tend to be higher for S&T graduates, other factors such as regulatory barriers, low salaries in the public sector, length and cost of study, or a poor image of S&T relative to other fields could be disincentives in some countries.

Figure 11a. Supply of university graduates in natural science and engineering, 1985 and 1995

As % of university graduates in all fields

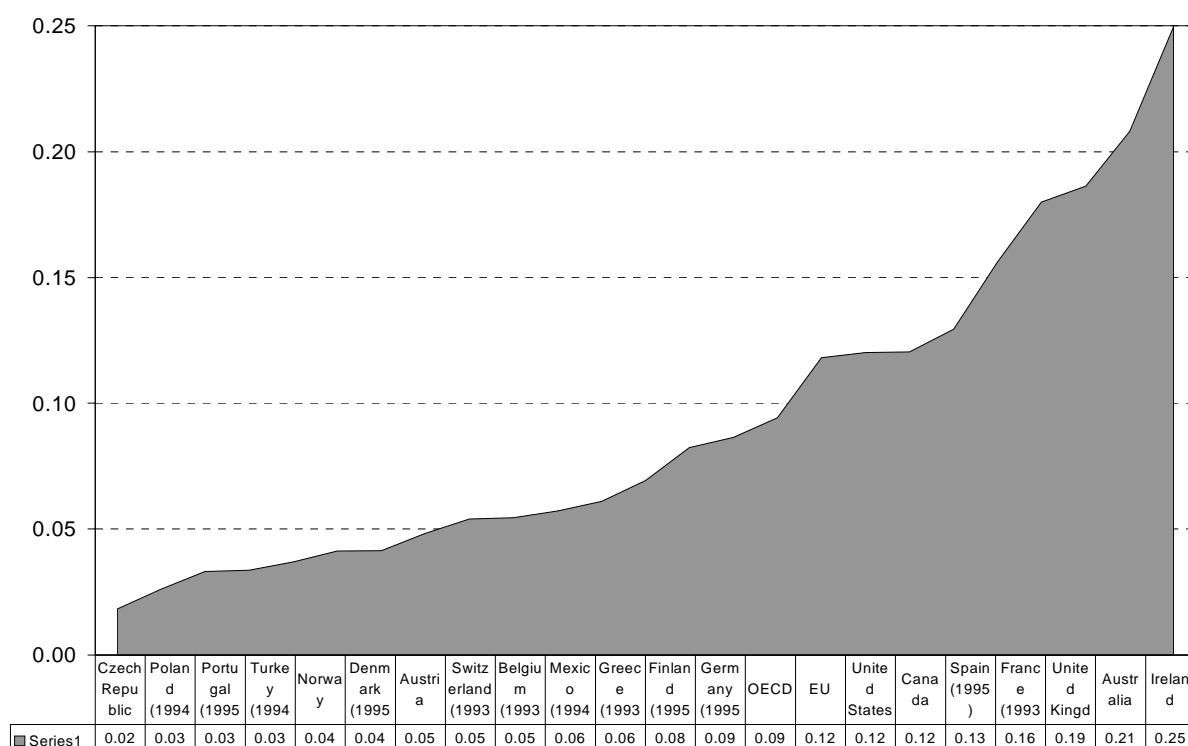


Source: OECD, Education at a Glance database, 1998. The figures for Norway do not reflect a change in data series resulting from including shorter-term engineering programmes. Adjusting for this change, the share of engineering graduates increases to 11% while that of natural scientists falls to 6%.

1. It should be noted that because of changes in surveys methods in 1992 which make it impossible to compare shares of graduates in all science and engineering fields as defined by the Canberra Manual with earlier data, this table only examines graduates in natural sciences and engineering (i.e. medical sciences are not included).

Data on labour market flows of S&T graduates show that Ireland, Australia, the United Kingdom, New Zealand and France have the largest shares of scientists and engineers entering employment. So while the leading countries in terms of the share of S&T graduates have a more “intensive production” of S&T graduates, these latter countries are increasing the stock in the workforce at a faster rate due in part to education policy measures, strong demand and large cohorts of young S&T graduates entering the labour

Figure 11b.
Flows of graduates in science and engineering, as a percentage of total employment
(1996 or latest available year)



force (Figure 11b).

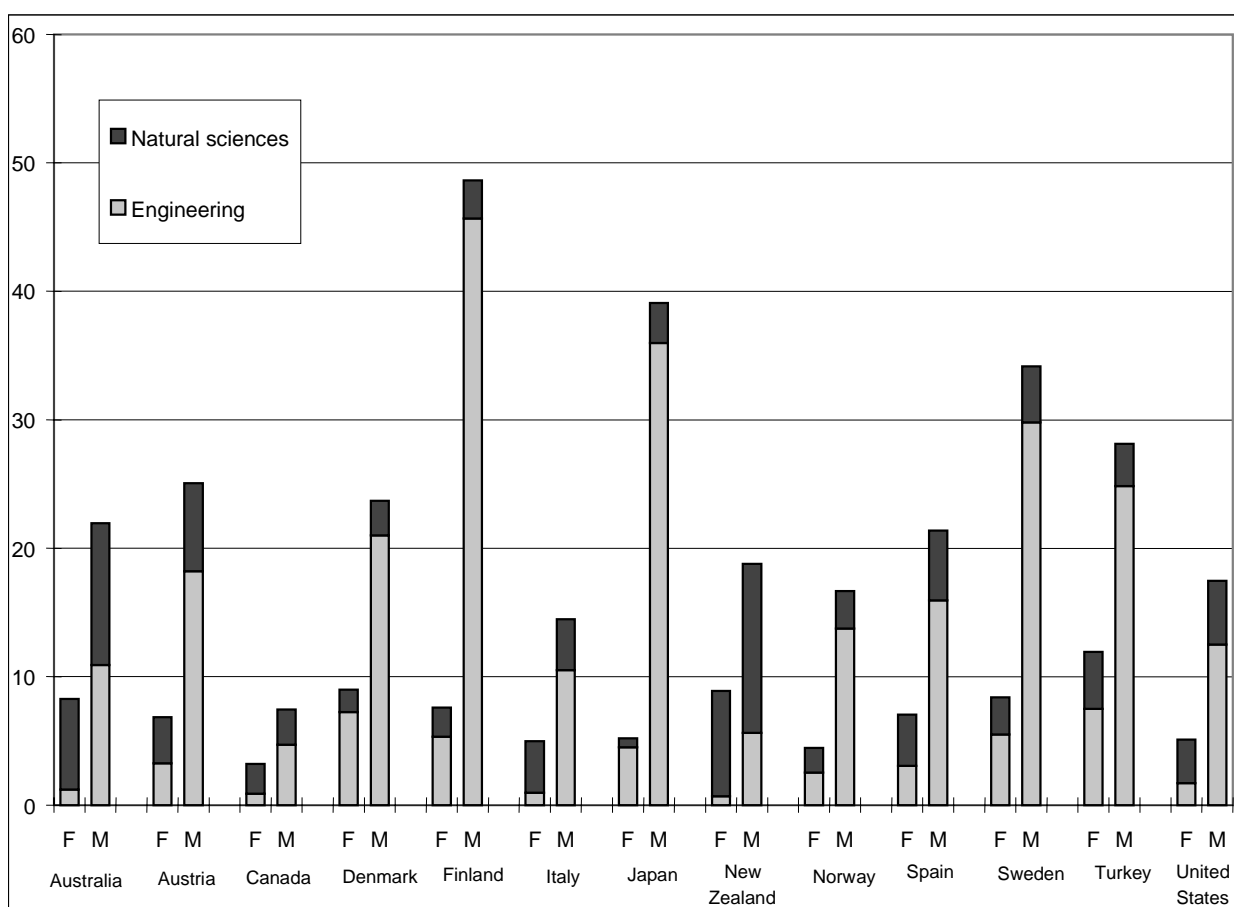
Source: *OECD Science Technology and Industry Scoreboard, 1999*. OECD calculations based on UNESCO data.

The persistence of the gender gap in the supply of S&T graduates

The distribution of the population with S&T qualifications among men and women is of major concern to policy makers, not least because of concerns of social equity but also because women represent the majority of new entrants into the labour force in many countries. While the proportion of women attaining higher education has continued to increase over the past decades, even to the point of surpassing the share of men attaining higher education in Norway, Sweden and France, women remain under-represented among graduates in science and technology across OECD countries. While this is particularly true among engineering graduates in all countries (Figure 12), women who graduate in science and engineering do so

mainly in natural sciences. This is the case in Austria, Canada, Italy, Spain, Turkey and the United States. The case of New Zealand where most science and engineering graduates (men and women) are in natural sciences illustrates the role national industrial and technological specialisation plays in the production of S&T graduates on both sides of the gender divide. A predominance of engineering among science and engineering graduates (both men and women) is equally observed in Denmark, Finland and Japan. At the doctorate level, where women are even more under-represented, graduate survey data from the United States show some progress for women in science and engineering. In 1988, women accounted for just 5% of PhDs in science and engineering but by 1995 this share had doubled to 10%. In France, women account for 37% of all university PhDs but they are concentrated in humanities and social sciences where course duration is shorter (Martinelli, 1999).

Figure 12. Supply of tertiary graduates (ISCED 5 to 7) in natural sciences and engineering by gender, 1995
As a percentage of graduates in all fields



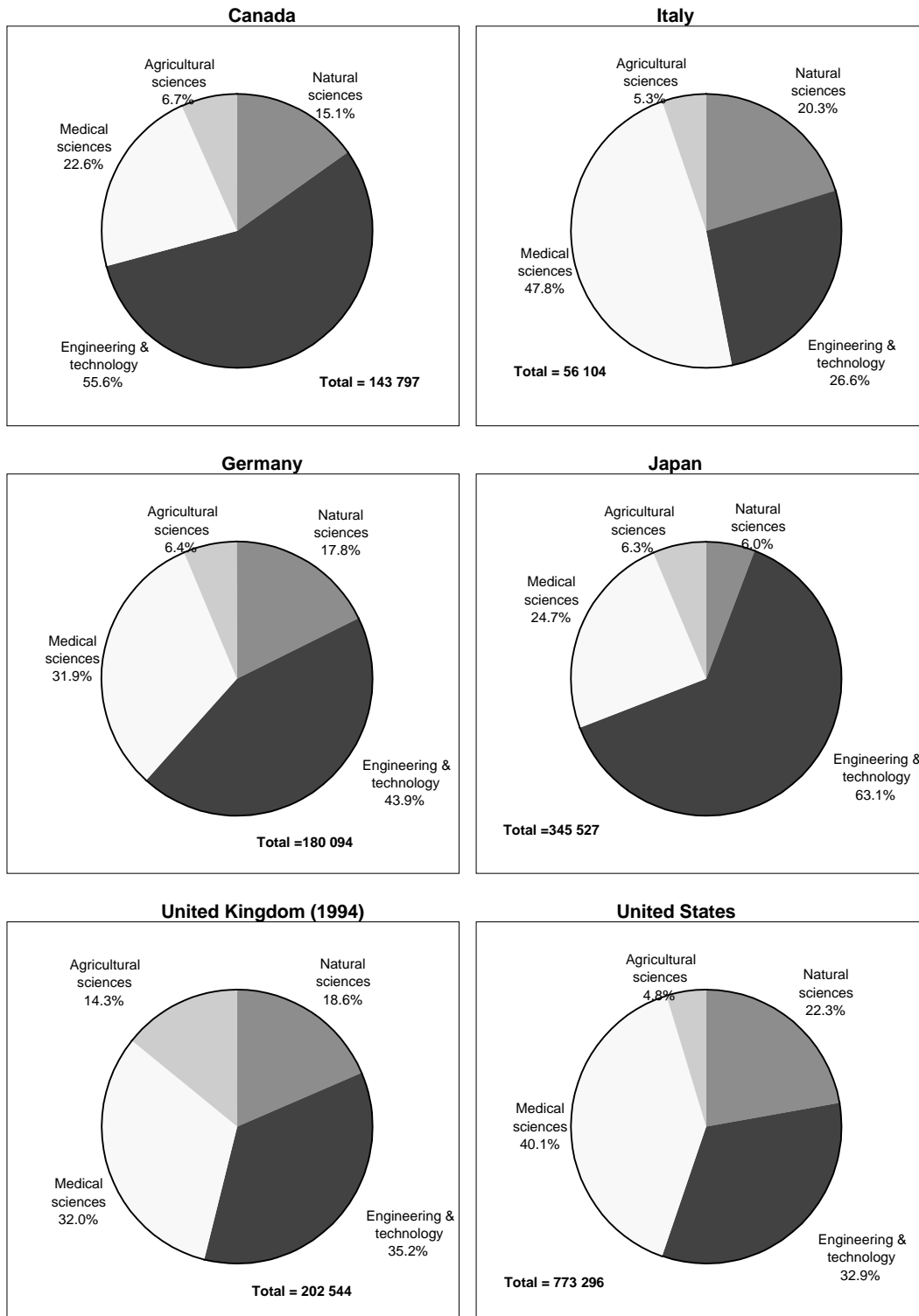
1. For Australia, ISCED 6-7 only.

Source: OECD, Education at a Glance database, 1998.

An analysis of the distribution of S&T graduates by field of study and by country in 1995 shows the relative specialisation within science and technology at all levels of tertiary education (Figure 13). Such data is important for monitoring trends in the supply of science and technology workers and the relevance of their education to job market needs. Germany and Japan show a high level of specialisation in engineering and technology graduates, while the United Kingdom shows a more even distribution among fields. In Japan this clearly reflects the industrial specialisation in production and technology development which draws more on engineering know-how than on scientific research. In Korea, 1994 data not included

in the chart below show a high specialisation in engineering graduates (64%) followed by natural and medical sciences. A breakdown by degree level shows that engineering graduates predominate among all tertiary level S&E graduates. Among PhDs, however, medical science graduates account for 35%. In other words, even if few graduates specialise in medical sciences overall, those that do account for a disproportionately high number of PhDs (Korean Ministry of Science and Technology, 1997). But the specialisation of countries within S&T fields must be placed in the context of overall specialisation. While most university level graduates in OECD countries are specialised in non-S&E fields (e.g. humanities, law and business) this varies greatly across countries. The share of graduates in science and engineering ranges from less than 30% in Canada, Portugal and the United States to over 45% in Finland, Germany and Switzerland. Thus in the case of Canada where specialisation within university S&E graduates is relatively strong in engineering, the numbers are low given that the total S&E graduates account for less than 30% of all university level graduates (OECD, 1998).

Figure 13. Number and distribution of S&T graduates (ISCED 5-7) by field of study,² 1995



2. Data for Italy concern only ISCED 6-7.

LABOUR MARKET PERFORMANCE OF RECENT S&T GRADUATES

Policy makers have only recently become concerned with the labour market performance of recent S&T graduates even if the producers of human resources in science and technology (e.g. higher education institutions) have devoted attention to this issue in response to cyclical peaks and troughs. Against a background of high youth unemployment in OECD countries coupled with growing demand for high skills, questions emerge such as how are S&T graduates performing in terms of employment and unemployment? What sectors are they finding work in? Answers to these questions are important because the labour market entry of S&T graduates affects the balance between supply and demand and also signals changes in the types of skills in demand. International data on the labour market entry of recent graduates by level of education and field of study are not readily available. But special employment surveys (e.g. youth employment surveys) as well as graduate surveys are an important source of information.

Overall, tertiary/university level graduates experience higher initial employment rates and less unemployment than those with only secondary education or less. As well, unemployment rates tend to fall with time especially for individuals with lower levels of education. Business cycles are also a factor in initial labour market entry as frictional unemployment tends to be higher among recent graduates in general. Long-term unemployment among the higher education graduates, notably S&T graduates, could signal structural problems in the labour market. The situation for individuals with tertiary/university level education, however, reveals some particularities. In the first year after leaving permanent higher education, the employment rate for women was actually slightly higher in Australia and Ireland (with corresponding lower unemployment rates). In France and especially Germany, women graduates had lower employment and higher unemployment rates than men. In the fifth year following graduation, unemployment for both men and women declined significantly even if women still had higher jobless rates in comparison to male university graduates.

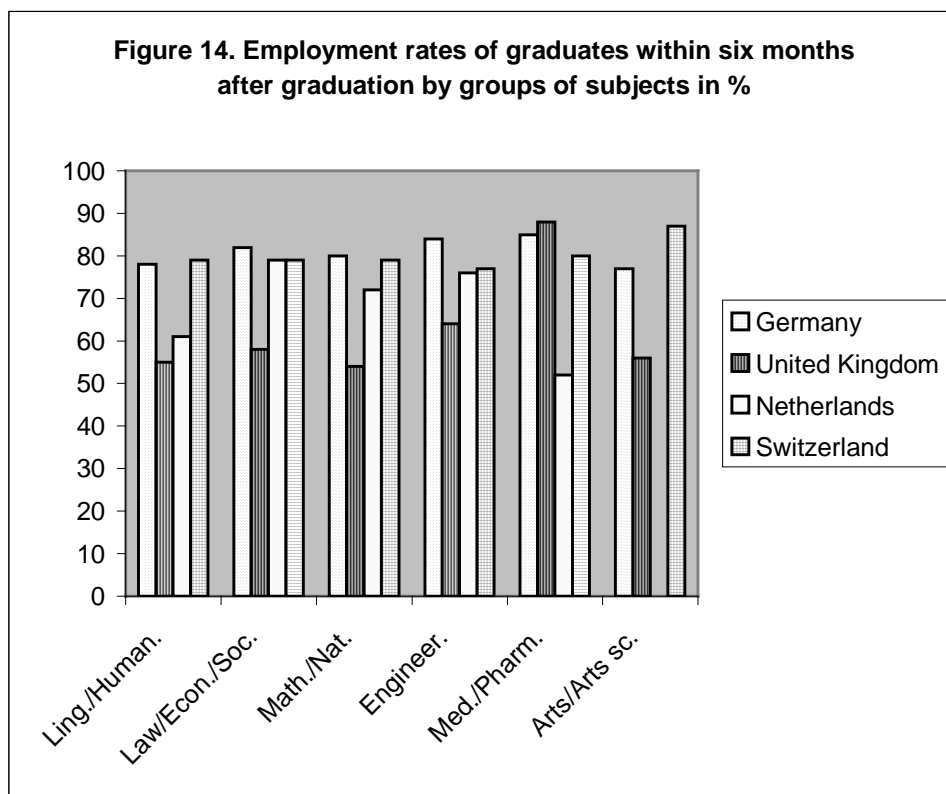
Table 2. Employment and unemployment rates of tertiary/university level graduates 1 and 5 years after permanently leaving education

Employment rates	<u>Men</u>	<u>Women</u>	<u>Men</u>	<u>Women</u>
	+ One Year	+ One year	+ Five Years	+ Five Years
Australia (1994 survey)	78.2 %	79.0 %	87.0%	77.6%
France (1991 survey)	80.4 %	77.6%	95.5%	91.2%
Germany (1995 survey)	85.9 %	75.4%	99.7%	86.9%
Ireland (1992 survey)	73.7%	78.6%	--	--
United States (1993 survey)	87.1%	81.0%	95.4%	81.8%
Unemployment Rates	<u>Men</u>	<u>Women</u>	<u>Men</u>	<u>Women</u>
	+ One year	+ One year	+Five Years	+ Five Years
Australia (1994 survey)	21.2%	17.0%	9.5%	10.5%
France (1991 survey)	14.4 %	17.2%	3.8%	5.3%
Germany (1995 survey)	4.9 %	17.9%	3.7%	0.0%
Ireland (1992 survey)	9.2%	8.5%	--	--
United States (1993 survey)	10%	9.7%	2.6%	4.2%

Source: OECD Employment Outlook (1998).

While the above data is not available by field of study, graduate surveys provide information on the first destination or labour market status of recent graduates by field. This data is important because labour market outcomes depend not only on level of educational attainment but on field and subject areas. Such

data also provide an indication of the match between a graduate's qualifications and his/her occupation and sector of employment. Even if it is not possible to directly compare the labour market performance of S&T graduates across countries given difference in survey methods and base years, some observations can nevertheless be made. Results from graduate surveys in Germany, the Netherlands, the United Kingdom, Sweden and Switzerland broken down by field of study appear in Figure 14.



1.Data based on national surveys in different years.

2.German data on medical graduates only includes dentists and pharmacists as most first degree graduates in medicine undertake further study/internship rather than entering employment.

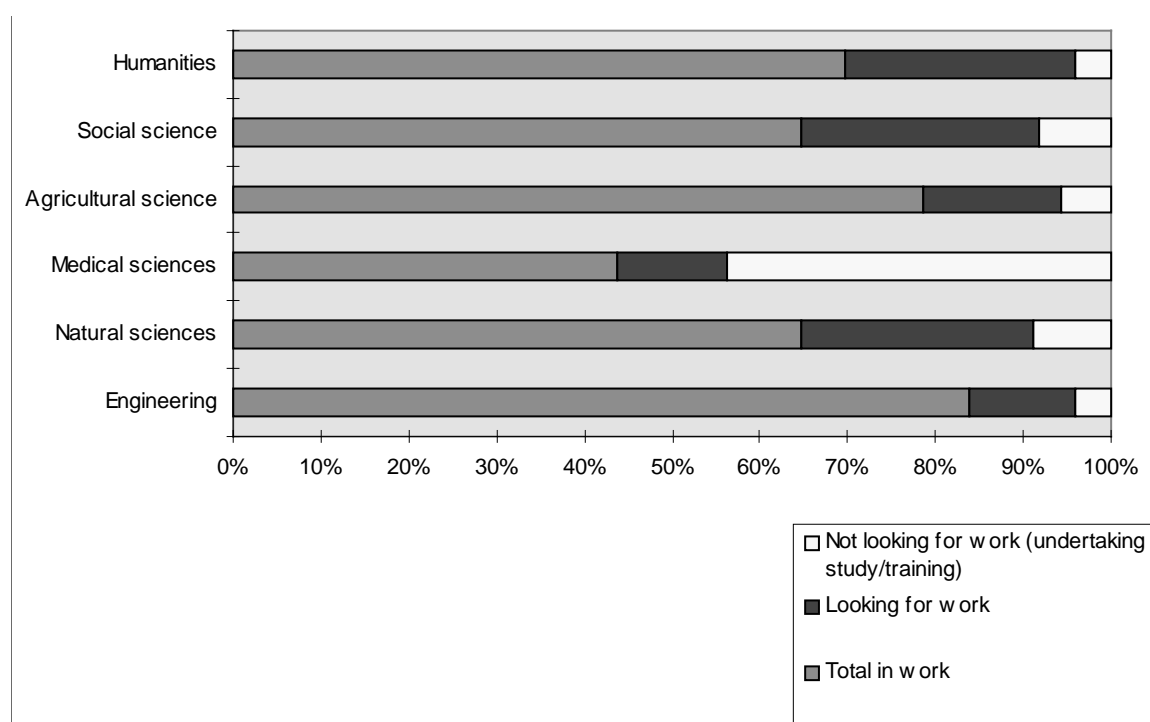
Source: OECD, Hochschul Information Systems, 1998.

A first observation is that in the United Kingdom where the share of S&T graduates in medical sciences and engineering/technology were roughly equal (32% and 35% respectively), within six months of graduation the employment rate for UK medical science graduates was 88% but just over 50% for graduates in engineering and natural sciences. This contrasts with the situation in Germany where engineering and technology graduates represented 44% of S&T graduates in 1995 but up to 84% of engineers and 80% of graduates in natural sciences/mathematics found employment 6 months after graduation. Independent of demand conditions, the strong performance of UK medical graduates and the low initial employment rates of UK engineering graduates may be due to a combination of factors. First, UK graduates in natural sciences are more likely to continue studies (given that first degrees are rather short in the UK) so it is not surprising to see low employment rates. As for UK engineering graduates, on the other hand, it may be that qualifications may not match skills demand in the labour market or that changing industrial specialisation has reduced demand for the type of engineers emerging from tertiary education. The high employment of German engineering graduates may in turn reflect differences in education systems whereby the German model of apprenticeship provides students with work experience,

thereby facilitating labour market entry. It is noteworthy that among S&T graduates in Switzerland, a high share of engineers and natural scientists found employment at rates only slightly below those of Germany.

As regards unemployment of recent S&T graduates in Italy, survey data reveal that unemployment is higher among graduates in natural sciences, humanities and social sciences than among engineers. Only a small share of medical science graduates enters the labour market, opting as in the Netherlands to continue education, which likely reflects the skill requirements of hospitals, medical services and pharmaceutical companies (Figure 15). In Australia, employment data from the 1997 *Graduate Destination Survey* show that first degree "science" graduates tend to do worse than the average in terms of unemployment: 34% of first degree graduates in science (excluding computer science) in 1996 were still seeking full-time employment in April 1997 compared to 21% for all graduates. Among engineering graduates only 14% were still seeking full-time employment but the figure among aeronautical engineers was 24% (Borthwick and Murphy, 1998). There may be several effects being played out here. First, it would appear to confirm evidence in other countries that engineers tend to find employment sooner than science graduates. As well, the fact that unemployment among science graduates is higher than the average could be an indication that demand is insufficient to absorb new science graduates. In countries with a weak industrial specialisation in knowledge-intensive sectors, for example in Portugal and Greece, initial unemployment rates for tertiary graduates are actually higher than for persons with lower educational attainment (OECD, 1998).

Figure 15. Labour market status of first degree (Laurea) S&T graduates in Italy
(1995 status of 1992 graduates)



Source: OECD calculations based on data from ISTAT (1996) *Inserimento professionale dei laureati 1995*. Fields of study re-classified according to Canberra Manual definitions.

According to the US National Science Foundation, the overall unemployment rate in 1993 for holders of science and engineering degrees was 2.7% for masters degree recipients and 4.4% for bachelors degrees and 6.8% for the overall labour force. As regards *recent* graduates, official unemployment data are only available for PhD graduates (1.2 % in 1997). Unofficial tabulations using data from the 1997 *National*

Survey of Recent College Graduates show that 1996 bachelors in science and engineering had a 5.9% unemployment rate while masters graduates had a 4% jobless rate compared to an unemployment rate of 5% for the entire labour force. Clearly the robustness of the US economy contributed to low unemployment among science and engineering graduates. In terms of the sector of employment, data on employment of recent first and second degree S&E graduates (bachelors/masters) in 1995 show most of them were employed in industry while the academic sector was the second largest employer. Again, as in other OECD countries, first degree graduates in science were more likely to continue education on a full-time basis than were engineers who more readily find employment in private industry with a first degree.

Table 3. Sector of employment of recent US S&E graduates at bachelors and masters level, 1995

Degree field	Sector of employment (percentages)*							
	Total employment (thousands)	4-years college & university	Other educational institution	Private for-profit	Self-employment	Private non-profit	Federal Government	State & local government
Bachelor's degree recipients								
Total science & engineering	585,6	13	9	59	2	6	4	6
Total science	476,7	14	10	56	3	7	4	7
Total engineering	108,9	11	1	75	2	1	7	4
Masters degree recipients								
Total science & engineering	128,4	23	9	47	2	6	7	6
Total science	86,0	26	12	38	2	9	5	7
Total engineering	42,4	17	1	66	1	1	10	4

Source: National Science Foundation, *Science and Engineering Indicators*, 1998.

Labour market performance of S&T PhD graduates

Doctoral graduates in science and technology are a small but important part of the total S&T workforce. PhD graduates play an important role as researchers, professors, but also in the management of research and innovation. OECD countries differ however with regard to the relative importance of PhDs in their educational supply systems (e.g. high in the United States, the Netherlands, Ireland but relatively low in Japan -- despite recent supply increases) as well as in the utilisation of the PhD workforce. Several OECD countries maintain employment data for PhD graduates in science and engineering fields based on a combination of graduate surveys and labour force data. In Sweden, for example, two thirds of all the new PhD recipients between 1990 and 1993 remained in universities, where the additional inflows from new PhD graduates exceeds the inflows and outflows to other sectors. During the same period, Swedish universities accounted for 70% of the net growth in the employment of S&T PhDs (Stenberg *et al.*, 1996). This is not surprising insofar as demand for S&T graduates in academic employment mainly concerns PhD graduates and post-doctoral students (although research support staff with lower levels of education are important). The higher education sector in Sweden also plays a strong role in performing R&D.

Data from a survey of graduates in France show approximately 15% of all new PhD graduates were unemployed in 1995 within a year following receipt of degree (Table 4). This exceptionally high unemployment rate, however, reflects the conjunction between a sharp increase in the total supply of doctorates between 1990 and 1994 and the weak economy at the time. In addition, performance within a one-year period is likely to underestimate the employment potential of graduates not least because finding a job takes time and applications for professorships or research positions are lengthy and may only be open once a year. A candidate may have to wait until the following year to apply, thus prolonging his/her period of unemployment. A more effective measure would be to monitor performance two or three years after graduation. Analysis of 1992 graduates in 1994, for example, shows that the share of unemployed PhD graduates fell from nearly 10% within the first year to 5% two years after graduation. In the future, an

analysis of this data by field of study will allow for a comparison of the labour market performance of PhDs with science and engineering degrees relative to those in social sciences and/or humanities. Nevertheless, while the employment conditions appear to improve for French PhDs over time, those leaving doctoral education continue to encounter problems entering the labour market following graduation partly because of limited demand in public research and the lack of a tradition for PhDs to seek employment in industry.

Table 4. Labour market performance of recent French PhD graduates
(6 months to a year after degree)

Labour market performance by sector of activity	1994 graduates surveyed in 1995	1995 graduates surveyed in 1996	1996 graduates surveyed 18 months later	1997 graduates surveyed 6 months later
Employment by sector				
Education sector	22.0	19.0	27.0	19.0
Secondary education	6.0	6.0	7.0	6.0
Higher education	16.0	13.0	20.0	11.0
Research organisations	8.0	7.0	8.0	6.0
Enterprises	13.0	15.0	22.0	18.0
Military service	2.0	2.0	--	1.0
Public administration	5.0	4.0	6.0	4.0
Post-doctorate	21.0	24.0	22.0	25.0
Temporary teaching and research attachés (ATER)	18.0	14.0	6.0	15.0
Unemployed	11.0	15.0	8.0	12.0

Source: *Rapport sur les Etudes Doctorales, Ministère de l'Education Nationale, de l'Enseignement Supérieur et de la Recherche, Secrétariat d'Etat à la Recherche, DGRT, various years.*

Data from graduate surveys in the United States show that most recent PhDs move to the industrial sector; academic employment being an even less important destination for PhD graduates in engineering and the physical sciences. While flows of S&T graduates into permanent university employment have stagnated -- in 1995 only 16% of PhD recipients obtained tenure-track positions in academia -- there has been an increase in graduates entering non-tenure and temporary academic employment (NSF, 1998). This may be due in part to the growing costs of tenured employment, low turnover among faculty as well as budgetary constraints in higher education.

According to the US National Science Foundation, the unemployment rate for US PhD graduates in science (including social sciences) and engineering within one to three years after degree rose from 1.7% in 1993 to 1.9% in April 1995 but fell again in 1997 according to preliminary estimates (Table 5). A breakdown by field shows unemployment rose markedly during 1993-1995 among recent PhD graduates in chemical engineering and mathematical sciences. Unemployment among recent PhD graduates in the social and physical sciences fell, including among doctoral graduates in physics (from 5.3% to 2.9%). While such rates are still low in comparison to the 5.7% of the civilian labour force that was unemployed in 1995, an important question is whether doctoral science and engineering graduates are actually employed in the occupations matching their skills. In 1995, approximately 4.3% of science and engineering PhD graduates in the labour force (either employed or unemployed) were unable to find full-time employment in fields that were "closely" or "somewhat related to their field" (National Science

Foundation, 1998). Again, graduates in some fields fared better than those in other disciplines: 6.7% of recent PhD graduates in physics were not working in their field of study on a full-time basis, while this was true of only 2.7% of doctoral recipients in computer sciences.

Indeed, there is concern that graduates in science and engineering are entering non-S&T occupations (e.g. mathematicians and physicists in the financial service industries, engineers in marketing), through a combination of being offered better salaries and fewer employment opportunities in academic and public research sectors as well as recent declines in manufacturing R&D. This may not be a problem, however, insofar as society does not lose potential opportunities from investment in scientific knowledge. The movement of engineers into management for example is thought to increase the technological competence of firms (Lavoie and Finnie, 1998).

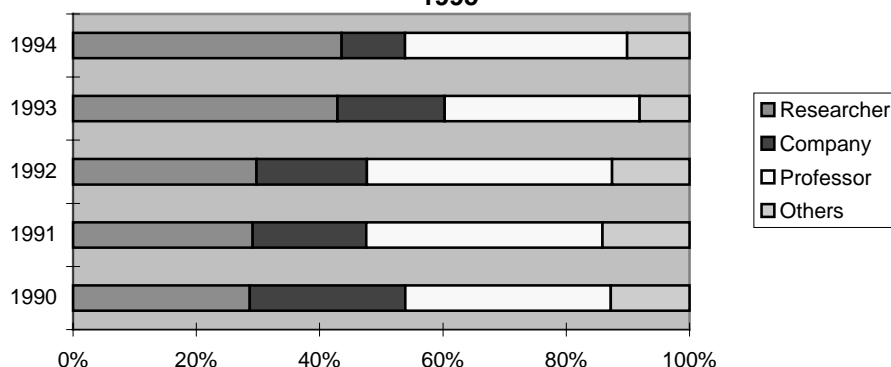
Table 5. Unemployment rates for recent US S&E PhDs, 1993, 1995, 1997
(One to three years after degree)

Field of degree	Unemployment rates		
	1993	1995	1997* estimate
All science & engineering	1.7	1.9	1.2
Engineering	1.9	1.7	
Chemical engineering	1.1	4.3	
Civil engineering	1.9	1.3	
Electrical engineering	1.9	0.9	
Mechanical engineering	1.3	2.8	
Life Sciences	0.9	2.0	
Agriculture	1.1	1.1	
Biological science	0.7	2.2	
Health/medical	1.5	1.3	
Math/computer sciences	1.1	2.6	
Computer science	1.5	1.1	
Mathematical science	0.7	4.0	
Physical sciences	3.0	2.4	
Chemistry	1.6	2.1	
Geosciences	3.4	1.7	
Physics	5.3	2.9	
Social sciences	1.8	1.4	
Economics	2.1	1.4	
Political sciences	2.4	2.5	
Psychology	1.4	0.5	
Sociology/anthropology	3.3	3.2	

Source: NSF, Science and Engineering Indicators, 1998; NSF Data Brief 99-340, April 1999.

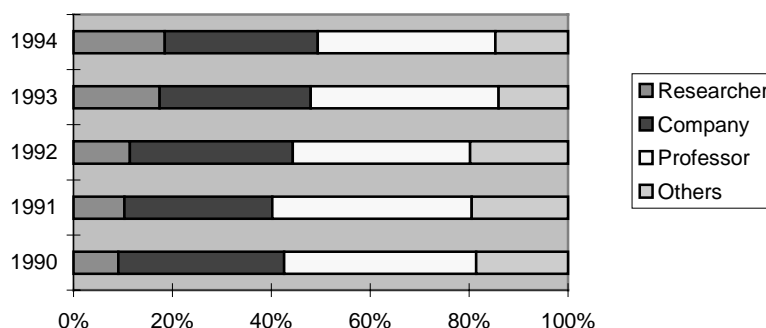
In Japan the employment path of PhDs differs significantly and most science and engineering graduates find employment in public research and universities. Over the period 1990-1995, the share of science PhD graduates entering employment in public research and universities has increased with a decreasing share working in companies. Engineering PhDs on the other hand continue to enter employment in companies and as university professors. The share of engineering PhD graduates going into research has increased somewhat during the period (Figures 16 and 17).

Figure 16. Destination of Science PhDs in Japan, 1990-1995



Source: Hee and Hirasawa, from national statistics (1998). Science data exclude agriculture and medical sciences.

Figure 17. Destination of Engineering PhDs in Japan, 1990-1995



Source: Hee and Hirasawa, from national statistics (1998).

Do increases in post-doctorates reflect a lack of employment opportunities for PhDs?

There has also been concern that PhD graduates in S&T are pursuing post-doctoral positions (which are temporary and lower paying research positions) for lack of permanent employment opportunities in academia and industry rather than for further training and research. While the rise in post-graduate training may reflect over-supply in the labour market for PhDs it may also reflect changes in training and skills development as well as competitive pressures in favour of prior labour market experience. In Japan most post-doctoral positions are mainly in government research institutes and are directly funded by government in contrast to other OECD countries where demand often comes from lead researchers in universities who receive competitive research grants and require temporary research staff. Since 1996 labour mobility of highly qualified S&T researchers has become an important policy issue in Japan. In this context, the number of post-doctoral positions offered by the government has increased to around 8 800 in 1998. At the same time, the annual number of PhD graduates who pursue post-doctoral positions as their first destination rose from about 1 300 in 1988 to 2 600 in 1997. The share of post-doctoral positions among new PhD graduates, on the other hand, has remained almost stable over the last decade at about 25%. According to a survey by the Japanese Science and Technology Agency in 1998, the main motive for seeking post-doctoral positions is to await permanent employment (56%), rather than to obtain additional research training *per se* (41%). In fact, almost half of the researchers surveyed entered into permanent employment (mainly in public research) *before* the end of their post-doctoral positions suggesting graduates used their position to leverage their employment prospects.

In France, approximately 22% of 1996 PhD graduates were pursuing post-doctorates a year and a half later while 27% had moved to employment in educational establishments (another 22% had moved to industry) (*Ministère de l'Éducation Nationale, de l'Enseignement Supérieur et de la Recherche, 1998*). In the United States research by the NSF shows that acceptance of post-doctorates depends on the field of study. While, overall, the pursuit of additional research training remains the most common motive, the lack of alternative employment is a factor among some graduates in physics (26%) and earth, atmospheric and oceanographic scientists (29%) (NSF, 1998). Interestingly, a related 1995 survey of 1993 postgraduates found that while 42% were still in a post-doctorate position, 17% had moved on to industry while the remainder moved to positions (tenure and non-tenure) in the education sector. This could suggest that the net movement of PhD graduates to industry and academia in a given year would be higher if adjusted for the delayed entry of postgraduates.

A survey in the United Kingdom examined the labour status of former “postgraduates” (study beyond first degree) funded by the Research Councils and found that almost half of the recipients viewed their period of postgraduate study as essential in obtaining their first job. Some 40% obtained their first job in private firms while 35% found employment in a university or polytechnic institute. Over a third of respondents worked in research-related job. This percentage was lower for those postgraduates who subsequently obtained another job following first employment (25%), suggesting the gap between initial educational qualifications and current occupation increases with mobility (ESRC, 1998). In Canada, the Natural Sciences and Engineering Research Council (NSERC) conducts surveys of former holders of NSERC Postgraduate Scholarships (which provide support to Canadian students undertaking advanced studies in natural sciences and engineering). A 1996 survey showed that approximately 98% of more than 500 recipients had science or engineering postdoctoral positions and only 2% were unemployed (NSERC, 1997). Italy’s National Research Council maintains a regular survey of PhDs which showed in 1993 that nearly three quarters of Italian PhDs in full-time employment were working in universities and/or teaching, but less than 4% were working in the enterprise sector.

In summary, graduate surveys and administrative data confirm industry is the main destination of recent graduates in science and technology but their employment outcomes depend on their field of study and demand conditions in industry. Survey evidence from Canada suggest that non-engineering jobs do not appear to be more attractive than traditional engineering jobs for graduates except for those entering engineering management occupations. For those that *choose* to change occupations, however, management positions appear to be an avenue for earnings mobility and job satisfaction but entail a greater divergence in the occupation/initial educational qualifications match (Lavoie and Finnie, 1998). As regards PhD graduates in S&T, many of them continue to move to universities and research institutes in the Nordic countries, Italy and Japan (for post-doctorates). In other countries (e.g. US, Canada, France) more are moving into industry and/or postdoctoral positions but some are still encountering problems entering the job market possibly due to mismatches in technical as well as non-technical skill requirements. Post-doctoral training appears to be a means of gaining additional training and employment relevant experience (e.g. research contacts, networking, etc.) but also a second-choice of employment insofar as it is a temporary position.

Trends in earnings

Data on earnings by educational level are available for nearly all countries and are generally derived from income surveys or micro-census data. A few countries maintain data (usually derived from graduate surveys) on earnings of graduates by field of study. In addition, some countries, notably France, Germany, Canada, Norway and the United Kingdom, maintain earnings data by occupational category. Other countries, for example Denmark, Switzerland and Spain, collect earnings data by broad skill groupings. Earning of S&T personnel are an important indicator of relative demand. Earnings vary according to higher education and training, including the field of study and the supply and demand conditions. However, internationally comparable data on earnings by educational level *and* field of study -- which would tell us which science and technology graduates are experiencing an increase or decrease in earnings growth relative to other graduates over a given period -- are unavailable.

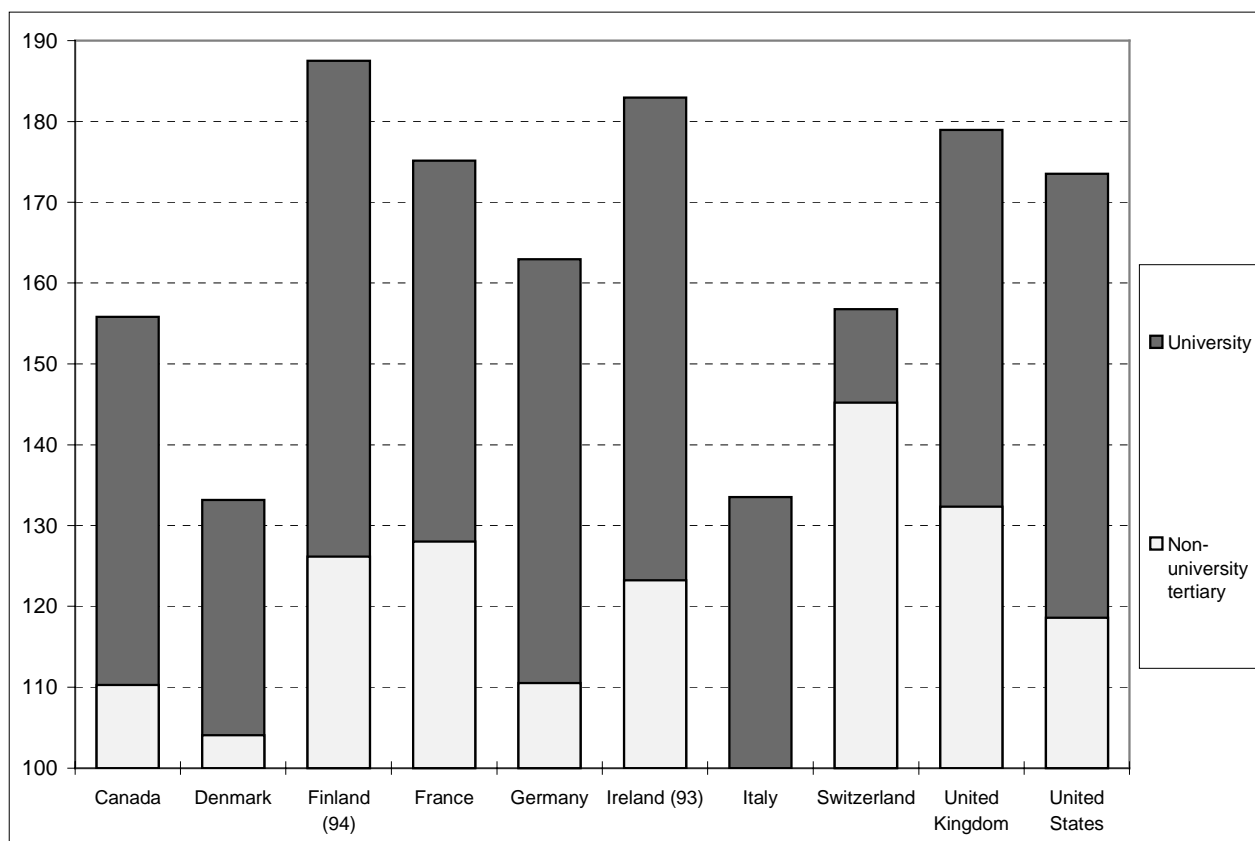
Data on earnings by level of educational attainment can provide a broad indication of the premium for tertiary-level graduates (including in sciences) relative to workers with only secondary education. As expected, there is a substantial premium on tertiary level education, both university and non-university. In the United Kingdom, for example, the premium is close to 80% for university level education and around a third for non-university tertiary graduates (Figure 18). Germany has a large number of graduates from non-university tertiary institutions, whose premium is much smaller than that of university graduates. Differences in the educational systems between countries play a role as does the distribution of men and

women. In Switzerland, for example, the difference between the wage premium for university and for non-university tertiary education is among the smallest in the OECD countries. This could reflect the fact that professional programmes taught at non-university level can lead to high-earning occupations, which in other countries may be dependent on university education.

Drawing on graduate surveys in some countries, it is possible to obtain data specifically on the earnings of science and technology graduates. In the United States, median salaries are higher for science and engineering graduates than for non-S&E graduates. This holds true at all levels of university degrees (i.e. bachelors, masters, PhDs) and for all disciplines. In both the business and government sectors, salaries were highest among PhDs in engineering, math and computer science. In the future, collecting earnings data from graduate surveys, while not directly comparable across countries, could provide insight on the earnings profiles of science and technology graduates within individual countries.

Analysis of trends in earnings of science and technology workers must also address the functioning of such price signals. Time lags in equilibrating labour markets can be expected, but changes in relative wages should play a role in matching supply and demand at some point. Thus, shortages for certain types of personnel will be reflected in higher wage levels and surpluses of workers in lower wage levels. However, wages in science and technology labour markets may not be able to adjust quickly. A large share of wages in this sector may be set by governments (including in universities and the public sector) and linked to the state of government finances and/or be unresponsive to private sector price signals. Rigidities in wage bargaining systems may further reduce the ability of science and technology labour markets to adjust.

Figure 18. The earnings premium from tertiary level education¹
Average annual gross earnings by educational attainment level, males+females, age 25-64, 1995
 As a percentage of post-secondary



1. The graph shows the percentage increase in average gross earnings from reaching educational attainment levels beyond post-secondary education.

2. University-level is defined as ISCED 6/7.

3. Non-university tertiary level is ISCED 5.

Source: OECD, Education at a Glance database, 1998.

MOBILITY IN S&T LABOUR MARKETS

Why is the mobility of S&T personnel important?

The mobility of science and technology workers has emerged as a key concern of policy makers, not least because of the role of personnel in diffusing knowledge and technology, but also because mobility of S&T personnel contributes to the upskilling of the labour force and innovative performance. Mobility among S&T personnel is also an indicator of knowledge transfer between firms, sectors and the relationships between knowledge-intensive organisations. In addition, the movement of S&T staff across regions, sectors, or occupations is an important function of a flexible labour market for matching supply and demand. Labour markets may not clear when wages (i.e. the price of labour) do not respond to changes in demand or when supply (i.e. the *quantity* of labour) does not adjust to new demand due to mismatches in skill levels or the lack of mobility. At a general level, the barriers and obstacles to mobility in labour market for S&T personnel relate to regulations on employment (hiring and firing), pension rules, distortions in housing markets, wage bargaining arrangements and changes in the supply of labour. Regulations such as employment protection legislation (EPL) could act as barrier to flexibility and mobility. From the employer's side, rules governing dismissal, including union rules, can increase the costs of hiring and laying off thus resulting in lower average mobility. In the public sector, researchers may not be willing to abandon civil servant status and permanent employment for employment in industry, even at a higher wage. Other factors in mobility include age limits on recruitment for junior faculty or research posts.

Distortions in housing markets and the non-portability of private pensions can act as barriers to mobility in the public research sector. Particularly among academics, housing may be tied to employment as in the case of subsidised university or research institute housing. High property taxes on sales by homeowners can act as a disincentive to moving while distortions in rental markets make renting unattractive. In cases where pension benefits are dependent, not only on individual participation, but on factors such as years of service with the same institution, there may be a disincentive to moving particularly for older S&T personnel. Pension rules may thus penalise inter-firm as well as regional mobility. Improved pension portability would lower the costs associated with inter-firm mobility. Tenure may also act as a disincentive to mobility; entry-level academics, for example, may prefer to wait for a tenured position to become available rather than move to another institution or region. But tenure can be an important incentive for higher education institutions to attract quality staff.

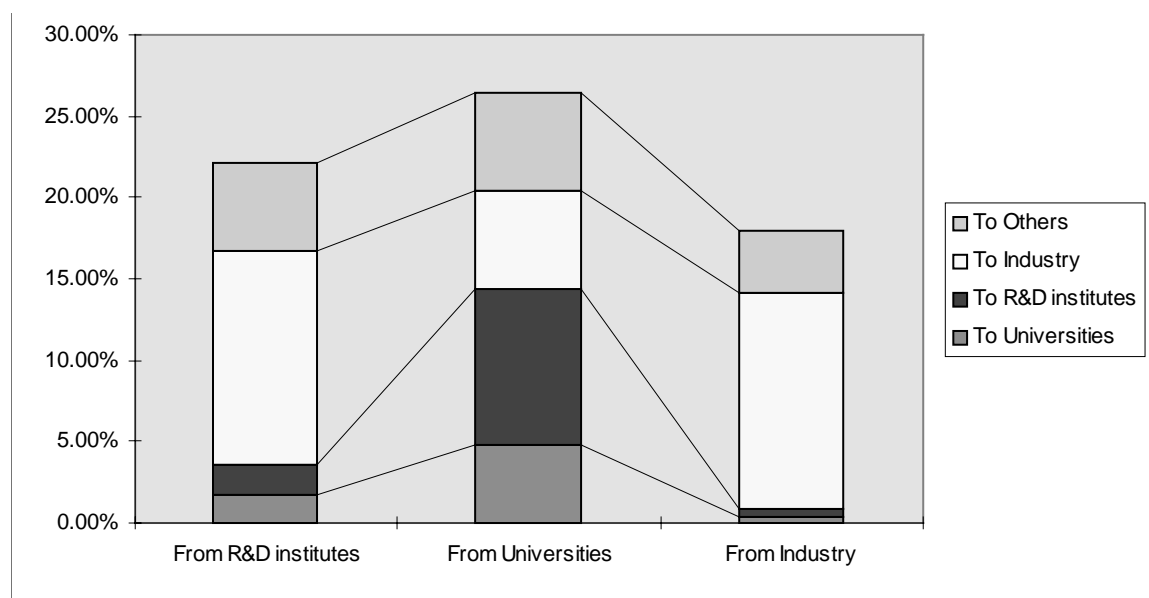
While mobility is an important component of a flexible labour market, too much mobility may have longer-term repercussions on both demand and supply for S&T labour. Frequent job changes involve a loss of job-specific skills and transaction costs for workers and employers. In a competitive model, higher turnover could act as a disincentive for firm training. Indeed, firms and workers have a greater incentive to invest in training if industrial relations are relatively stable and predictable. In the face of rapid technological change and the resultant need for continuous upgrading of skills, governments, firms, trade unions and the social partners have a stake in ensuring workers, including the highly skilled, have incentives to upgrade skills and invest in new ones. The role of science, technology and innovation policies is to complement labour market policies by removing excessive barriers to mobility and thereby allowing for S&T workers to respond to changes in demand.

Measuring mobility of S&T personnel

Measuring the mobility of science and technology personnel is a complex issue and the available data continues to limit the scope for analysis. R&D surveys, for example, are of little use for measuring mobility of researchers in non-manufacturing sectors. Work by the NIS Focus Group on Human Resource Mobility at the OECD has focused on the following types of personnel mobility for S&T personnel: i) mobility of science and technology workers between universities, research institutes and industry; ii) mobility of workers within the business sector; and, more recently, iii) international mobility, which sheds light on migration of science and technology workers and national issues of “brain gain” and “brain drain”. Ideally, mobility measures could allow one to measure the mobility of individuals with specific S&T qualification (e.g. engineering PhDs moving from university to industry or computer science graduates in manufacturing moving to the banking and financial services sectors). At the general economy level, labour force data suggest overall labour mobility (as measured by tenure data) among professionals in occupations ISCO 2 and 3 is higher in North America and Australia than in Japan and several European countries (OECD, 1998). Graduate surveys discussed above indicate industry is the main destination of recent graduates in science and technology, but data on their subsequent mobility is scarce. With regard to data on mobility of S&T personnel across economic sectors, the Nordic countries have made the most progress in this area.

Trends in mobility: from the public research sector

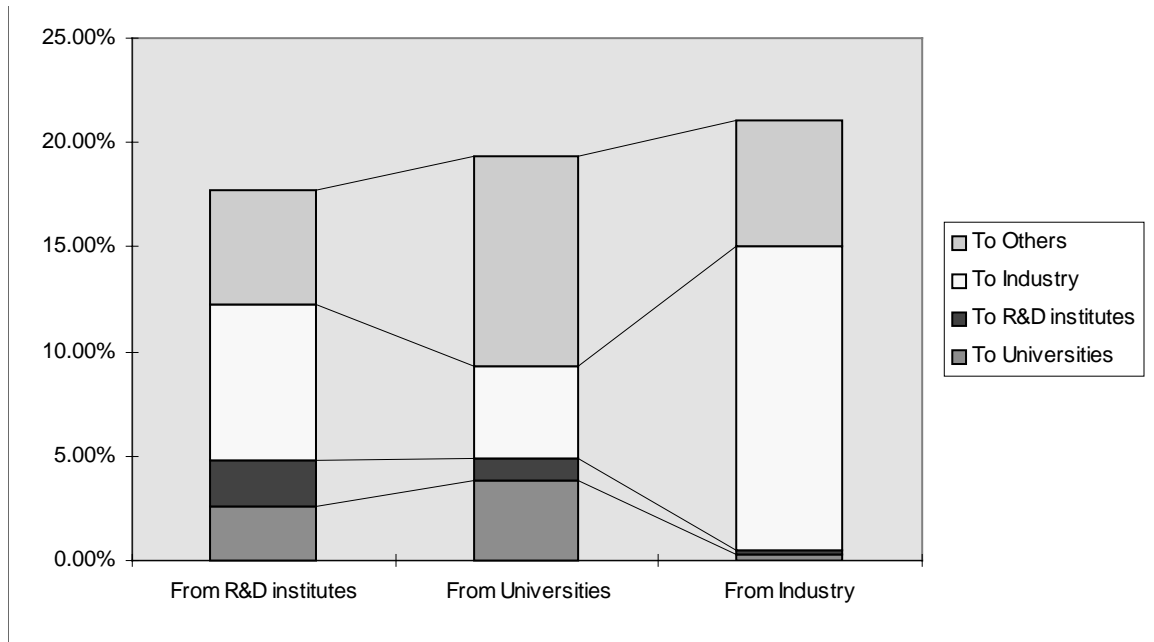
Indicators of the mobility of researchers between the public research base (universities, research institutes, and laboratories) and industry can help assess the importance of public research efforts to different industries and monitor mismatches between public and private resources. Sweden has mapped the circulation of highly qualified personnel in S&T between the public and private sectors, between industries and between firms. “Highly qualified personnel” are defined as people with higher education levels of ISCED 6 or 7. Their educational fields are also categorised into three broad fields of science: i) natural sciences and engineering, ii) medicine, iii) social sciences, humanities or other scientific fields. On the basis of these definitions and categories, labour mobility is defined as a change of establishment for highly qualified personnel or movement to education, unemployment or outside the labour force. By dividing the number of personnel moving out by the total number employed, the labour mobility rate (outflow) from universities to industry in the year can be calculated as 6% compared with the reverse mobility rate of 0.3%. Manufacturing was the largest receiver of this inflow, accounting for almost a half of the flows from universities (Figure 19).

Figure 19. Mobility between public research base and industry in Sweden, 1995

Source: OECD calculations based on Svanfelt (1998).

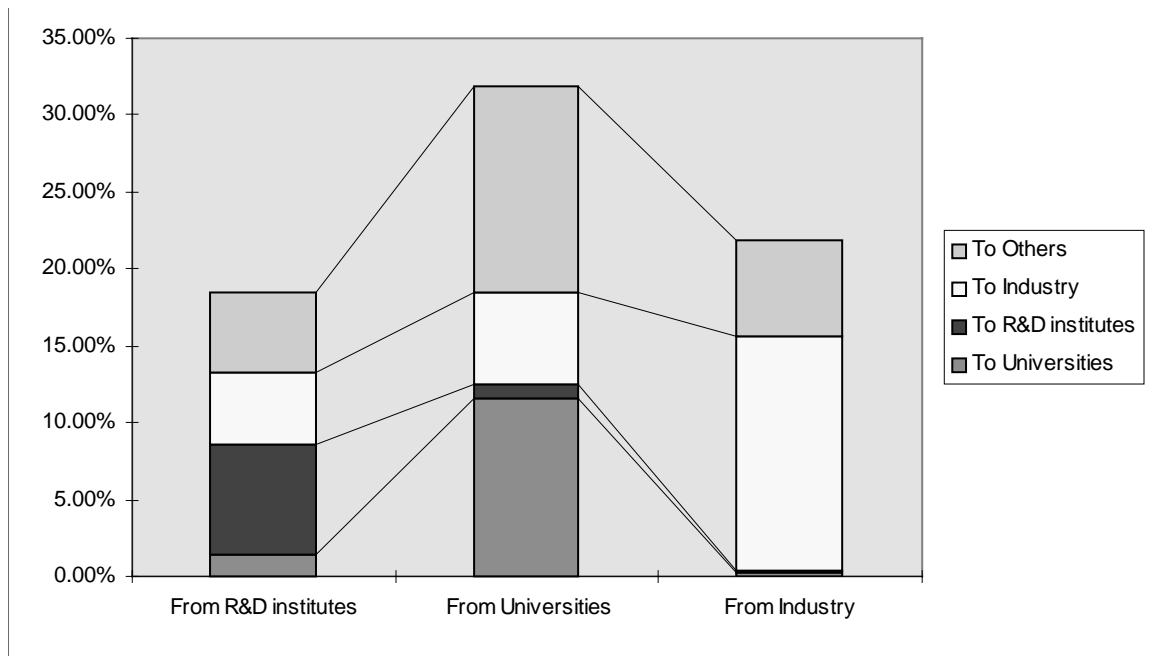
This data, beyond suggesting greater industry demand for personnel, unfortunately says little about the underlying factors (e.g. price signals, demand for specific S&T qualifications, etc.) (Svanfeldt, 1998). Public R&D institutes are also main players in public research. Contrasting with the situation in Sweden, data from Norway indicate that public R&D institutes are more active than universities in supplying S&T personnel to industry. In 1995, they delivered more personnel to industry (261) and also received more from there (114) than universities (176 and 93, respectively). The labour mobility rate from public R&D institutes to industry that year was 7.5% and that of reverse flow was 0.3% (Figure 20). Based on these limited examples, the direction of net-flow is always from the public research base to industry. The flows into the public research base from the manufacturing sector are particularly small compared with the outflows to manufacturing. This may reflect wage differentials as well as the permeability of public labour markets for researchers (which often require strict formal qualifications with little recognition of professional experience) in determining the extent of movement from industry to public research. The results thus suggest the university sector is the least flexible and insider power is significant there. Improving mobility from industry to the public sector will require policies that address entry barriers to academic employment.

Figure 20. Mobility rate between public research base and industry in Norway, 1995



Source: OECD calculations based on Svanfelt (1998).

Figure 21. Mobility rate between public research base and industry in Finland, 1995

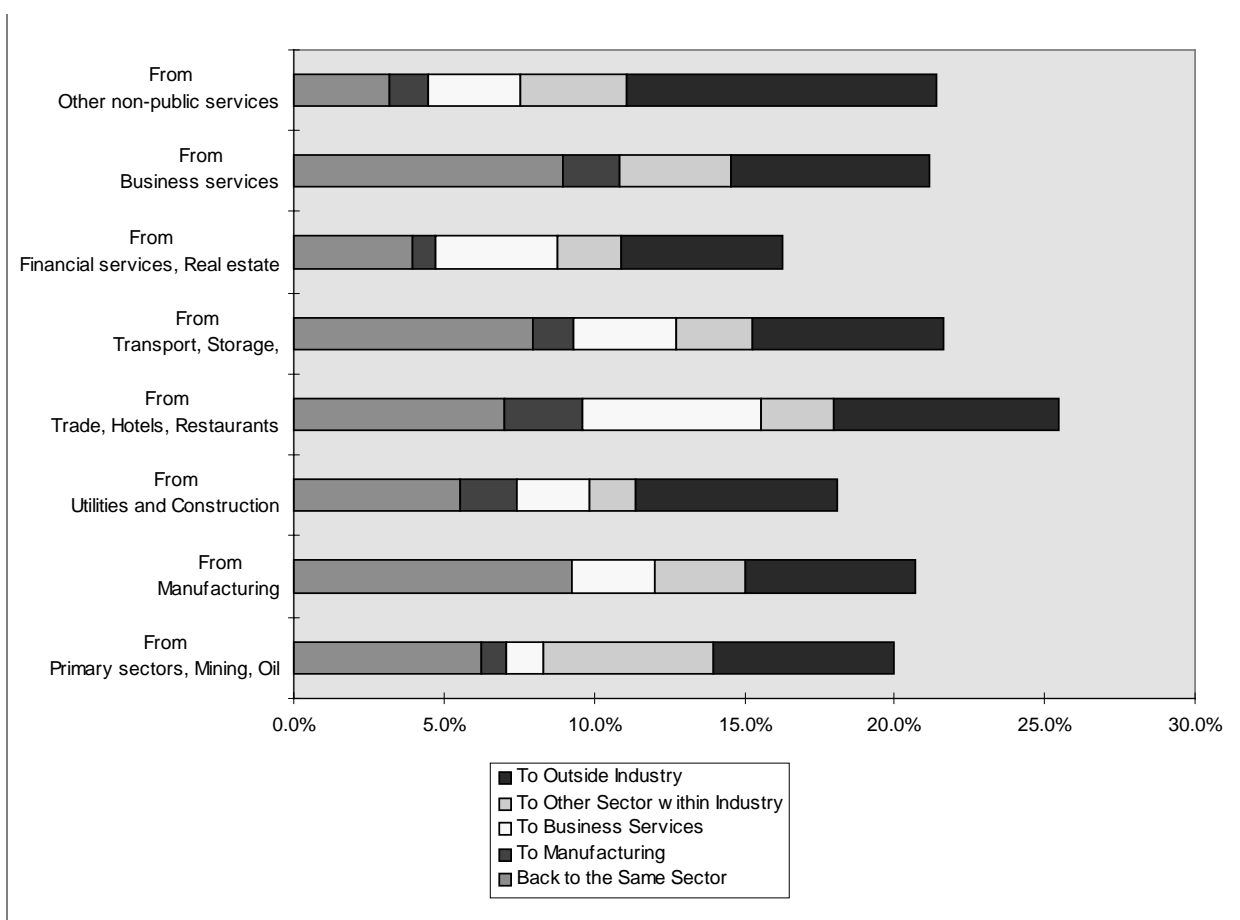


Source: OECD calculations based on Svanfelt (1998).

Mobility within industry

In general, the Nordic data on mobility of S&T personnel within industry suggest the main inflows and outflows of S&T labour occur within the same industrial sector. This is in line with broader OECD findings on the upskilling of workers which takes place mainly within sectors rather than between them. This trend is best observed in the manufacturing sector where around 50% of movement took place within the sector in 1995. In the other sectors intra-sectoral mobility, while high, accounts for below 50% of labour turnover. For example, the percentage of mobility within financial services and the real estate sector in Norway was 24% and that of the trade, hotels, and restaurant sector in Finland was 28% in 1995. The most prominent exception is the business services sector in Sweden where inter-sector mobility exceeds intra-sectoral mobility. In 1995, for example, business services was the most important destination of the outflows from all other industrial sectors except manufacturing, and the largest source of the inflow to all the other industry sectors except manufacturing and the trade, hotels and restaurants sectors. The manufacturing sector is the second largest source and destination of inter-sector mobility in the country. These sectors are also the dominant players in inter-sector mobility in Finland and Norway. However, this trend is partly due to their relative size in industry. They are by far the two largest sectors in terms of the number of employees with high qualifications in S&T and consequently account for the largest amount of turnover.

Figure 22. Rates of mobility within industry in Norway, by industrial sector, 1995



Source: OECD calculations based on Svanfelt (1998).

The R&D intensity of industry provides another way to analyse mobility within industry. A study in Sweden divided industry into six sectors on the basis of R&D expenditure and types of business (i.e. manufacturing or service) and analysed trends in mobility from 1990 to 1993. The results showed that large firms with high R&D expenditure demonstrate less mobility for highly qualified personnel than other firms. While only 13% of the PhDs employed in the nine largest R&D spenders in 1990 had left their sector by 1993, the corresponding figure for smaller firms was 37%. With regards to the inflow of PhDs, the relative importance of other industry sectors as a source of PhDs differs across sectors. The nine largest R&D spenders recruited only one fifth of their PhDs from other firms during the period, compared with almost one half for other manufacturing firms and one third for the non-manufacturing firms. Instead, their primary source of PhDs was universities. Therefore, in terms of both intra- and inter-sectoral mobility, large firms with high R&D expenditure are characterised by low levels of mobility (Stenberg *et al.*, 1996). This may be in part explained by the fact large firms tend to hoard employment early in downturns while small firms generally experience labour shedding (and hiring) sooner.

Mobility within the public research sector

Mobility within the public research base is likely to be low insofar as in most OECD countries S&T personnel in public research benefit from a high degree of employment protection (e.g. civil servant status, tenured or career life employment). As well, in universities tenure positions continue to dominate even if there has been a trend towards an increase in temporary and non-tenure positions in some countries in the face of university deregulation. There is also an element of prestige in leading universities and in large renowned research institutes that limit incentives to move. Data from the Nordic countries suggest that in general new personnel entering academic employment come from the university sector rather than from outside (e.g. industry or public R&D institutes). R&D institutes also prefer to recruit among themselves with the exception of Sweden where the greatest inflows (more than 70%) originate from universities. The closure of the internal labour market for university/research institute employment may be due to the hiring regulations, the timing of openings (generally positions become vacant only once a year) and the fact that university researchers tend to co-operate among themselves and thus recruit personnel with similar backgrounds.

Case study evidence in Austria show that mobility is higher in universities than in research institutes. In 1994 two thirds of the universities (67%) and 45% of research institutes hired at least one new scientist. A similar pattern is observed concerning the “exit” of researchers with 49% of universities reporting the departure of one or more researchers while only 65% of research institutes did so. The difference in inflows and outflows may be due to the relative small size of research institutes in comparison to universities. Interestingly, research institutes were more likely to use external sources for hiring than universities (13% against 1%) (Hutshenreiter *et al.*, 1996). As concerns mobility between laboratories and universities/public research institutes, a survey of five major laboratories in Belgium, France and the United Kingdom found that secure employment provisions often result in a low employment turnover and a concentrated age structure towards older workers. Anecdotal evidence indicates flows of graduate students from universities to laboratories appear to be an important source of mobility in France and Belgium, although this is less the case in the United Kingdom where there is evidence of a decline (Lawton Smith, 1998).

In summary, results from mobility studies in the Nordic countries show the basic pattern of labour mobility of highly qualified S&T personnel is broadly similar to that of all employees. Preliminary results show the greatest flows of science and technology personnel are from university to industry and research institutes while mobility of technical personnel within industry is moderate and movement from industry to the public sector is even weaker. As concerns PhDs in particular, the data from Sweden show they have a low level of mobility and thus are a weak mechanism of knowledge transfer. In Norway, the business service sector recruits and supplies skilled labour to a broader number of sectors than any other sector.

GLOBALISATION OF S&T PERSONNEL

The international mobility of S&T personnel is an integral feature of the globalisation process. Indeed, the globalisation of R&D is characterised, *inter alia*, by increasing international collaboration between scientists and growing reliance on co-operation among firms, researchers and scientists to achieve faster technological innovation at lower costs. Concerned with maintaining an attractive domestic base for national and international research, OECD countries are addressing weaknesses in regulatory frameworks tax systems and higher education systems, that may dissuade potential foreign R&D investors or impede the capacity of domestic firms to innovate. Shortages of workers with certain skills, for example, may lead firms to seek skilled S&T labour abroad or to consider delocalisation of research activities. OECD countries are concerned that they might lose their competitive edge in what seems to be a global competition for certain skills. In response, OECD countries are internationalising their higher education and research systems and using temporary and immigrant qualified S&T professionals to improve flexibility in adjusting to demand shocks.

International mobility of S&T personnel is also a channel through which technology and knowledge is diffused. There are two kinds of international mobility: active and passive. The first involves the transfer or exchange of personnel associated with a firm is business strategy; a country's co-operation and development strategy in the case of government exchange programmes. The second channel can be considered passive or spontaneous insofar as the individuals moving are responding to broader economic "pull" and "push" factors. Although comprehensive data on international flows of S&T workers is lacking, country-level data provide some indication of recent trends with regard to inflows and sometimes outflows. A few countries such as the United States, Australia and Canada collect data on the educational background of immigrants as well as their intended or previous occupation. In Canada, for example, immigration data show that between 1987 and 1992 both the number of immigrants and the share of those in the natural sciences, engineering and mathematics group rose sharply before falling slightly in 1996. That year most of the immigrants in those fields came from Asia (48%), Europe (28%) and the Middle East and Africa (18%). Comparing immigration data with graduate rates provides an indicator of the relative *dependency* of a country on foreign supply of S&T personnel. Thus Canadian data show that there were two to three times more immigrants with PhD degrees in computer science than were produced by Canadian universities. At the same time, Canadian emigration to the United States has increased in recent years (from 14 500 in 1988 to 18 000 in 1995), including among information technology personnel (NSERC, 1997). Recent studies suggest higher after tax earnings in the United States may have acted as "pull" factors, facilitated by post-NAFTA changes in immigration legislation, while the weak performance of the Canadian economy and the mismatch between education and the Canadian labour market has contributed as a "push" factor (DeVoretz, 1998).

In the United States, foreign-born science and engineering personnel (i.e. non native-born US citizens) made up 50% of the US science and engineering workforce in 1995. As regards PhDs, the foreign-born accounted for nearly a quarter of the *stock* of individuals holding PhDs in science and engineering and 29% of those PhDs conducting R&D (Table 6). In addition, the foreign-born accounted for half of all recent engineering doctorates. More foreign-born work in industry but those with PhDs work almost equally in education and industry.

Table 5. U.S. and foreign-born scientists and engineers in R&D in the United States, by sector and location of S&E degree (1993)/1

Scientists and Engineers in U.S. R&D	Total		Education		Industry		Government	
	All degree levels	Ph.D.s	All degree levels	Ph.D.s	All degree levels	Ph.D.s	All degree levels	Ph.D.s
Total engaged in U.S. R&D	2,685,000	345,000	592,000	179,000	1,747,000	135,000	346,000	31,000
U.S.-born	2,254,000	244,000	470,000	128,000	1,477,000	90,000	307,000	26,000
Foreign-born	431,000	101,000	122,000	51,000	270,000	45,000	39,000	5,000
Location of S&E degree								
Foreign school	138,000	32,000	41,000	16,000	87,000	14,000	9,000	2,000
U.S.school 2/	293,000	70,000	81,000	35,000	183,000	31,000	29,000	4,000
Foreign-born in R&D as percent of total engaged in R&D	16,1	29,3	20,7	28,5	15,5	33,2	11,2	17,3
U.S.school as percent of foreign-born in R&D	67,9	68,7	66,1	67,9	67,6	69,6	75,8	69,2

1/ In table 1, numbers for all degree levels have been revised to include only those with science and engineering degrees.

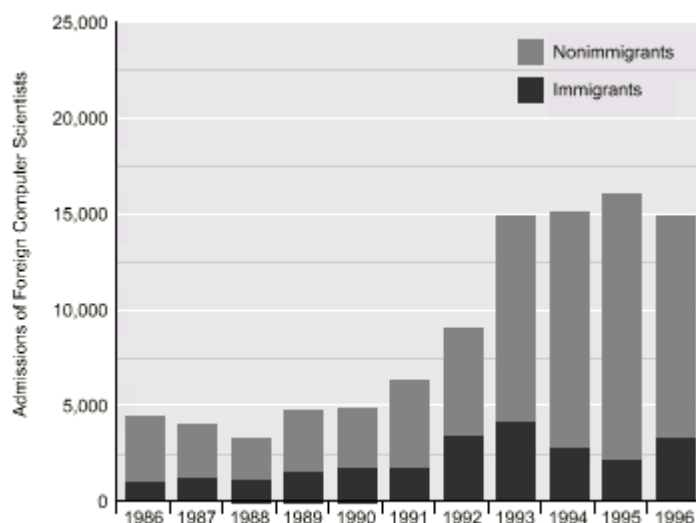
2/ U.S. school was the location of the highest earned S&E degree.

Note: Data are headcounts of those with science or engineering degrees who reported R&D as their primary or secondary activity in the three surveys contained in the SESTAT database. These data differ from estimates of full time equivalent (FTE) scientists and engineers in R&D, and from estimates of scientist and engineers defined by occupation. Industry in this table includes the nonprofit sector. Numbers in general may differ from similar SRS tabulations due to the conclusion of degrees from foreign schools.

Source: National Science Foundation, *NSF Issues Brief*, January 1999.

Among IT professionals, foreign-born computer scientists account for 20% of all working computer scientists in the United States. Flow data of admissions of immigrants shows that the number of computer scientists entering as permanent immigrants has in fact remained quite low since the 1980s. Less than 5 000 per year entered as permanent immigrants between 1986-1996. What has occurred is that the growth in the number of temporary immigrants (visa holders) has increased their share and accounts for over 10 000 entries since 1993 as changes in immigration policy led to a sharp rise in the number of temporary visas granted to S&T personnel (Figure 23). In addition, this discrepancy between stock and flow data is explained by the fact that the stock of foreign born S&T personnel, including computer professionals, increases by the number of foreign students who obtain degrees in the United States and subsequently stay and find employment in industry and academia.

Figure 23. Permanent and Temporary Immigrant Computer Scientists in the United States, 1986-96



Source: Johnson and Bobo, 1998. Data compiled by David S. North, IEEE.

Australia is another country which has partially met its demand for S&T personnel through immigration policy -- in 1990 the net migration (difference between inflows and outflows) of engineers was over 3 000 (BIE, 1996). In 1996-1997 the net gain in permanent immigration was 550 for natural scientists and 800 for engineers (this later category includes some building professionals) (Borthwick and Murphy, 1998). In Japan, data on the employment of foreign research personnel show that approximately 73% of Japanese researchers working abroad are in the United States and Europe while foreigners from Western countries account for only 18% of foreign researchers. The high percentage of Japanese researchers in the United States is in part related to the number of Japanese R&D facilities located there (Japan Science and Technology Agency, 1997). Case study evidence on foreign employment in European R&D centres shows that the employment of non-national scientists has increased over the past years in more than half the organisations surveyed and about one quarter of them expected non-national employment to increase in the next five-year period. Among the main factors driving demand were the need for specific expertise and the internationalisation of research (Connor and Pearson, 1998). Security and defence considerations, however, may be an obstacle to international mobility in some cases (especially in nuclear energy).

Cross-border mobility of students

International flows of foreign students in tertiary education (all fields combined) are a crude proxy for temporary flows of individuals with S&T qualifications but represent an indicator of the potential pool of *future* S&T personnel. International data regarding the share of foreign students as a share of the total student population in tertiary education show that seven OECD countries alone account for the large majority (85%) of the total number of foreign students studying in OECD countries in 1995. In absolute numbers, the United States (34%) is the leading receiver of foreign students in tertiary education followed by France (13%), Germany and the United Kingdom (12% each). Australia, Canada and Japan are also main host countries of foreign students. Data on the origin of foreign students in OECD countries indicate that over half come from *outside* the OECD area. The main non-OECD countries sending students are China, India, Malaysia, Morocco and Hong Kong, China. Data from the US National Science Foundation

show that for the United States, the main countries are in Asia (China, India, Japan, Korea and Chinese Taipei).

Foreign students from Asia at the graduate level tend to enrol mainly in natural sciences and engineering, especially those from China, India, Korea and Chinese Taipei. Japanese students enrol mainly at the undergraduate level and in non-science and engineering fields (e.g. business). At the doctorate level, the share of foreign students earning doctoral degrees in natural sciences and engineering rose from 31% in 1986 to 47% in 1994 but has since levelled off. Over half of PhDs in NS&E in 1995 were granted to candidates from China, India, Korea and Chinese Taipei. There is, however, evidence Asian countries are becoming less dependent on US higher education for training PhDs. Since 1993 the annual rate of increase of science and engineering degrees earned in Asian countries greatly exceeds the rate of increase of PhDs earned by Asian students in US institutions (NSF, 1998).

Of the number of foreign students coming from within the OECD area (intra-OECD), the main “sending” countries are Japan, Korea, Germany, Greece, France and Italy. If one compares the share of foreign students relative to the population of tertiary students in OECD countries, an indicator of the relative importance of foreign students, Switzerland, Austria, Belgium, Australia, and the United Kingdom dominate followed by France and Germany (Table 6).

Table 6. Foreign students in higher education (ISCED 5, 6, 7), 1995; foreign graduates as a percentage of all graduates (ISCED 6)

	Foreign Enrolment (men and women) as share of total student population	Foreign Enrolment (% men)	Foreign Enrolment (% women)	First University Degree Only (ISCED 6) (men and women)	Foreign Graduates First University Degree (men and women)
North America					
Canada	3.1	55.9	44.1	2.1	2.7
Mexico	M	M	M	m	m
United States	3.2	M	M	m	m
Pacific Area					
Australia	9.0	52.6	47.4	12.5	13.3
Japan	1.4	55.9	40.1	1.3	m
Korea	0.1	57.0	43.0	0.1	m
New Zealand	3.6	52.6	47.5	3.9	4.2
European Union					
Austria	10.8	55.0	45.0	11.2	
Belgium	9.9	m	M	m	m
Denmark	4.9	48.9	51.5	4.2	m
Finland	M	m	M	m	m
France	7.8	m	M	x	m
Germany	7.2	57.4	42.6	7.6	m
Greece	M	m	M	m	m
Ireland	4.3	49.0	51.0	m	m
Italy	1.3	52.1	40.4	1.3	m
Luxembourg	M	m	M	m	m
Netherlands	M	m	M	m	m
Portugal	2.0	48.3	51.7	2.1	m
Spain	1.4	50.3	49.7	1.5	m
Sweden	M	m	M	m	m
United Kingdom	8.7	57.6	42.4	6.9	m
Other OECD countries					
Czech Republic	1.8	68.5	31.5	2.0	.9
Hungary	3.8	m	M	7.3	3.7
Iceland	2.2	30.6	69.4	2.2	m
Norway	6.5	51.4	48.6	5.4	4.2
Poland	M	m	M	m	m
Switzerland	11.8	m	M	19.7	m
Turkey	1.3	72.5	27.5	1.8	m
Country Mean	4.8	54.1	45.5	5.2	-

Source: *Education at a Glance: OECD Indicators 1997*.

Data on the share of foreign students who actually graduate in S&T are available only a country basis. In Australia, foreign students accounted for 13% of first university graduates in 1995. In 1996 approximately one third of doctorate and masters degrees in engineering were earned by foreign students. Once foreign students graduate, many of them return to their home country but others stay on as permanent immigrants increasing capacity in OECD countries. In the United States, data from the *National Science Foundation*, on the share of foreign PhD graduates who remain in the United States on extended temporary or permanent visas suggest nearly half of recipients in 1990-1991 with temporary visas were still in the country (NSF, 1998). In France, which hosts a large number of foreign students, there is concern that French PhDs may be going abroad in response to fewer opportunities in academia and industry. A survey

of French science and engineering PhD candidates and graduates working as researchers or post-doctorates in the United States found nearly two-thirds had gone abroad to improve their chances of obtaining employment in public research in France (Terouanne, 1997).

While the internationalisation of higher education in S&T is a reality, it is nonetheless strongly influenced by national education and immigration policies and the growth of “catching-up” countries, notably in Asia, whose reliance on OECD countries for higher education is decreasing. Indeed, the scope for student exchange programmes or immigration policy to address supply shortages is limited, particularly in larger OECD countries where high unemployment and restrictive immigration policies (with regard to non-OECD countries) have slowed inflows, even as these countries have become more selective in admissions. Ensuring the benefits of student mobility are translated into overall labour mobility will also require complementary efforts at the EU level in terms of harmonising diplomas and formal educational qualifications systems. Recent measures in France aim to facilitate the temporary migration of foreign scientists and researchers. Germany is promoting greater foreign student inflows at a general level through grants and fellowships schemes. Japan seeks to double the number of foreign students (50 000 in 1997) by the year 2000, also through scholarships (NSF, 1998). Ultimately, international mobility of S&T students and personnel provide countries with a supplementary source of qualified personnel and can help facilitate international co-operation but this cannot replace national efforts to train future generations of scientists and technology personnel. Nevertheless, science and technology policies, in particular international technology co-operation measures, must henceforth consider immigration development and policies.

RECENT POLICY RESPONSES

Science and technology policies have a role in both the education and training of S&T personnel and their deployment in the private and public sectors. Together with broader labour market and education policies, S&T policies can help address policy challenges such as IT skill shortages or barriers to mobility in the public research sector. Because technology is bringing about rapid change in organisational structures and in the workplace, there is a tendency for tasks to change continuously which increases the need for life-long learning within the firm. Science and technology policies have recently made the training and mobility of scientists and technical staff an explicit objective of R&D support as well as of technology diffusion policies. On the one hand, R&D support schemes raise demand for S&T personnel and can help provide practical training. Even though most technology diffusion policies are geared towards technology transfer embodied in equipment, patents, licenses, etc., measures to promote flows of tacit knowledge are gaining ground in OECD countries. Most recently, public/private partnerships between industry, universities and laboratories offer an additional policy option for encouraging greater linkages between scientists in the public and private sectors. On the one hand, universities are interacting more with industry and this is changing the skills and qualifications profiles of academic employees. On the other hand, firms face competitive pressure to reduce product and research cycles as well as costs and therefore are partnering with other firms or with public research and thus need personnel who know both cultures. Partnership policies are therefore integrating labour mobility as an implicit and sometimes explicit objective. Box 2 below provides a non-exhaustive list of recent policy measures in a few Member countries that aim to help S&T personnel better respond to changing demand and skill requirements and to improve their contribution to innovation and growth.

BOX 2. RECENT POLICY DEVELOPMENTS IN OECD COUNTRIES

FIELDS OF POLICY ACTION	OECD COUNTRY EXAMPLES
General labour market reforms	Following the OECD <i>Jobs Study Recommendations</i> , Member countries, notably the United Kingdom, the Netherlands, Italy and Spain have made a substantial number of changes to improve labour market flexibility. While many of the <i>Jobs Study</i> measures such as active labour market policies focus on the low skilled and long-term unemployed, improving overall labour market performance benefits the labour market for S&T personnel by improving demand signals for skills and mobility. Reforms to education and training policies were also recommended by the <i>Jobs Study</i> and most countries have initiated policy measures in vocational and secondary education.

<p>Labour reforms in public research sector</p>	<p>Germany: The Federal government plans to introduce more market compatible employment and remuneration structures in higher education institutions and research establishments.</p> <p>Japan: The latest Basic S&T Promotion Plan outlines a series of regulatory reforms to the labour market for public sector research.</p>
<p>S&T education and training</p>	<p>Austria: Austria has taken measures to introduce <i>Fachhochschulen</i> study courses as a supplement and alternative to university studies. While the national government is responsible for setting the standards for admission, the organisation of courses devolves to the provinces, communities and private bodies. This should ensure that education programmes are adapted to local needs.</p> <p>Germany: New framework conditions have been imposed for the German university system. A number of reforms aim at adapting the “dual system” to the ongoing structural changes in the economy. Measures to encourage the upgrading of training, facilitating access to university education, including from the <i>Fachhochschulen</i>, have also been taken.</p> <p>France: Subsidies have been granted for the hiring of S&T graduates by small and medium-sized firms in order to provide training.</p> <p>Norway: The Ministry of Education, Research and Church Affairs has announced policies to improve recruitment in the public sector and is creating an average of 150 posts per year over 5 years, notably in priority areas: medicine, informatics and law. The Ministry also supports measures to increase the proportion of women in natural sciences and technology, and to increase their share in permanent posts, particularly at professorial level. Finally, a new programme for workplace training has also been launched.</p> <p>United States: Federal legislation is under consideration to amend the tax code and allow employers an income tax credit for high-tech job training. Employees already benefit from tax deductions for continuing education in their professional fields. There is legislation under review in California that would grant the workers tax exemption of company sponsored graduate education benefits.</p>
<p>IT skills</p>	<p>Denmark: The Ministry of Education has launched several initiatives to foster the development of IT skills in schools and other learning centres.</p> <p>Germany: <i>The Partners Alliance for Jobs Training and Competitiveness</i>, comprising representatives from government, labour and management, have agreed on a wide range of measures aimed at eliminating the current shortage of IT workers. This includes improving the infrastructure for IT in schools and universities and training of teachers in IT as well as increasing career training in IT professions to 40 000 over three years.</p> <p>Finland: The government has launched a public/private partnership programme whereby industry contributes to the training of new IT graduates by putting equipment and experts at the disposal of educational institutions, offering internships and encouraging their interns to graduate. The programme will involve over 20 000 students between 1998 and 2002 and is expected to increase the number of degrees by one third from 1999 to 2006. To increase the pool of potential students, an additional programme is being launched to strengthen education in mathematics and science. Measures are also being taken to find ways to attract more female students to the fields and alleviate the shortage of qualified teachers:</p>

<p>Researcher mobility and co-operation with industry, including SMEs</p>	<p>Ireland: Ireland's government has committed IRP 95 million to addressing problems related to skills shortages.</p> <p>United States: The Labor Department is investing USD 8 million to create the largest electronic job and resumé database in the country. It is merging America's Job Bank--the country's largest job openings data base--with America's Talent Bank--a data base of worker-posted resúmes, in order to improve the match between high-tech job opportunities and US workers. The Department of Labor recently awarded USD 3 million in demonstration projects to train dislocated workers for high-tech jobs. The Departments of Education and Labor have awarded USD 6 million in grants to expand industry involvement in School-to-Work Systems. The Commerce Department's <u>Go4IT!</u> Web site promotes partnerships between industry and education providers to expand IT skills at regional and local levels.</p> <p>United Kingdom: The government has recently announced a series of initiatives to foster better IT skills in the workforce. These include efforts to connect all schools, libraries, colleges and universities to the National Grid for Learning by 2002; the launch of the University for Industry in 2000, using new technology to deliver lifelong learning at home, at work and in the community, with IT skills a key target area. Under the proposed National IT strategy, 80% tax breaks for Individual Learning Accounts when used for ICT training will be granted.</p> <p>Austria: Austria has several measures to promote mobility of researchers including the Scientists for the Economy scheme and the promotion of junior researchers through the Industrial Promotion Fund.</p> <p>France: The new Innovation Law encourages public sector researchers to collaborate with industry on a temporary basis and enables them to accept remuneration for outside work.</p> <p>Japan: Japan's latest Basic S&T Promotion Plan, which outlines a series of regulatory reforms to the labour market for public sector research, aims to improve mobility between the public and private research sectors.</p> <p>Netherlands: The Netherlands' <i>KIM</i> scheme that promotes the movement of technology personnel to SMEs has shown success. Furthermore, under the WBSO (Act to promote R&D) small firms are allowed a tax deduction for the labour costs of R&D staff.</p> <p>Norway: The FORNY scheme for researcher-based spin-offs is entering its third phase.</p> <p>Sweden: The NUTEK competence centres at universities promote collaboration between public researchers and those in firms which may help break down non-regulatory barriers to mobility.</p> <p>United Kingdom: The Faraday Programme promotes a continuous flow of industrial technology and skilled people between industry, the universities and intermediate research institutes. A key element of the concept is the training and development of doctoral students, who combine technical expertise with commercial awareness by undertaking industrially relevant research within intermediate institutes. In 1999, the Faraday programme is to be expanded with a focus on entrepreneurial activities and research commercialisation.</p>
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<p>International mobility of S&T students and personnel</p>	<p>France: Several recent measures seek to facilitate the temporary migration of foreign scientists and researchers.</p> <p>Germany: The government seeks to increase foreign student inflows through grants and fellowships schemes.</p> <p>Japan: The government seeks to double the number of foreign students (50 000 in 1997) by the year 2000 through the use of scholarships (NSF, 1998).</p> <p>United States: The US Congress has temporarily increased the annual cap on the number of temporary visas granted to professional immigrants under the H-1B visa programme whose statutory limit is presently set at 115 000 visas per year.</p>
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CONCLUSIONS

Human resources in science and technology labour markets are of vital importance to the competitiveness of OECD economies. While measuring the number of people working and/or educated in science and technology is a highly complex issue, the above analysis confirms the growing demand for S&T labour across sectors and countries but also reveals profound mutations in the labour market for S&T personnel. A trend rise in temporary employment, a decline in public employment and rapidly changing skill requirements all increase pressures for greater flexibility and mobility in S&T labour markets. Across sectors and firms, employers are seeking S&T personnel with multiple skills who can adapt quickly to new tasks and to changing market demands. Even the public research sector which still employs a significant share of S&T personnel in some countries, is facing the same challenges as industry (e.g. globalisation of research, rising research costs, shrinking budgets, and need for multidisciplinary skills) with implications for supply and demand of S&T personnel.

So while S&T personnel suffer less from unemployment and generally enjoy higher wages than other categories of highly-qualified groups, formal S&T qualifications are in themselves no guarantee of successful and quick integration into employment. Spot shortages of S&T personnel (e.g. information technology (IT) workers) are a sign that supply systems are not responding quickly enough and with the right skills for human capital requirements of the knowledge economy. Meanwhile issues of international brain gain, brain drain or brain circulation are of growing importance and those countries with open higher education and research systems, as well as favourable immigration policies, succeed better in attracting a pool of foreign S&T personnel and adjusting to demand shocks. This highlights the importance of good conditions for research and innovation at home in order to foster opportunities for S&T personnel and attract new students and personnel.

The analysis in this report also reveals the interrelationships between education, labour market, and technology and innovation policies. The adequacy of supply systems, notably higher education systems that in the past relied strongly on planning strategies with a focus on *quantity* are of growing concern to policy makers. Firms, industry associations, trade unions and other societal actors are increasing their role in the production of scientific and technological personnel directly and indirectly. Thus, higher education

institutions, while the main providers of S&T education, no longer hold a monopoly position in the traditional sense. On the demand side, policies to improve regulatory structures and incentive systems in the science system and the business sector are also important. Meeting the challenges that lie ahead for S&T personnel will require strengthening partnerships between OECD governments and business to provide workers with the skills for the knowledge economy and to remove impediments to their contribution to advancing research and innovation.

REFERENCES

- AUSTRALIAN BUREAU OF STATISTICS (1998) "Labour Mobility in Australia", February 1998, ABS Catalogue No. 6309.0.
- BORTHWICK. S. and T. MURPHY (1998) "Supply and Demand for Scientists and Engineers", Analytical paper (No. 98/4) prepared for the Department of Employment, Education, Training and Youth Affairs, Canberra, Australia.
- BUREAU OF INDUSTRY ECONOMICS (1996) *Science System: International Benchmarking*, Australian Government Publishing Service, Canberra.
- DANISH MINISTRY OF EDUCATION (1997), *White Paper on Engineering Studies in Denmark*, Ministry of Education, Copenhagen.
- DeVORETZ, D. (1998) "Brain Drain, real costly" Communiqué from the CD Howe Institute, Toronto.
- ESRC (1998), Survey of Postgraduates Funded by the Research Councils, Economic Social Research Council (ESCR), London.
- EUROPEAN COMMISSION (1997), *Second European Report on S&T Indicators*, Brussels.
- EUROSTAT (1998a) Paper prepared by George Paterson for Eurostat Unit 4 and presented to the OECD NESTI Group as "Using the Community Labour Force Survey as a Source of Data For Measuring the Stocks of HRST - Revisited".
- EUROSTAT (1998b), Revision of data contained in "Human Resources in Science and Technology", *Statistics in Focus, Research and Development 2*, 1997.
- ESRC (1998), Survey of Postgraduates Funded by the Research Councils, Economic Social Research Council (ESCR), London.
- FEDERATION OF SWEDISH INDUSTRIES (1998), *Kunskap Koch Kompetens: 1997*.
- HEE, CHO HWANG and HIRASAWA (1998), "Changes in Japanese Government policies to be a front-runner in science and technology " in *Science and Public Policy Vol. 25 No. 1*.
- HOSCHUL INFORMATIONS SYTEM (1998) *European Higher Education Systems*, Hannover.
- HUTSHENREITER G., L. JOERG, F. OHLER and W. POLT (1996) "Tracking Knowledge Flows within the Austrian System of Innovation" Pilot case study for the OECD NIS project:
<http://oecd.org/dsti/nis>.
- INFORMATION TECHNOLOGY ASSOCIATION OF AMERICA (1998a), *Help Wanted 1998: A Call for Collaborative Action for the New Millennium*.
- INFORMATION TECHNOLOGY ASSOCIATION OF AMERICA (1998b), *Digital Planet: the Global Information Economy*.

JAPAN RESEARCH INDUSTRY ASSOCIATION (1998) *Report on the effective utilisation of R&D related personnel.*

JAPAN SCIENCE AND TECHNOLOGY AGENCY (1998) *Research system with high mobility and the lifecycle of researchers.*

JOHNSON, SUSAN TINCH and BOBO, JACK A. (1998) *Software Workers for the New Millennium: Global Competitiveness Hangs in the Balance*, National Software Alliance, Arlington, Virginia.

KOREAN MINISTRY OF SCIENCE AND TECHNOLOGY (1997) Report on the Survey of Research and Development in Science and Technology, Korea.

LAVOIE, M. and R. FINNIE (1998), "The Occupational Dynamics of Recent Canadian Engineering Graduates Inside and Outside the Bounds of Technology", *Research Policy* No. 27, 143-158. Elsevier Publishing.

LAWTON SMITH (1998) "The Contribution of National Laboratories to the European Scientific Labour Market" unpublished working document, Hertford College, Oxford.

MARTINELLI, D. (1999) "Labour Market Performance of PhDs: A Statistical Survey" in this report.

MINISTERE DE L'EDUCATION NATIONALE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE (various years), *Rapport sur les études doctorales*, Secrétariat d'Etat à la Recherche, DGRT.

NSERC (1997), "Highly Qualified Personnel", Draft Report prepared by the Scholarships and Fellowships Division and the Policy and International Relations Division, Natural Sciences and Engineering Council of Canada (NSERC), Ottawa.

OECD (1998a), *Employment Outlook, June*, OECD, Paris.

OECD (1998b) "Interdisciplinarity in Science and Technology", unpublished working document.

OECD (1998c) *Technology, Productivity and Job Creation: Best Practice Policies.*

OECD (1998d) *Education at a Glance, OECD Indicators, 1998.*

OECD (1999a) *The Economic and Social Impacts of Electronic Commerce: Preliminary Findings and Research Agenda.*

OECD (1999b) *Promoting Innovation and Growth in Services.*

STENBERG L., E. GUSTAFSSON and G. MARKLUND (1996) "Use of Human Resource Data for Analysis of the Structure and Dynamics of the Swedish Innovation System", Nutek, Sweden.

SVANFELT, C. (1998) "Formal competencies in the Innovation systems of the Nordic countries: An analysis based on register data", unpublished paper presented at the Joint NEST/TIP/GSS Workshop on New S&T Indicators for the Knowledge-Based Economy held at the OECD in Paris on 25 June 1998.

TEROUANE, D. (1997) *Présence française en science et en ingénierie aux Etats-Unis, cerveaux en fuite ou en voyage?* CNRS working paper.

US DEPARTMENT OF COMMERCE (1999), *The Digital Workforce: Building Infotech Skills at the Speed of Innovation*, Office of Technology Policy, June 1999.

US NATIONAL SCIENCE FOUNDATION (1998), *Science and Engineering Indicators, 1998*.

US NATIONAL SCIENCE FOUNDATION (1999a), *Will Small Business Become the Nation's Leading Employer of Graduates with Bachelors Degrees in Science and Engineering?* NFF Issue Brief, May 1999.

US NATIONAL SCIENCE FOUNDATION (1999b), *International Mobility of Scientists and Engineers to the United States - Brain Drain or Brain Circulation?* Issue Brief, NSF-98-316.

VERGNIES, J.F. (1997), *Diplômés de l'enseignement supérieur : insertion des étudiants sortis en 1992*, Centre d'Etudes et des Recherches sur les Qualifications (CEREQ).

CHANGING DEMAND AND SUPPLY FOR SCIENCE AND TECHNOLOGY PERSONNEL

A. INFORMATION TECHNOLOGY WORKERS IN THE KNOWLEDGE-BASED ECONOMY

by

Charlotte V. Kuh³, *National Research Council, Washington DC*

Even the most casual observer must admit that information technology is an increasingly ubiquitous presence in the developed economies. In the past 15 years, it has transformed the way we process words, analyse data, manage businesses, and communicate with our colleagues. In the years ahead, it is likely to be key to similar transformations in health care, education and commerce. In the course of this transformation, the national boundaries that have defined labour markets, capital markets and cultures are becoming blurred. The Internet has become a source of information and misinformation that can be communicated and responded to in nanoseconds. The world is demonstrating a voracious demand for information technology and an enthusiasm for the transformations it enables. Along with this demand goes a commensurate demand for the workers who are engaged in creating, developing, managing, and maintaining information technology.

The National Research Council is in the initial phases of a study that will examine US workforce needs in information technology (IT) over the next ten years and establish a common base for national discussions. It will describe the range of industries in which IT workers are employed (in the US or abroad), the types of jobs held, and the skills and education needed. It will profile the current IT workforce, including older workers, describe the market demand for IT workers, and examine the availability of both domestic and non-US workers. Looking to the future, the project will explore the capacity of the US educational system and of employer training programmes to produce qualified workers, as well as the feasibility of meeting labour needs from abroad. This paper is an initial exploration of some of the data and economic concepts needed to conduct that study.

The paper first examines three approaches to a definition of the IT workforce -- by industry, by occupation, and by educational training -- and presents how many there are by each definition. It then looks at the problems of forecasting labour demand when the technology that labour produces is changing rapidly. While avoiding the issue of whether there is a shortage of IT workers, it finally looks at sources of additional workers for the IT labour force and discusses data collection needed to lead to more informed policy decisions.

What is IT and how many people are employed at it?

With the current national statistics, there are three approaches that may be taken to defining the "IT sector" and those who work in it. They are:

3. The views expressed herein are those of the author alone and not of the National Research Council.

1. *Industry-based.* The fundamental question here is: which industries are to be included? One industry-based definition of the information technology workforce would include: those businesses that produce software, provide online services and Internet access, supply computer programming and software development (SIC 737), that manufacture computers, their components and peripherals (SIC 357), that produce or sell communications services and equipment (SIC 367, 361, and 483), and that provide systems analysis services or data processing education, (SIC 8742 and 8243) (ITAA, p. 37). This is a very broad definition, however, and many sources limit the definition of the IT industry to SIC 737. (GAO, 1998—p. 5). Both the larger and the more narrow industry definitions include firms that employ many people who support the industry but are not directly involved in creating, developing, managing, and maintaining information technology. On the other hand, both GAO and ITAA exclude workers in IT occupations in other industries. By the narrow SIC 737 definition, employment in the IT industry more than doubled in the US from 628 600 in 1987 to 1.34 million in 1997. The ITAA report estimates that more than twice as many core IT employees are employed in non-IT companies as in SIC 737 companies. (ITAA, p. 9)
2. *By occupation.* The distinction between counting IT workers by occupation and counting them by industry is shown in Figure 1. Many more workers say that they are employed in IT occupations than are employed in IT industries. More concrete data may be obtained from the Bureau of Labor Statistics Industry/Occupation Matrix (as reported by Ellis and Lowell I. p. 4). In manufacturing, for example, only 122 000 of 268 000 who say that their occupation is in IT are employed in clearly identifiable computer-related industries. In the service sector, which employs a preponderance of IT workers defined by occupation, only about 40% of the one million IT workers by occupation were employed in the computer and data processing industry.

Another approach would rely on an occupational definition enumerated through surveys of households and individuals conducted as part of the Current Population Survey of the US Census, or collected as part of the Scientists and Engineers Statistical Data System (SESTAT) of the National Science Foundation. (Ellis and Lowell, Veneri). “Core” IT occupations are usually defined as computer scientists, computer engineers, and systems analysts. There is debate as to whether programmers should be included as a fourth core occupation. They certainly should be, under our broad definition. Without programmers, Ellis arrives at 1.5 million IT workers in 1998 which becomes 2.2 million if programmers are included. These are shown in Figure 2. Inclusion of programmers is an important issue for policy, since the narrow definition gives rise to descriptions of soaring demand, while the broader definition reflects a much slower rate of increase and may actually turn to decline once Year 2000 fixes are complete.

3. *By education.* A third approach is to count people who have been educated in the core IT fields. The annual production of degree holders in computer science is shown in Figure 3. Baccalaureate production reached a peak in 1986 and then declined, at least until 1997. Since IT employment has been growing, there must be sources of IT workers beyond conventional degree programmes. In fact, only 41% of those employed as computer scientists, computer engineers, systems analysts, and programmers in 1995 had received a baccalaureate degree or higher in computer science or computer engineering. Another 19% had received a degree in some other engineering field (Ellis and Lowell II, p. 1). The next largest source was social

science, with 8%. Thus, tracking core IT degrees alone will provide a misleading picture of supply.⁴

The SESTAT surveys reveal yet another difficulty in tracking IT workers. Different kinds of computer employment draw on graduates from different fields. The situation in 1997 is shown in Figure 4. About one-quarter of those who identify their occupation as systems analyst and more than one-quarter of information systems scientist and “other” do not have a degree in either science or engineering. Further, in the computer science intensive fields where there was a relatively low proportion of non science and engineering graduates, the percentage of those with computer science degrees declined between 1997 and 1995.

Is there a shortage of IT workers in the United States?

The rapid rise in employment of workers in computer specialties evident in Figures 1 and 2, combined with the downturn in degrees shown in Figure 3 would suggest that shortages of IT workers might be emerging. If this were the case, we would expect to see rising salaries for new entrants. Salary offers for baccalaureate candidates in the IT fields are shown in Figure 5. In constant dollars, these have been rising steadily since 1995 in all fields.

In addition to training, there are options available to employers, such as opening branches in low wage countries, thus keeping salaries down, even in the face of rapidly increasing demand. It may be that, by looking at salaries for US graduates alone, we are ignoring what is in fact a global supply of skilled IT workers.

Possible evolution of demand for IT workers

Given the slipperiness of defining the current IT workforce in the United States, it is very difficult to forecast future demand for IT workers, let alone know whether public policy should be directed toward increasing the supply. Some factors that may influence the evolution of demand are listed below.

Industry structure. Every day brings news of changes in industries that will have an impact on IT worker demand. The long-heralded convergence of communications and computing is finally occurring. As information technology equipment has become ubiquitous so has the need for standards so that the products produced through IT can be shared and widely used. The apparent tendency toward increased concentration in the design and use of operating systems and applications languages is an example of this standards-driven evolution. Mergers and acquisitions typically result in job loss as the partners learn to manage the combined business more efficiently. On the other hand, once standards are set there may be a proliferation of down stream firms innovating to that standard, when earlier such ventures would have carried the additional risk of choosing the wrong standard.

Productivity and wage gains from IT. Some studies (Autor, Katz, and Krueger, 1997) have found that increases in the use of computer technology have been associated with a general rise in the relative return to higher education and demand for highly skilled workers. It would now appear that the “productivity paradox” in which productivity growth seemed unaffected by large investments in information technology

4. It should be noted that there is a generational problem here. Formal computer science degree programmes became widespread only in the late 70s, so part of the explanation of non-computer trained people in computer-related fields may reflect this change. This observation would not explain the growth in IT employment while degrees granted in computer science are declining in the years since 1985.

has been resolved. Microeconomic studies (Brynjolfsson and Hitt, 1998) have found a strong association between investment in IT capital and revenue increases. At the macroeconomic level, the United States is experiencing levels of productivity growth higher than any seen in the past 40 years. Economists are now taking a new look at how IT changes the nature of work within the firm. The implication of these increases in productivity for demand for IT workers is less clear. The lag between investment in computer-related capital and improvement in productivity suggests that technology adoption is a slow process. Rapid technical change may actually hamper the organisational changes necessary to the productivity-enhancing use of IT.⁵

Rates of technical change in IT itself. Computing power and the degree of connectivity of computers has been growing exponentially for the past 20 years and no end is in sight. Each jump in power and connectivity has given rise to a need for new applications. IT personnel who work on long term projects find that their skills rapidly become obsolete and that constant retraining is necessary in order to compete with new hires who are expert in the latest technology. It is not clear that IT employers provide that training. Rather, anecdote suggests that IT workers change employers often and established IT firms absorb successful start-up firms that have been able to capitalise on the latest technology. For non-IT industries, one way of dealing with the difficulty in finding IT workers is to outsource the development of computer applications to specialised firms. This increase in specialisation may also limit demand for IT-trained workers.

Research is needed to find out about the career paths of IT workers. It means one thing if IT workers move out of IT in order to manage IT development. It means something very different if IT workers leave an IT occupation totally and abandon IT-related work because their skills are irrelevant to newly developed technology.

Will the IT work of the future be done by IT-trained workers? There seems to be no end in sight to the growth of IT-using applications. Current perceived shortages in IT personnel could give rise to a number of possible responses only some of which would justify public investment to increase IT worker supply. We need to develop data-based models of the substitutability between IT workers and software. As software becomes user-friendlier, tasks that used to require programming skills today may simply require educated users in the future. This does not mean that those skilled in the technical aspects of IT will no longer be needed. It does mean that the demand for IT personnel may not grow as rapidly as the demand for IT itself.

Data needs to track the evolution of employment in a knowledge-intensive economy

The reader will note that I have discussed the demand for and supply of IT workers without discussing the evolution of the “knowledge-based” economy. As IT becomes increasingly ubiquitous, that term will become redundant. It will simply be “the economy.” In the meantime, however, we need to track the evolution to the knowledge-based economy and we know that those who create, develop, manage, and maintain IT play a key role in that evolution.

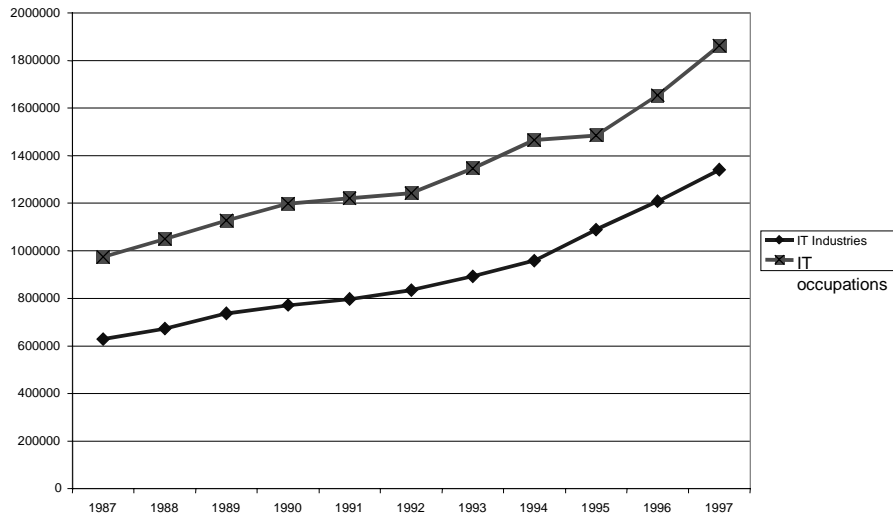
Two OECD documents provide a useful framework for data collection to understand what is happening to information and communications technologies and the workers that make it possible. The OECD *Canberra Manual* (OECD, 1995) in Chapter 4 presents a helpful framework to define stocks and flows that could be used both nationally and internationally to examine the dynamics of the IT labour market. More recently, the OECD has produced a succinct paper on *User Needs and A Proposed Set of Core Tables* to track information and communications technologies (OECD, 1998) which is a good first step. It would be difficult, however, to apply these approaches to US data. In addition to obtaining agreement on taxonomy,

⁵. See, for example, P. A. David (1990) on past introductions of new technology.

it is likely that the problem in developing meaningful data on IT workers that is comparable across industries and countries is to create these taxonomies with some flexibility. We need to agree on some fairly basic concepts: what is IT? Who is an IT worker? Are there IT career paths? Do IT workers receive common sorts of training, either formally or informally? Then, we need to create a system that can monitor a rapidly changing technology. The basic question is: how do we make a swiftly evolving technology sit still long enough to develop a consistent set of data concepts?

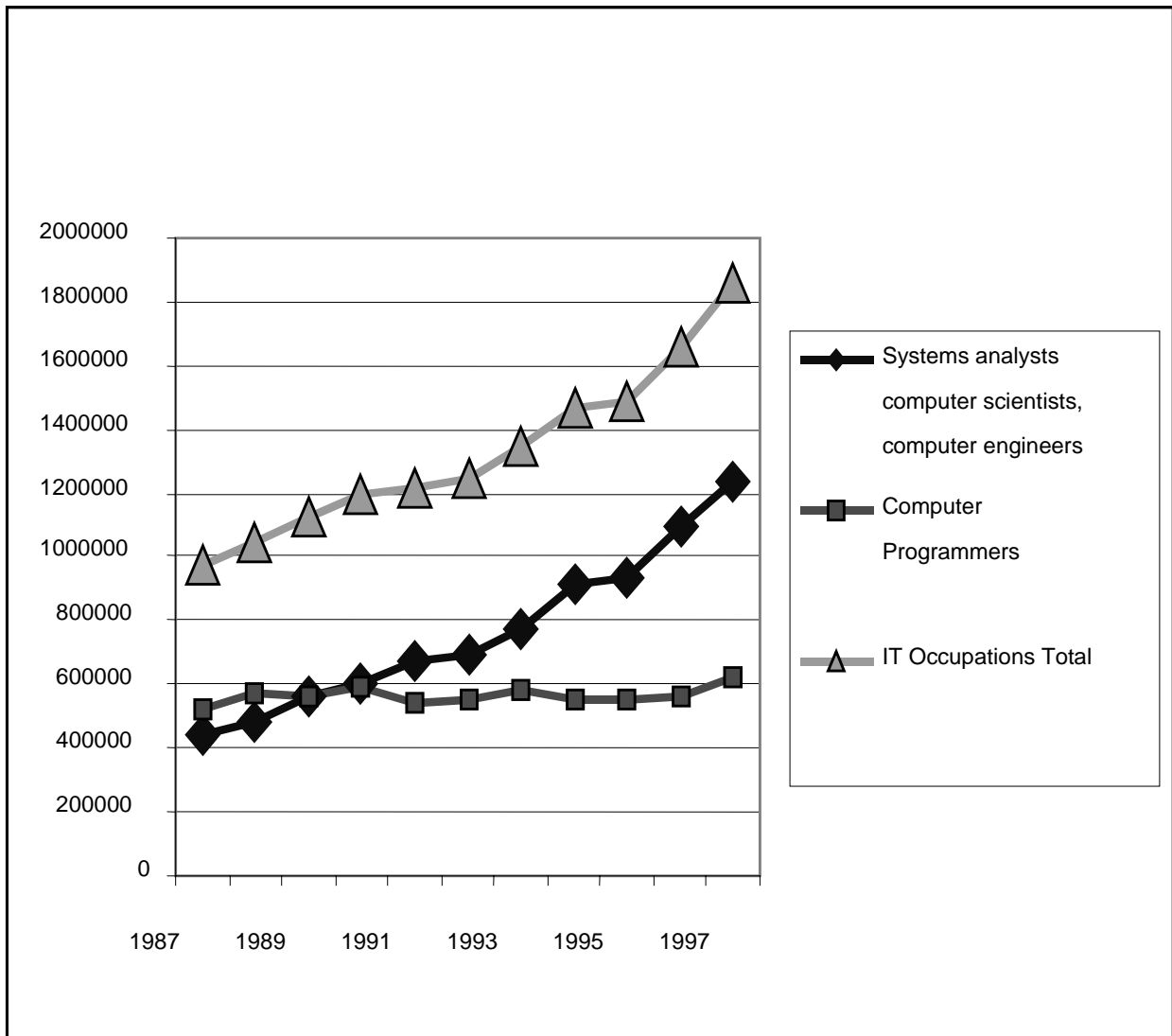
Why is this important? We have a set of data collection concepts that are appropriate to industrial economies. If IT is the key infrastructure in a world economy that is increasingly knowledge-intensive, we need to develop appropriate forms of measurement -- of output, input, and the organisational structures that change one into the other.

Figure 1. Information Technology Employment



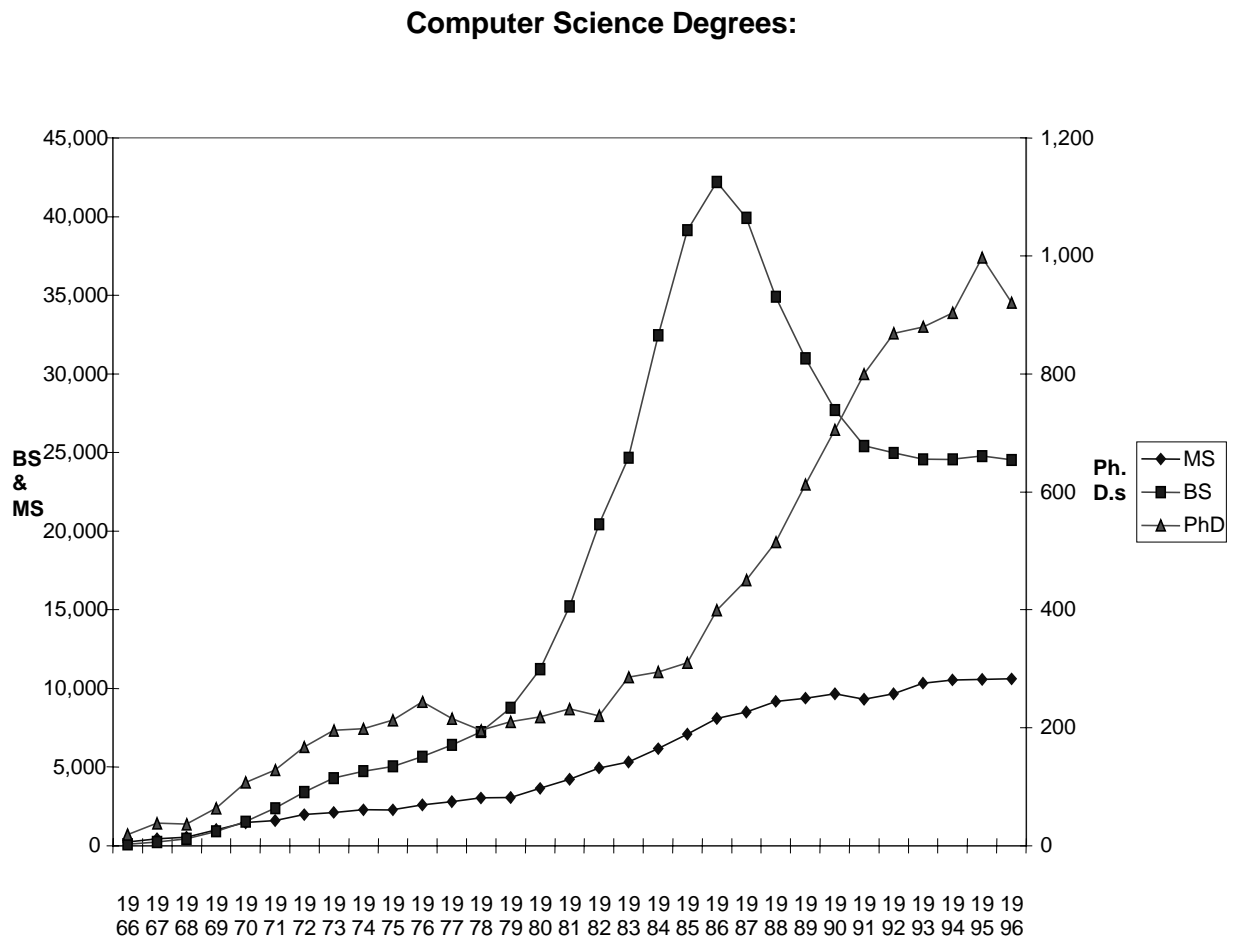
Source: CPS and CES data as reported in GAO, p. 17.

Figure 2. Information Technology Employment by Occupation



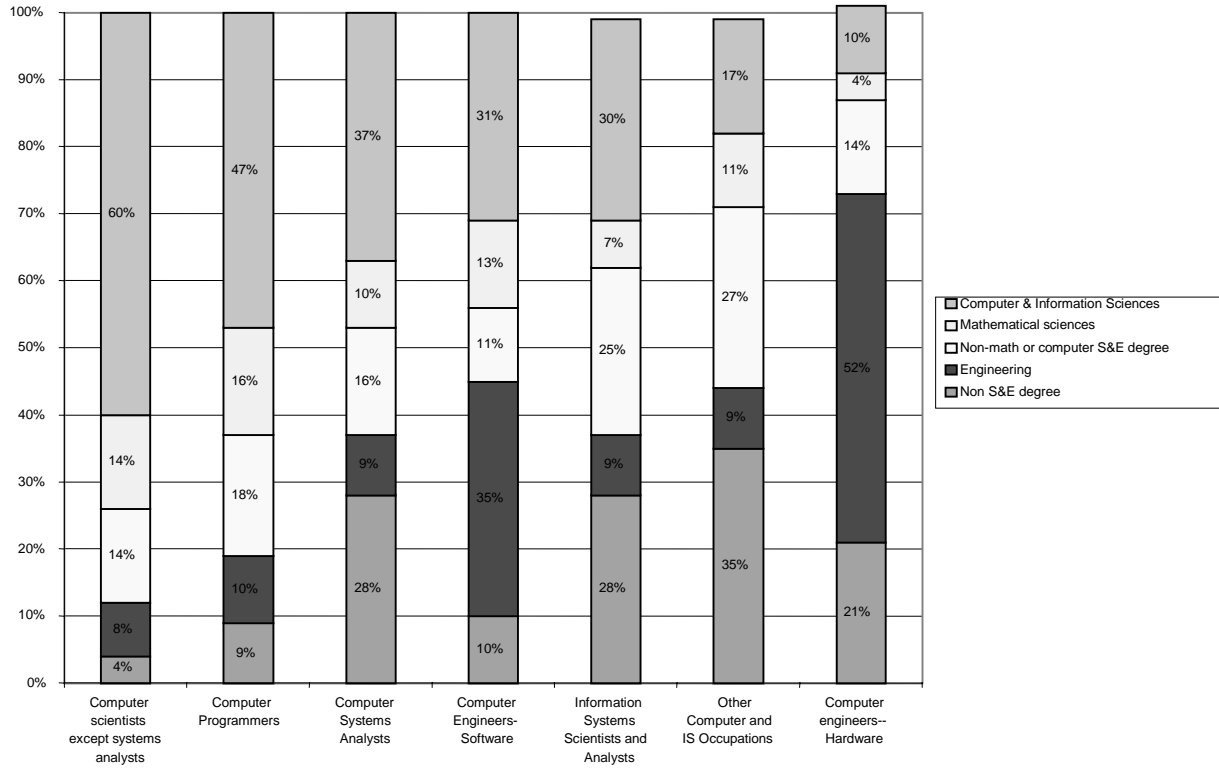
Source: CPS data reported in GAO, p. 17.

Figure 3. Degree production in computer science



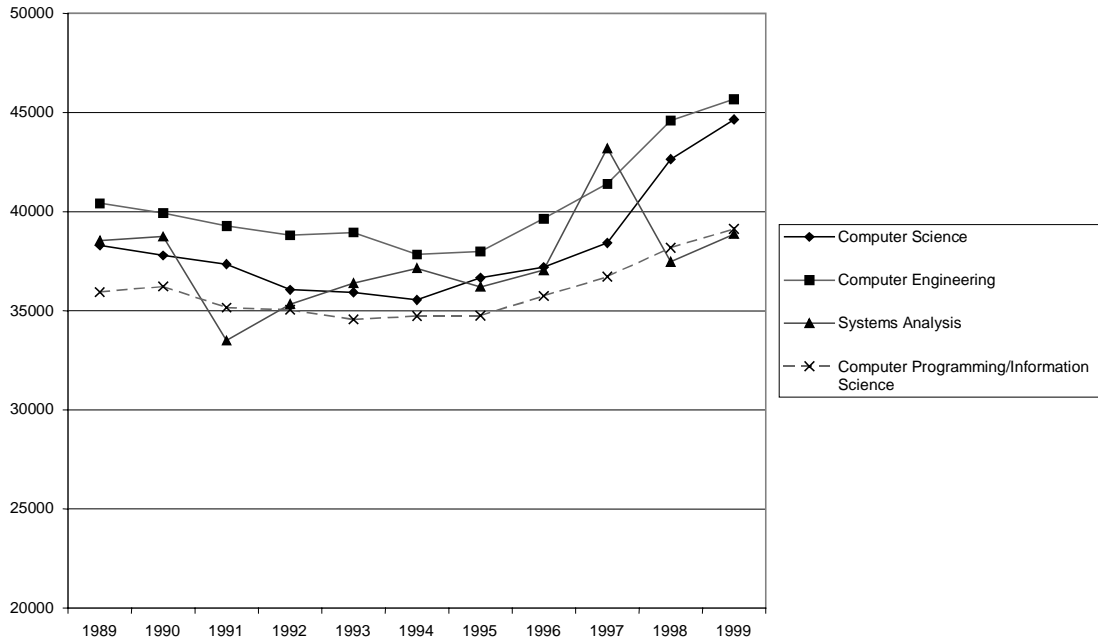
Source: CPS data reported in GAO, p. 17.

Figure 4. Occupation by Degree



Source: Veneri, p. 50.

**Salaries for Bachelor's Degree Recipients by Field
Constant (1999) Dollars**



Source: National Association of Colleges and Employers. 1999 Data through August.

REFERENCES

- AUTOR, David H., KATZ, F. LAWRENCE , and Alan B. KRUEGER (1997)
 “Computing Inequality: Have Computers Changed the Labor Market?” Industrial Relations Section Working Paper #377, Princeton University.
- BRYNJOLFSSON, Erik, and Lorin M. HITT (1998)
 “Beyond the Productivity Paradox: Computers are the Catalyst for Bigger Changes.” Communications of the ACM.
- BRYNJOLFSSON, Erik, and Lorin M. HITT (1998)
 “Information Technology and Organizational Design: Firm Level Evidence,” MIT Working Paper.
- DAVID, P.A. (1990)
 “The Dynamo and the Computer: A Historical Perspective on the Modern Productivity Paradox.” American Economic Review Papers and Proceedings, pp. 355-361.
- ELLIS, Richard, and B. Lindsay. LOWELL (1999)
 “Core Occupations of the US Information Technology Workforce.” Report 1 of the IT Workforce Data Project.
- ELLIS, Richard, and B. Lindsay. LOWELL (1999)
 “The Production of US Degrees in Information Technology Disciplines.” Report II of the IT Workforce Data Project.
- ELLIS, Richard, and B. Lindsay. LOWELL (1999)
 “Foreign-Origin Persons in the US Information Technology Workforce.” Report III of the IT Workforce Data Project.
- Information Technology Association of America (1998)
 “Help Wanted 1998: A Call for Collaborative Action for the New Millennium.”
- OECD (1995),
 The Measurement of Scientific and Technological Activities. (1995)
 Manual on the Measurement of Human Resources Devoted to S&T. “Canberra Manual”
 OCDE/GD(95)77.
- OECD (1998)
 “User Needs and A Proposed Set of Core Tables”. Directorate for Science, Technology and Industry, Committee for Information, Computer and Communications Policy.
- US Department of Commerce, Office of Technology Policy (1997)
 “America’s New Deficit: The Shortage of Information Technology Workers.”

DSTI/STP/TIP(99)2/FINAL

US Department of Commerce, Office of Technology Policy (1998)
“America’s New Deficit: Update.”

US Government Accounting Office (1998)
Information Technology Workers: Employment and Starting Salaries (GAO/HEHS-98-159R).

US Government Accounting Office (1998)
Information Technology: Assessment of the Department of Commerce’s Report on Workforce Demand and Supply. (CAS/HEHS-98-106R).

VENERI, Carolyn (1998)
“Here Today, Jobs of Tomorrow: Opportunities in Information Technology.” *Occupation Outlook Quarterly* 42(3). 44-57.

B. LABOUR MARKET SPECIALISATION AND EARNINGS OF ENGINEERS AND SCIENTISTS IN GERMANY

by

Friedhelm Pfeiffer, *Zentrum fuer Europaeische Wirtschaftsforschung* (Centre for European Economic Research), Mannheim, Germany

Overview

This paper analyses the main fields of activities and the determinants of income and occupational choice in a sample of engineers and natural scientists taken from the *Mikrozensus* 1991, 1993, 1995. Engineers and natural scientists develop specific patterns of occupational specialisation, which depend among other things on the length of their education. University graduates (five years of education) for example are more often employed in research departments than the graduates from technical universities (four years of education) and engineers are more often part of the management than natural scientists. The returns to investment in an additional year of education (from four to five years) are around 7-8%. The German *Mikrozensus* as an important research tool for labour economists could be improved if individuals between different cross-sections could be identified.

Introduction

Despite the wide range of its observations and questions, and the regularity with which it is carried out, the *Mikrozensus* is, comparatively speaking, still not used much as a source for empirical labour market and economic research. It is, however, the range of observations and the regularity in particular which also facilitate systematic analyses of sections of the labour market, investigations which are otherwise not possible within the framework of empirical labour market analyses carried out in Germany primarily on the basis of the socio-economic panel. This is true, for example, for the group of about 1 600 000 engineers and scientists who, by means of their training, have gained the basic methodological and vocational competencies to ensure Germany's technological viability.

In the present study, selected aspects of the vocational activities of engineers and scientists, taken from the *Mikrozensus* 1991, 1993, 1995, are to be presented economically from a labour market perspective and theoretically from a human capital perspective, including analyses of major fields of activity, net monthly earnings and reasons for self-employment.⁶

6. This text constitutes a revised version of parts of a report prepared at the Centre for European Economic Research (*Zentrum für Europäische Wirtschaftsforschung GmbH* - ZEW) on behalf of the German Ministry for Education, Science, Research and Technology, entitled "Employment of Human Capital in the Nineties, Analyses with the *Mikrozensus*" and "Innovations, Qualification and Employment" c.f. Pfeiffer/Falk (1999). The analytical aspects of the material were prepared in the project "Technical Progress, Qualification and Job Demand" supported by the German Research Society, a project which has been underway since 1996 under the joint supervision of the Chair for Political Economy, in particular Econometrics of the University of Constance, and of the ZEW.

Information technology is strengthening the trend observed in all industrial countries for an increase in job demand for more highly qualified individuals, a trend which has become evident both in the research and development divisions of companies and in the employment situation of university and technical college graduates. Research on the job market and in education (c.f. Berman/Bound/Griliches 1994, Franz 1996, Gerlach/Hübler/Meyer 1998, Pfeiffer/Pohlmeier 1998, OECD 1996, Tesaring 1998, vonWeizsäcker 1998) has been focussing on the concomitant impetus created for the job supply and demand, on salary structures and on the choice of vocation.

The data of the *Mikrozensus* carried out annually by the German Office of Statistics (*Statistisches Bundesamt*) allow us to make a micro-economic, person-oriented analysis of this process of change. Information is gathered on individual vocational qualifications (including the field of studies), on job income, on the sectoral and company location of jobs and on the position of the vocation in question.

The following section of this study contains remarks on vocational specialisation from a theoretical human capital perspective. Section 3 presents the database. Section 4 contains an analysis of fields of activity, Section 5 an analysis of earnings, and section 6 an analysis of reasons for self-employment. The final section contains an outlook on research.

Theoretical remarks on human capital with regard to vocational specialisation

The objective of the human capital theory is to explain individual demand for education and training, i.e. investments in human capital, dependent upon capabilities, supposed advantages and the job market situation. Conclusions will be made here not only about the length of primary training, but also about the amount of human capital invested during working life. Expectations of the consequences of human capital investments now, and of resulting income in the future, play an important role.

In the models it is assumed that individual capacities can be expanded and developed. To attain an improvement, an effort must be made in advance in the form of time and/or teaching aids. The improvement of individual capacities depends upon the level of training already attained. Specific assumptions will be made with regard to salary progression in relation to human capital. Many models assume perfect job markets with perfect foresight on the part of individuals.⁷

In the theory of human capital, it is the individual who usually makes the choice as to his or her first field of training (in particular the length and intensity of training) and the time frame for further training during his or her working life. Individual capabilities and characteristics, time preferences, the length of working life, the price of training material, the state institutions and the earnings which can be made on the job market for the various levels of qualification are all set factors for the choice made by an individual, whereby perfect foresight subject to general balancing effects is assumed.

Human capital is a multidimensional quantity. Becker (1983) differentiates between general and specific human capital. General human capital according to definition can be transferred between sectors, companies and professions. Specific human capital is only transferable to a limited extent. Know-how can be specific to an employer, a profession, a sector or a technology. Since we are generally led to believe that the economic advantages of specialisation and labour division are enormous (c.f. for example Becker/Murphy 1992), investments in specific human capital are necessary and worthwhile. On the other

7. C.f. von Weizsäcker (1986). The investment of human capital has been supplemented in many respects. In more recent growth theories, the external effects of training are also taken into consideration (e.g. Lucas 1988). Theoretical aspects of information on training investments are investigated in selection, signal and sorting models (c.f. Weiss 1995).

hand, the danger of a devaluation in the process of technological and institutional change is greater here than for general human capital. The extent of the devaluation depends upon the type of know-how and the speed of change.

Training institutions, accordingly, play an important role for the course of technical progress and economic development in general. The range and availability of training determine opportunities for vocational specialisation in person-linked human capital (c.f. Clar/Dore/Mohr 1997). The economic advantage of specialisation (e.g. electrical engineers, mechanical engineers, chemists, physicists, and salesmen) depends to a great extent on the amount of costs involved in co-ordinating the specialists. According to Becker/Murphy (1992), increasing vocational specialisation is, generally speaking, advantageous in view of the increase in knowledge, although the co-ordination costs should not be underestimated. Information and communication technologies, in view of their potential to reduce co-ordination costs, will no doubt contribute to a further increase in vocational differentiation and specialisation in working life. New technologies also create new jobs with new qualification profiles, which in turn make room for further vocational differentiation.

Creating human capital costs time and resources. If general human capital facilitates the creation of specific human capital (hypothesis of complementarity between general and specific human capital, Mincer 1974), is it worthwhile in times of great insecurity with regard to future economic and technical developments to shift more to general human capital. This is certainly an important reason for the increase that has been observed in higher education and better general education in all industrial nations. If developments are foreseeable and no technical or other shocks occur, it would, accordingly, be profitable to begin vocational specialisation in early years. Theoretically, there is an optimal ratio between general and specific human capital according to the type and speed of change in a region or industry. General human capital is necessary in particular to keep down the costs of creating and altering specific human capital in the course of working life.

Data base: the *Mikrozensus*

The *Mikrozensus* is an annual household questionnaire by the German Office of Statistics (*Statistisches Bundesamt*) comprising 1% of the total population, in which members of households are questioned directly by an interviewer. The *Mikrozensus* is prescribed and regulated by law. The information attained from the persons questioned is made ready for a specific reporting week. The *Mikrozensus* includes not only socio-demographic information (gender, age, marital status, and citizenship) but also information from the fields of employment, profession, sources of income, and basic and further training. Not all statistics are gathered on an annual basis. Information on basic and further training and on the field of graduation from training is gathered on a biennial basis in accordance with the *Mikrozensus* law in the version of 10 June 1985, which was applied in particular to a great extent for surveys up to 1995⁸.

The Centre for European Economic Research (*Zentrum für Europäische Wirtschaftsforschung – ZEW*) in Mannheim disposes of a 70% sampling of the *Mikrozensus* of 1991, 1993 and 1995. In 1991, the 70% sampling involved 515 886 persons, of whom 231 516 were gainfully employed and 16 514 unemployed. The 70% sampling of the 1993 *Mikrozensus* involved 513 830 persons, of whom 220 421 were gainfully employed and 23 090 were unemployed. The 70% sampling of the 1995 *Mikrozensus* involved 514 630 persons.

8. The *Mikrozensus* law was modified on 17 January 1996. This means the following changes for future analyses: Information on vocational training is to be gathered on an annual basis; the year of the highest vocational training or educational qualification and the subject involved are now gathered on a four-year basis. The first survey took place in 1996 and is not yet available to the ZEW.

Random tests of gainfully employed university graduates in the fields of science and engineering were chosen for the analyses from the ZEW 70% samplings for the three years in question. Some of the questions in the *Mikrozensus* are obligatory (e.g. age, nationality, employment status), whereas information on basic and further training is voluntary. This is also true of information regarding fields of study for university graduates, which is gathered on a biennial basis (e.g. 1991, 1993, 1995). Accordingly, data for such information can be missing. Data concerning the highest level of school education, the highest vocational training, further training and the fields of study involved are missing for a maximum of 10% of persons (c.f. Pfeiffer/Falk 1999). In the following material, there is therefore no sense in calculating the number of employed engineers and scientists.

The information gathered in the *Mikrozensus* facilitates a link between the field of study and earnings on the one hand, and sectoral and company information on jobs and vocational activity (e.g. research and development) on the other.⁹ From an economic point of view, the earnings attained from investments in further training are more important than the level and type of certified qualifications. Theoretically, human capital is equivalent to the monetary value of earnings made during the whole of an individual's working life. As such, income derived from economic processes constitutes an important indicator of success in vocationally motivated training investments. Further training and learning-by-doing also play an important role in the development of human capital. Its significance can be seen according to age groups in the analysis of earnings.

In addition to earnings, activity analyses will be presented for the various divisions of a company and on vocational status. Almost one-tenth of those employed do not fit into one of the categories of the *Mikrozensus*, most likely because many small companies are not organised into divisions. In an age of science and technology, engineers and scientists constitute an important input for the production of knowledge.

Employees responsible for the development of innovations, can, with the help of the data from the *Mikrozensus*, be identified according to job group (division). A total of nine divisions are recognised, which are grouped into five for the purposes of the analysis. In addition to production, logistics, administration and management, the divisions of research and development, construction, model construction, and design are of particular interest to technological achievement. This definition of the research and development field, known here as RDC (C = construction), is somewhat broader than that proposed by the OSLO manual in its definitions of innovation activities. This broader definition also includes design, which involves only optical changes to a product.

Analysis of fields of activity

This section deals with the question of the relationship between the field of studies and subsequent employment. In which divisions are scientists and engineers who have specialised during their studies in science and technology employed, and what activities do they exercise? The increasing significance over the past few years of qualified service activities has also brought about a change in vocational fields of activity among university graduates (c.f. BMBF 1998, Licht/Kukuk/Grupp/Hipp 1997). Little positive employment impetus can be expected from the public service or from industry in the future. It remains to be seen which fields of studies correspond to which divisions, in particular research, development and construction (RDC) divisions.

9. On earlier work with the data of the *Mikrozensus*, c.f. Bellmann/Reinberg/Tessaring (1994). On works with regard to fields of study, c.f. Cornelsen (1995).

In Germany, the largest group of university graduates in 1995 were engineers (including architects and construction engineers), with an employment potential of over one million persons. The third largest group, after teachers and educators, were scientists, with about 650 000 persons to be employed.

The development of new products and new production procedures requires special knowledge and capabilities. Creativity and the generation and implementation of new ideas are becoming more and more important, whereas the exercise of what one has learnt is very much on the back burner. From an economic perspective, the significance of research and development can often be seen in the level of expenses made for research and development as well as for other innovation activities. About two-thirds of expenditures for research and development involve personnel costs (c.f. BMBF 1998). The 'stock of knowledge capital,' seen primarily in the totality of company research and development expenses, is thus, to a large extent, a 'stock of human capital.' The results and experience acquired in the course of innovation activities are only partially secured by trademark rights and patents. They are mostly secured in the wealth of experience gained by the research and development personnel in question.

A division of university graduates into the fields of research, development and construction, production, marketing, personnel/finances and management for 1991 and 1995 can be seen in Table 1 (technical college graduates) and Table 2 (university graduates). Between 24% and 36% of technical college graduates are employed in the RDC field. Of university graduates, 38% of the engineers and up to 43% of the physicists are employed in the RDC field. Engineers, chemists and physicists are also employed in production, management and distribution.

Table 1. Employment of technical college graduates according to divisions in industry in 1991 and 1995 (ABL) (%)

Div.	Production		RDC Div.		Marketing, Sales		Management	
	91	95	91	95	91	95	91	95
Field/year	91	95	91	95	91	95	91	95
Engineers ¹	23	24	37	32	14	16	8	9
-Mechanical engineering	24	24	38	36	12	15	8	10
-Electronics	24	24	38	31	13	16	7	6
Science	20	18	29	24	14	17	8	8
-Chemistry	19	23	34	31	16	21	9	7

1. Excluding architects.

Source: ZEW 70% samplings of the 1991 and 1995 *Mikrozensus*; the two other groups 'finances' and 'no dept. assigned' are excluded here to save room.

Technical college engineers tend to be more involved in production than university engineers, the proportion being relatively stable between 1991 and 1995. In the field of RDC, the proportion of mechanical and electronics engineers who graduated from technical colleges declined slightly, whereas the proportion of physicists and computer specialists who graduated from universities increased slightly. The proportions of university and technical college graduates in management differ very little from one another. As a general rule, engineers tend to be found in management more than scientists. The proportion of scientists rose from 24% in 1991 to 28% in 1995. These are primarily research experts who studied chemistry, physics or computer science. As in other company fields, this reflects the increasing presence of data processing in the field of research and development, although there is not necessarily a direct connection between the field of study and the activity carried out.

Table 2. Employment of university graduates according to divisions in 1991 and 1995 (ABL)

Div.	Production		RDC Div.		Marketing, Sales		Management	
	91	95	91	95	91	95	91	95
Field/year								
Engineers ¹	16	15	36	38	12	12	10	10
-Mechanical Engineering	16	16	37	36	9	12	11	12
- Electronics	16	15	38	41	14	13	8	8
Science	8	6	29	27	8	8	7	7
-Computer science	6	6	34	30	10	10	3	6
- Chemistry	13	11	41	39	8	8	9	8
- Physics	8	5	42	43	5	5	7	7

1. Excluding architects.

Source: ZEW 70% samplings of the 1991 and 1995 *Mikrozensus*; the two other groups 'finances' and 'no dept. assigned' are excluding here to save room.

The public service is the most important employer for university graduates. Its proportion is on the decline. In the territory of the former West Germany, 42% of university graduates were employed in the public service in 1995 and 45% in 1991, 18% of university graduates were employed in manufacturing and 41% in other sectors of the economy in 1995. A total of 55% of biologists, 30% of chemists, 38% of physicists, and almost 60% of mathematicians are employed in the public service. Scientists are dependent in general upon hiring practices in the public service whereas engineers and chemists are more dependent upon developments in the labour market.

Analyses of earnings

In this section, the earnings of scientists and engineers will be differentiated according to age, gender, field and type of studies and will be quantified according to job site. Earnings paid by a company concerned should, at least in private industry, be equivalent more or less to what the employee achieves for the company. A graduation certificate from a technical college or university need not have the same 'value' in all cases. A university graduation certificate in science may, for example, be less 'valuable' in terms of monetary production outside the research sector or outside the research division than it would be in a research and development or other sector or division.

The survey is based methodologically on a calculation of an empirical earnings ratio in the tradition of Mincer (1974), in which earnings are considered to be returns on an investment in education. A difference is made here between the years devoted entirely to training and the years of professional activity, in which the professional experience and further training can be interpreted as investments in human capital.

Serving as a data basis is a sampling of employed male university graduates in science and engineering who are working in manufacturing in the former West Germany. Only full-time salaried employees (not public servants) who have given their job as their major source of income, who do not have other sources of income and who do not work in company management are included.

In the *Mikrozensus*, available monthly net income is divided into 18 categories. The highest category is income over DEM 7 500. Income under the DEM 1 400 limit is not included. The comparison of incomes is made on the basis of an ordered Probit Model with known limits. This procedure takes into consideration not only the income progressions but also the problem of the categories above the DEM 7 500 and below the DEM 1 400 limits. Since net income is dependent upon the tax and transfer system, the comparison contains other variables, including data about marital status and size of household. Between 1 614 and

1 695 full-time employed scientists and engineers have been included in the ZEW samplings of the 1991, 1993 and 1995 *Mikrozensus*.

The earnings of engineers and scientists with professional experience in the manufacturing sector developed positively between 1991 and 1995 for most of the age groups. There are substantial differences here though. Earnings for the age group between 25 and 29 years showed no substantial improvement during this period (see Table 3).

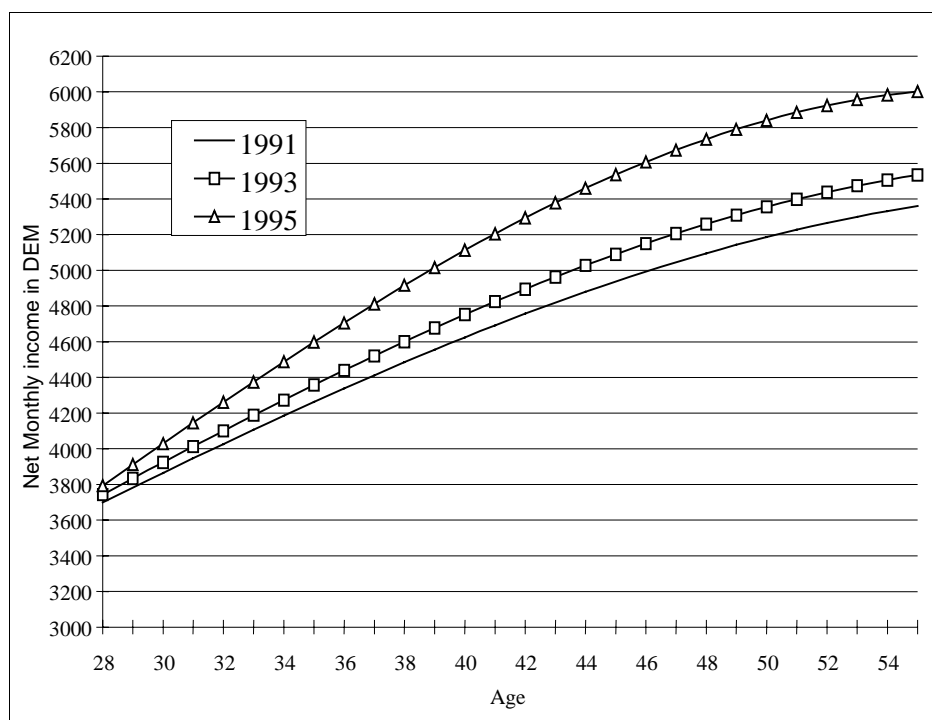
Figure 1 shows estimated net income in relation to age. Earnings by younger engineers and scientists remained constant whereas those of higher age groups showed an increase. The result is an indication of the surplus in offer for qualified beginners in the first half of the 90s. Unemployment rates for engineers and scientists in particular rose sharply in the period 1991 to 1995.

The earnings of engineers and scientists differ in relation to divisions and age. The earnings in a research and development division are higher than in other divisions (excluding management) up to the age of about 45 and lower for higher age groups. This progression of earnings, and in particular the almost 6% higher income at the start, can be interpreted as compensation for creativity and other unobserved characteristics which are required in the field of research and development. University graduates are thus not, generally speaking, 'more valuable' in research and development than they are in other divisions, but usually only in the early years following their studies. This coincides with the observation that university graduates are employed initially in research and development and then transfer to other divisions (e.g. to management), where earnings are about 20% higher.

Working in research is thus financially attractive in younger years in particular. But work in the research and development sectors of industry is advantageous for all salaried engineers and scientists. In 1995, with all other variables constant, the earnings of salaried university graduates in this sector were 5.5% higher than earnings in non-research and development sectors.

Very few foreigners with university degrees are employed by manufacturing companies in the former West Germany (5% in 1991 and 6% in 1995). Their earnings are between 7 and 9% lower than those of their German colleagues. Scientists and engineers with temporary job contracts (a total of 2%) made 14% and 9% less than permanent employees did in 1993 and 1995 respectively. No significant influence can be elucidated for the cross-section of 1991. In 1995, university graduates, who study for an average of one year longer than technical college students, earned almost 8% more than technical college graduates. The difference in earnings for mechanical engineers and electro-technicians was about 11% from 1991 to 1995. The highest difference is among chemists: 15 to 16%. This may be a result of the longer training time for chemists, or of other unobserved factors such as high job risk. Other university graduates in science (physicists, computer specialists, biologists) suffer a loss of net income over the years relative to technical college graduates, whereby a further differentiation according to field is not possible in view of the scant numbers involved.

Figure 1. Profile of estimated earnings for a graduate in the field of mechanical engineering in 1991, 1993 and 1995 (ABL)a



Source: ZEW 70% Sampling of the 1991, 1993 and 1995 *Mikrozensus*, independent calculation.

In general, it can be said that earnings within a group of university graduates depend very little on the field of studies. One exception are chemists with a university degree, who on an average study longer than other scientists and tend more often to have doctoral degrees. In 1995, they received 5% higher salaries than engineers with a university degree.

A further exception is the group of other scientists with university degrees who do not have higher salaries than those of technical college graduates. Within the group of technical college graduates, only minor differences in earnings can be seen between the various fields of study. One exception is other scientists with technical college degrees, including in particular computer specialists, process engineers, chemical technicians and operations technicians. In 1995, these scientists with technical college degrees had a 5% income advantage compared to mechanical engineers with a technical college degree.

Table 3. Earnings for engineers and scientists in 1991-1995 (ABL, Manufacturing)

Year	1991		1993		1995	
Variable	Coeff.	T value	Coeff.	T value	Coeff.	T value
Age	0.04#	5.47	0.04#	5.94	0.06#	7.66
Age squared	-3.2E-04#	-3.70	-3.6E-04*	4.11	-5.2E-04#	5.69
R&D* age	-5.5E-04	0.33	2.4E-03	1.46	4.1E-03*	2.38
R&D* age squared	5.2E-06	0.15	-4.35E-05 -	1.22	-9.4E-05*	2.48
R&D sector	0.06#	2.69	0.08#	4.06	0.05	2.49
- electronics	0.01	0.28	0.03	1.51	-0.01	-0.41
- chemistry	0.05	1.11	0.04	1.09	0.02	0.52
- other sciences	0.04	1.65	0.01	0.42	0.05	1.95
-mechanical engineering* Univ.	0.12#	4.64	0.08#	3.51	0.08#	3.19
Electronics* univ.	0.10#	3.60	0.02	0.54	0.13#	4.30
Chemistry* univ.	0.16#	3.23	0.14#	3.12	0.12*	2.41
Other sciences* univ.	0.10#	3.23	0.04	1.37	0.05	1.70
Temp. contracts	-0.07	-1.24	-0.15#	-3.13	-0.09	-1.98
Foreigners	-0.08#	-2.52	-0.09#	-2.82	-0.08*	-2.22
Married	0.14#	5.58	0.13#	5.50	0.14#	5.57
Divorced	0.01	0.05	0.17	1.39	0.10	0.96
Widowed	0.08	1.71	-0.03	-0.57	-0.07	-1.39
2 person household	-0.01	-0.21	-0.05	-1.81	-0.06*	-2.15
3 person household	0.01	0.24	-0.04	-1.35	0.00	0.02
4 person household	0.04	1.48	0.05	1.87	0.05	1.83
5+ person household	0.03	0.96	1.05	1.05	0.07*	2.01
Constant	0.18	1.21	0.15	0.99	-0.18	-1.14
Sigma	0.29#	57.29	0.29#	57.78	0.30#	58.22
Log likelihood		-302.21		-276.4		-369.80
Observations	1.614		1.669		1.695	

Source: ZEW 70% samplings of the 1991, 1993 and 1995 *Mikrozensus*; maximum likelihood evaluation of the ordered Probit Model with known limits; Category for the fields of study: mechanical engineering at technical college; the comparison also includes the variable: size of town. Category marital status: single; Category size of household: one-person household.

Not all income differences between graduates from various fields remain constant over time. The deviations and assimilation of income over time from and to standard income progressions is a function of supply and demand. As with real capital investments, one can also note a correlation in investments in human capital for various fields of study over a longer period of time.

One reason is the divergent levels of investment under long-term stable difference, e.g. investments made to finance a chemist as compared to a mathematician, or a university graduate as compared to a technical college graduate. The difference in earnings between the latter two is 7% to 8%. Taking into account the fact that studies at a university require an investment phase lasting an average of one year longer, the yield in this supplementary year of training is 7%. This is similar to the results of other estimates for education returns in Germany (c.f. Bellman/Reinberg/Tessaring 1994, Pfeiffer/Brade 1995).

Despite the well-known methodological limitations of the *Mikrozensus*, an analysis of earnings here has nonetheless shown that imbalances on the job market, be they a surplus in supply or in demand, have left their traces in the earnings of the employees. It has also become apparent that estimates from the cross-section data of the *Mikrozensus* do not suffice to explain a good proportion of the differences in income observed.

Determinants for salaried employment vs. self-employment

The self-employed¹⁰ are considered the torchbearers of growth, innovation and employment. Young, technologically oriented businessmen are the ones who will forge ahead towards the information society. An analysis of the self-employed according to their fields of graduation shows that self-employment is much more common among masters, technicians and university graduates than among those who have only gone through an apprenticeship or who have no formal training (cf. Pfeiffer/Falk 1999). 18% of university graduates were self-employed in 1995 as opposed to 16% in 1991. For technical college graduates, the percentage of self-employed rose 1% to 16% over the same period. Part of the increase in self-employment in the 90s is thus due to the disproportionate increase in self-employed university graduates.

The rate of self-employment among university graduates can differ substantially according to fields of study. There is a disproportionately high level of self-employment among students of medicine, pharmacy, architecture, the fine arts, economics and the social sciences (including law), whereas scientists, mechanical and electrical engineers rarely turn to self-employment (see Table 4).

Table 4. Rates of self-employment according to fields of study 1991-1995

Region	Former West Germany			Former East Germany		
	1991	1993	1995	1991	1993	1995
Field of studies						
Engineers in general	9.3	10.5	10.0	6.2	9.1	12.9
- Mechanical engineering	9.5	10.1	9.7	5.9	8.5	12.2
- Electronics	6.7	7.9	8.1	4.6	9.1	13.3
- Other engineers ¹	25.5	27.3	31.1	18.7	14.5	16.8
Scientists in general	6.4	8.4	9.2	2.4	5.8	7.5
- Mathematics	3.5	4.3	3.5	1.9	2.8	4.7
- Computer science	10.5	10.3	9.3	1.2	2.7	10.0
- Biology	3.7	4.3	11.6	--	--	--
- Chemistry	4.7	6.7	5.6	1.6	3.7	6.0
- Physics	3.9	7.3	10.7	3.4	8.3	8.3
- Other sciences	9.7	12.6	12.7	2.8	9.8	9.1
Total	14.2	14.8	15.9	7.4	12.3	13.5

1. Fields of study: wood, paper production, printing, photography, textile and leather production.

Source: ZEW 70% samplings of the 1991, 1993 and 1995 *Mikrozensus*.

An average of only 11% of scientists and engineers are self-employed, although more physicians, biologists and electro-technicians chose self-employment in the period between 1991 and 1995.

The road to self-employment depends on individual financial assets. In general, savings increase with age. The consequence of this is that self-employment becomes more and more possible. One can thus expect an increase with age in the rate of self-employment among university graduates. A Multinomial Logit Model

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10. At the moment there are 3.7 million people self-employed in Germany, equivalent to 10.9% of all employed. The terms self-employment and salaried employment are used in scholarly literature to characterize professional status (c.f. Pfeiffer 1994). The self-employed are those who (i) run a business independently and are not subject to instruction, as owners, co-owners or leaseholders, and who (ii) hold responsibility for the running and success of that business. Salaried or dependent employees, accordingly, are those who act under instructions and receive a salary determined in advance in accordance with their job contract. A further category is the unemployed. The German Federal Office of Statistics uses a similar definition of self-employment in its surveys, including the national census, the labour market census and the *Mikrozensus*.

has been evaluated in order to test this hypothesis and to test whether there are differences in the inclination towards self-employment between the various fields of study.

A sampling of self-employed and salaried scientists and engineers with an average rate of self-employment of 11% in 1995 was used as a database. With the help of a Multinomial Logit Model, reasons were evaluated as to the probability of being self-employed without employees, self-employed with up to four employees and self-employed with five or more employees (instead of being a salaried employee in each case): 4.6% of university graduates from the sampling were self-employed without any employees of their own, 4.5% had up to four employees and 2.1% had over five employees (see Table 5). The results of the Multinomial Logit Model confirm the hypothesis of an increase in self-employment with age. There are also some differences between the various fields of study. Mathematicians and chemists tend to remain salaried employees whereas biologists and other engineers tend to be self-employed without any employees of their own.

The probability of choosing self-employment rises disproportionately in the age group of those between 35 and 45 years old. It also rises proportionately above the age of 45. The results of the survey also show that the probability of being self-employed and having one's own employees (in comparison to being a salaried, dependent employee) is greater with increasing age than the probability of being self-employed without any employees.

Table 5. Reasons for self-employment 1995

Category of employment Variable	Self-employed with no employees		Self-employed with 1-4 employees		Self-employed with 5+ employees		Average
	Proportion	T value	Proportion	T value	Proportion	T value	
	4.62%		4.51%		2.09%		
	Coeff.	T value	Coeff.	T value	Coeff.	T value	
30-34	0.23	0.8	0.64	1.6	-0.06	-0.1	0.20
35-39	0.33	1.1	0.86	2.0	0.73	1.2	0.18
40-44	0.45	1.4	0.95	2.3	1.19	2.0	0.17
45-49	0.76	2.4	1.30	3.1	1.13	1.9	0.13
50-54	0.84	2.6	1.23	2.9	1.39	2.4	0.13
55-59	0.55	1.4	1.18	2.6	1.34	2.2	0.08
Electronics	0.21	1.0	-0.18	-0.9	-0.11	-0.4	0.25
Other engineers ¹	1.37	3.8	0.62	1.5	0.27	0.4	0.02
Mathematics / computer sc.	-0.10	-0.4	-0.62	-2.1	-1.15	-2.1	0.10
Biology	1.09	2.7	0.24	0.4	0.77	1.2	0.01
Chemistry	-0.32	-0.8	-0.19	-0.6	-1.39	-1.9	0.07
Physics	0.40	1.3	-0.14	-0.4	-0.22	-0.5	0.06
Other sciences	0.36	1.6	0.08	0.4	0.14	0.5	0.14
Constant	-4.41	-10.4	-4.54	9.5	-4.96		

1. Engineers in the fields of wood, paper, photography, printing and textiles.

2. Independent calculation. ZEW 70% samplings of the 1995 *Mikrozensus*. Maximum likelihood estimates of the multinomial logit model. The sampling contains 4 700 full-time employed male university graduates from the fields of science and engineering (excluding architecture and construction) who are active in the private sector (excluding agriculture). Mechanical engineering serves as the reference group for the field with 34% of all degrees in the sample, the 25-29 year olds (10.9% of the sampling) serve as the reference group for age classes, and other manufacturing serves as the reference group for the sector. Other variables in the calculation: town size, marital status and household size.

Source: ZEW.

A substantial amount of funds may be needed on the road to self-employment. The founding of a business with other employees requires in many sectors of the economy a higher level of capital investment than the founding of a business without other employees. Usually, this increased level of capital investment has to be saved first. For this reason, the road to self-employment takes time. The estimated probability of being

self-employed rather than being a salaried employee increases disproportionately with the age of the engineers and scientists.

As a rule, more funds are available with increasing age, but the willingness to take risks tends to decrease. Another factor is the relatively high level of financial security enjoyed by salaried employees after many years of employment (a research expert will of course want to have at least the same income he or she had as a salaried employee).

With age, many employees are no longer willing to take the risky road to founding a business of their own. The above points to a problem in the dynamics of technology-oriented sectors of the economy if money markets are imperfect and if potential young founders of businesses in innovative sectors do not have sufficient risk capital. The road to self-employment takes time in view of the long years needed to save enough money. For many engineers and scientists who in earlier years intended to start up a business of their own, these years end in a lucrative job as a salaried employee in a research and development division or in management.

Outlook on research

The analysis based on the *Mikrozensus* of 1991, 1993 and 1995 has shown that there are specific patterns of occupational specialisation among engineers and scientists which depend among other things on whether training has taken place at the university or the technical college level. Engineers, for instance, tend to be found more often in management than scientists, and university graduates tend to be found more often in research divisions than graduates of technical colleges.

Despite the well-known methodological limitations of the *Mikrozensus*, an analysis of earnings has shown that short-term imbalances on the job market, be they a surplus in supply or in demand, leave their traces in the earnings of the employees. However, in the long run there is a stable relationship between the amount of investment in training on the one hand and earnings on the other hand. Estimates have also shown that there are success factors in training which have no direct relationship to age, field of studies or division. The *Mikrozensus* is only partially suitable to analysing these factors, firstly because it provides too little information, for example, about social influences and, secondly, it is currently impossible to establish a link to the place of training.

The potential of the *Mikrozensus* for a scholarly analysis of the job market and of professional mobility would go much farther if links could be established for individual data comparing the various survey periods and if data were collected with regard to the place of training. Inclusion of the various fields of study does constitute a methodological advance, but the surveys are not tuned finely enough to study any possible differentiating effects that the place of training might have.

REFERENCES

- BECKER, G. S. (1983)
Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education,
 Chicago Press: Chicago.
- BECKER, G. S./K. M. MURPHY (1992)
 "The Division of Labour, Coordination Costs and Knowledge", *Quarterly Journal of Economics*,
 Vol. 107, 4, 1137_1160.
- BELLMAN, L./A. REINBERG/M. TESSARING (1994)
 "Bildungsexpansion, Qualifikationsstruktur und Einkommensverteilung: eine Analyse mit Daten des
 Mikrozensus und der Beschäftigtenstatistik", in: L. R. LUDEKE (ed.), *Bildung,
 Bildungsfinanzierung und Einkommensverteilung*, 13-70, Duncker & Humblot: Berlin.
- BERMAN, E./J. BOUND/Z. GRILICHES (1994)
 "Changes in the demand for Skilled Labor within U.S. manufacturing: Evidence from the Annual
 Survey of Manufacturers", *The Quarterly Journal of Economics*, 109, 2, 367-397.
- BMBF (1998)
Zur technologischen Leistungsfähigkeit Deutschlands. Aktualisierung und Erweiterung 1997,
 Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie: Bonn.
- CLAR, G./J. DORE/H. MOHR (ed.) (1997)
Humankapital und Wissen - Grundlagen einer nachhaltigen Entwicklung Springer: Heidelberg.
- CORNELSEN, C. (1995)
 "Erwerbstätige mit Hochschulabschluß nach Hauptfachrichtungen", *Wirtschaft und Statistik*, 11,
 810-818.
- FRANZ, W. (1996)
Arbeitsmarktökonomik, 3rd ed., Springer: Berlin.
- GERLACH, K./O. HUBLER/W. MEYER (ed.) (1998)
*Ökonomische Analysen betrieblicher Strukturen und Entwicklungen. Das Hannoveraner
 Firmenpanel*, Campus: Frankfurt/New York.
- LICHT, G./M. KUKUK/H. GRUPP/E. HIPPE (1997)
 "Innovationen im Dienstleistungssektor. Empirischer Befund und wirtschaftspolitische
 Konsequenzen", Nomos-Verlag: Baden-Baden.
- LUCAS, R. E. (1988)
 "On the Mechanics of Economic Development", *Journal of Monetary Economics*, Vol. 22, 3-42.

MINCER, J. (1974)

Schooling, Experience and Earnings, NBER: New York.

OECD, (1996)

Technology, Productivity and Job Creation, Vol. 2 Analytical Report: Paris.

PFEIFFER, F. (1994)

Selbständige und abhängige Erwerbstätigkeit, Arbeitsmarkt und industrieökonomische Perspektiven, Campus: Frankfurt a. M.

PFEIFFER, F./J. BRADE (1995)

“Weiterbildung, Arbeitszeit und Lohneinkommen,” in: STEINER V./L. BELLMAN (ed.), *Mikroökonomik des Arbeitsmarktes*, BeitrAB Nr. 193, Nürnberg.

PFEIFFER, F./W. POHLMEIER (ed.), (1998)

Qualifikation, Weiterbildung und Arbeitsmarkterfolg, Nomos: Baden-Baden.

TESSARING, M. (1998)

“Training for a Changing Society”. A Report on current vocational education and training research in Europe, European Centre for the Development of Vocational Training (CEDEFOP): Luxembourg.

VON WEIZSACKER, R. K. (ed.) (1998)

Bildung und Wirtschaftswachstum, Schriften des Vereins für Socialpolitik, Vol. 258, Dunker & Humblot: Berlin.

VON WEIZSACKER, R. K. (1986)

Theorie der Verteilung der Arbeitseinkommen, Tübingen.

WEISS, A. (1995)

“Human capital vs. signalling explanations of wages”, *The Journal of Economic Perspectives*, Vol. 9, 4, 133-154.

C. CHANGES IN THE S&T LABOUR MARKET AND ITS FUTURE: ARE THERE TOO MANY PHD GRADUATES?

by

Shin-ichi Kobayashi, Associate Professor, *Graduate School for Information Systems,
University of Electro-Communications, Tokyo*

Introduction

The number of doctoral students in Japanese universities increased rapidly during the 1990s. This notwithstanding, demand for S&T personnel is expected to decline in the near future, thereby leading to a shrinkage in the labour market for PhDs. Many experts believe that the future is bleak for new postgraduates. Policy actions are necessary to address the serious discrepancy between the supply of doctoral students and the actual demand for S&T personnel.

During the 1980s, the vast majority of new recruits in the S&T sector was drawn from "masters" level graduates. As the economy expanded during those years, industry demand for S&T personnel expanded accordingly. When the "bubble" burst in the early 1990s, policy makers decided to shift their priorities from the training of master level students to the training of PhD students and an expansion of post-doctoral fellowship programmes. This led to a surplus of doctoral students in the ensuing Japanese recession and a decline in the demand for S&T personnel.

The imbalance between supply and demand has caused a rift between experts. There are those who see an expansion of PhD programmes as the best way forward, while there are others who believe this policy would only lead to higher unemployment. To fully understand these arguments and counter arguments it is best to look at the future trends in industry demand and the recent changes in the employment system.

Future demand for S&T personnel in industry is expected to weaken: the total demand will stay at around the same level as today, while a fall is predicted in the demand for newly graduated S&T personnel. Even if there is a slight increase in the demand for PhDs, it will not match the supply. An important factor in PhD unemployment is that many of the students simply do not have the appropriate skills needed by industry. Indeed, in an empirical survey conducted by the author, the extent of the mismatch has been shown to be substantial. If this issue is not resolved, the glut of PhD students will grow.

There have recently been notable changes in the Japanese employment systems that have also adversely affected the opportunities of new postgraduates. Fixed-term employment and the temporary staffing system in the S&T sector have superseded the tenure system and lifelong employment. A large number of younger S&T personnel today, especially in universities and public laboratories, work under non-tenure or part-time employment contracts. While the greater flexibility and mobility in the employment of S&T personnel enhances the efficiency of both human resource allocation and selection, it also makes it more difficult for PhD students to find employment and will undoubtedly lead to a serious distortion in the age distribution of S&T personnel.

Although the number of doctoral students in Japanese universities increased markedly in the 1990s, the actual demand for S&T personnel is currently falling. This has led to a shrinking of the PhD labour market and, in the opinion of many experts, spells a bleak future for new postgraduates.

This paper will briefly introduce trends and relevant policies in regard to the supply and demand of S&T personnel in Japan. Secondly, recent perspectives on the future supply and demand of S&T personnel will

be described. Finally, recent changes in the S&T labour market will be introduced, as well as problems in regard to relevant systems and policies.

Overview of the S&T labour market in Japan

Trends in supply and demand of S&T personnel

Growth of the number of S&T personnel

The Bureau of Statistics provides two major statistical data sets on S&T personnel. The first consists of the annual results of the Survey of Research and Development, which describes the activities of a number of personnel engaged in R&D. The second contains data on engineers and scientists taken from the Population Census conducted every five years. The former statistics follow the OECD manual group, whose figures are not full-time equivalent. The latter, because it also includes engineers, covers a wider range of personnel.

Table 1 shows trends in the data on S&T personnel. By either data set, there is a clear growth pattern in the number of S&T personnel in Japan prior to the 1990s. Engineers in particular experienced two periods of rapid increase, from 1965 to 1970, and from 1980 to 1990. The first increase corresponded to both a supply-side boom in S&T personnel, the so-called “S&T education boom”, and a demand-side boom in corporate investments in R&D, or the “corporate laboratory boom”. The expanded supply of engineer personnel was the direct result of a policy to enhance engineering education in order to secure economic development, a strategy that was heavily influenced by OECD arguments concerning human resources.

Table 1. Growth of S&T personnel (in thousands)

Survey of Research and Development - Population Census						
Number of researchers – Scientific						
Year	Total	University	Public	Company	Researcher	Engineer
1965	118	39	19	59	62.5	401.1
1970	172	55	23	94	99.6	701.0
1975	255	82	27	147	69.0	752.3
1980	305	103	29	173	66.2	874.1
1985	381	118	32	231	97.7	1 729.5
1990	484	134	36	314	116.1	2 108.2
1995	575	156	42	377	160.5	2 443.5

Source: Statistics Bureau.

The expansion of S&T personnel in the 1980s resulted from the success of Japanese industries on the world market, the penetration of microelectronics and information technologies, and a “bubble economy”. Because this expansion exceeded the supply of new S&T graduates, there was a general transferring of jobs from other professions, particularly into the field of information technology. In the early 1990s, however, the “bubble economy” burst, and this climate of expansion turned to one of moderation.

Expansion of graduate students

Table 2 provides an overview of graduate school education, the major source of new S&T personnel.

Table 2. Overview of graduate education

Year	Entrants master courses	Graduates PhD courses	Unemployed master courses	Stock of PhD courses	Graduates of PhD courses	Unemployed doctorates
1980	16 844	4 669	15 258	3 614	1 053	1 450
1982	19 717	4 914	15 855	3 969	1 109	1 441
1984	22 201	5 749	18 493	4 090	1 146	1 708
1986	25 164	6 645	21 021	4 496	1 091	1 717
1988	27 342	7 170	23 779	5 330	1 332	1 619
1990	30 733	7 813	25 804	5 812	1 319	1 601
1992	38 709	9 481	29 193	6 484	1 407	1 646
1994	50 852	11 852	36 581	7 366	1 639	1 441
1996	56 567	14 345	47 747	8 968	2 253	1 421

Source: Ministry of Education.

The 1980s saw an increase in graduate enrolment, particularly in the science and engineering fields, in response to the above-described increase in the demand for S&T personnel. This expansion of graduate enrolment was intensified in the 1990s, when rapid growth occurred not only in science and engineering education, but in graduate-level programmes in the humanities and social sciences as well. This trend was further enhanced by the policy of graduate school expansion of the Ministry of Education (Monbusho; see below). In this climate, masters level courses became popular suppliers of professional employees, and PhD programmes became an important source of S&T personnel.

Gradually, as the existing PhD graduates became researchers and engineers, the demand for S&T personnel began to stagnate. At the same time, the expansion of PhD programmes led to a glut of unemployed doctoral graduates. The situation was alleviated slightly by the post-doctoral fellowships introduced in the 1990s, which decreased the stock of unemployed PhD graduates by engaging them in unsalaried research activities at the university level.

Recent depression and high unemployment rate

In order to better understand the current circumstances of S&T personnel, we must consider Japan's recent depression and growing unemployment rate. Table 3 shows the rates of economic growth and unemployment after 1980 in Japan.

Table 3. Economic conditions in Japan

Year	GDP growth rate(%)	Unemployment rate(%)
1980	2.6	2.1
1982	3.1	2.5
1984	4.1	2.7
1986	3.1	2.8
1988	6.0	2.4
1990	5.5	2.1
1992	0.4	2.2
1994	0.6	2.9
1996	4.4	3.4
1998	-2.2	4.1

Source: Economic Planning Agency.

Although Monbusho is ultimately responsible for all policies concerning training and employment for university research, other groups take part in the discussion. For example, the University Council, a council for higher education policy, discusses the training of S&T personnel, while the Science Council, a council for science policy, discusses the demand for S&T personnel in the academic sector. Because the University Council targets the problems of universities as a whole, graduate school policies comprise only a small part of its mission. Discussions are thus limited mainly to the supply side of graduate education. On the other hand, the Science Council focuses not only on postgraduate training, but also on the education and securing of researchers for academic sector research. Historically, then, the discussion of the two councils has been distinct but complementary.

More recently, however, along with the increase in the number of PhD courses, the University Council has begun to prioritise graduate schools, meaning that both councils are now heavily involved in doctorate-level education. It is critical that the level of co-ordination and co-operation between these groups rises to match their new mutual interests.

Table 4 presents the history of major policies concerning S&T personnel.

Table 4. S&T personnel policies

1984	Science Council, Report Launch of post doctoral fellowship programmes
1991	University Council, Report Doubling the number of graduate students
1995	Monbusho, STA and the Ministry of International Trade and Industry Joint Plan for 10 000 postdoctoral fellowships
1996	Science and Technology Basic Plan - Cabinet decision Authorisation of the Joint Plan for 10 000 postdoctoral fellowships
1996	Science Council, Proposal Arguing weak demand of S&T personnel in the future, and proposing enhancement of postdoctoral fellowship programmes
1998	University Council, Report Expansion of graduate schools, 300 000 students in 2010

Source: Author.

The 1984 Report of the Science Council was the first report to forecast the future supply and demand of S&T personnel. Based on this simulation, the council recommended launching the first postdoctoral fellowship programmes in Japan. At the time, the vast majority of new recruits in the S&T sector were

being drawn from masters courses, and thus the unemployment of PhD graduates, especially in the fields of the basic sciences, had become a small but very real problem. To address this situation, postdoctoral fellowship programmes were introduced for the first time.

In their 1991 report, the University Council made their first attempt to treat the future scale of graduate schools as a policy issue. The report proposed that the number of graduate students should be doubled - from 100 000 to 200 000 by the year 2000 - based on such trends as the expanded demand for science and engineering master course graduates in the 1980s. Although the proposal itself focused on the future supply and demand of masters and postdoctoral graduates, the ensuing expansion actually incorporated graduate programmes in the humanities and social sciences, whose graduates were ultimately in less demand than their contemporaries in science and engineering.

In 1995, a plan for supporting 10 000 fellowships for younger researchers was proposed jointly by Monbusho, STA and the Ministry of International Trade and Industry (MITI). The Science and Technology Basic Plan of 1996 placed a governmental priority on the securing, training, and increased mobility of S&T personnel. The plan also officially authorised the joint plan of Monbusho, STA and MITI for the realisation of 10 000 fellowships for younger researchers.

Along with such policy direction, the 1996 Report of the Science Council proposed an enhancement of postdoctoral fellowship programmes and research assistantship programmes. This discussion was also based on a simulation analysis, in this case predicting a reduction in the demand for S&T personnel.

In their 1998 Report, the University Council proposed a further expansion of graduate schools based on a projected increase in the number of graduate students to 300 000 by 2010. This number, 300 000, was in fact larger than the University Council's projected number of job opportunities for such graduates, a problem currently being investigated also by the Science Council. This is a good example of the relative conservatism of the Science Council, which hesitates to expand postdoctoral fellowships, compared to the more optimistic predictions of the University Council.

Outlook for supply and demand for S&T personnel

This section examines the outlook for supply and demand of S&T personnel. In 1998, as described above, the University Council forecast the future supply and demand of graduate students. The Science Council is now discussing various problems associated with this forecast. In the present paper, I will attempt to revise the 1996 proposal of the Science Council so that it is consistent with the 1998 forecast of the University Council.

Changes in the S&T personnel environment

There are several critical conditions that both Councils should consider, including the decline in the population of young people in Japan, the reform of governmental administration and finance, and the current depression and economic structure reforms.

Ultimately, the declining population of younger generations is likely to result in a decrease in the number of university students. The population of 18 year-olds is expected to decline to 1 210 000 by 2010, or approximately 60% of the peak value of 2 050 000 in 1992. Even if the university enrolment rate for this generation were to increase, the population decline would still result in a decrease in university students. Accordingly, it follows that the demand for university instructors would decline -- or that, at best, it would remain the same. In addition, the ever-increasing competitiveness among private universities -- which make up a large portion of the university sector in Japan -- can be expected to lead to university staff

reductions in the name of cost-effectiveness. All these changes would reduce the demand for new teachers and researchers in the university sector.

With respect to the demand for S&T personnel in the public sector, this is also expected to remain low, both because of the stable number of researchers over the last 20 years, and because of recent governmental reforms of administration and finance.

I will now provide a brief analysis of the private sector. The regression equation below denotes relationships among the number of researchers in the private sector, the intensity of R&D in the private sector, and the scale of national economic activity between 1976 and 1991.

$$\begin{aligned} & \text{Log(number of researchers in private sector)} \\ & = 1.189 + 0.990 * \log(\text{real GNP}) + 0.341 * \log(\text{R\&D expenditure in private sector /GNP}) \\ & \qquad \qquad (0.465) \qquad \qquad (6.058) \qquad \qquad (2.573) \\ & \text{adj.R}^2 = 0.991, \text{ D.W.} = 1.449 \text{ year: } 1976 - 1991 \end{aligned}$$

This equation indicates that the number of researchers in the private sector was growing along with economic growth and an expansion of the scale of private R&D, the speed of which exceeded economic growth. A clear intensification of R&D activity can be observed. However, the equation simultaneously expresses that the demand of researchers stays at around the same level unless the scale of the economy changes, since the elasticity between them is almost 1.0, and that the decline in demand for researchers results from a decline in the intensity of R&D, because the elasticity of R&D intensity toward the demand of researchers is positive.

Therefore, the spell of the economic depression is a critical factor affecting any possible new demand for researchers. The depression weakens corporate resolve to conduct R&D so that the demand for new S&T personnel remains low. Such demand may also be lowered as a reaction to the rapid expansion of S&T personnel in the 1980s. Within the context of the depression, in order to decrease S&T personnel and R&D expenditures, private firms try to raise R&D productivity by, for example, withdrawing from or reducing basic research, introducing information and automatic technologies into R&D, enhancing outsourcing, and so on. Under such conditions, it can be estimated that such trends would bring a reduction of S&T personnel.

At the same time, other new trends must be considered, such as the growth of R&D in SMEs, ITC industries, and finance and service industries. Currently, however, we lack sufficient data to investigate R&D in these industries. Consideration should also be given to the relatively recent rise in the recruitment of PhD recipients by private firms. Since the early 1990s, private-sector recruitment of postdoctoral students has increased rapidly. It has reached the level of slightly over 1 000, which is only a very small part of industries' total recruitment of S&T personnel. How it would grow might affect significantly future demand for doctoral S&T personnel.

Forecasts of supply and demand of S&T personnel

This section takes a closer look at methods of forecasting the supply and demand of S&T personnel, focusing on PhD recipients. According to the estimation adopted by the University Council in 1998, the

total number of graduate students, including those involved in both masters- and doctoral-level coursework, is expected to increase from about 180 000 in 1998 to 250 000 by 2010, based on trend analyses of students entering graduate schools. Again, when estimated based on simulations of job opportunities for masters and PhD students, this number is considered to range from 220 000 to 240 000. Although aware of these figures, the University Council estimated a total of 300 000 graduate students by 2010, based on the supposition of new demand.

According to the estimation, although the number of postdoctoral students is expected to reach 18 000 by 2010, demand for graduates is only expected to be around 12 000, leaving a surplus of 6 000 unemployed graduates. It should be noted that the demand for 12 000 graduates is broken down into a demand for 1 900 university instructors, 1 800 clinical doctors, 4 300 industrial professionals, and so forth. However, in the case of the 300 000 graduate students no such breakdown is given, and it seems very likely that the excess of unemployed graduates would increase still further if this figure were reached.

The author revised the 1996 forecast of demand and supply of researchers devoted to the Science Council, where the estimation was limited to demand and supply of personnel engaging in R&D activities, with the estimation framework based on one in the forecast of the University Council. According to the revised estimation, the number of postdoctoral graduates will reach 18 000 in 2010, just as in the University Council projection. The potential supply of research personnel would be 11 000, while the demand for new doctoral graduates would be from 6 000 to 12 000. The difference of 6 000 students would depend on a future share of doctorates among the newly recruited researchers in the private sector. Specifically, the share of doctorates among newly employed researchers in the private sector stays at the level of 3% at present. If the share remains at the same level, demand is expected to be 6 000. If it goes up to 14%, the share is expected to be 12 000. According to the survey carried out in the 1996 Science Council forecast, the share of doctorates in 2010 is estimated at 14%. However, it is 7% today according to our new survey. The shift to doctorate intensive demand of S&T personnel will be slower. In this (7%) case, demand for new doctorates will be 8 500, where an excess supply will be 2 500.

This revised estimation indicates that an increase in the demand for postdoctoral workers in the private sector will result in a slight shortage of supply. Otherwise, an excess supply might occur. In any event, it is certain that any change in the private-sector demand for such personnel will have a serious impact on the postdoctoral labour market.

It is important to remember that, in Japan, Monbusho must approve the capacity of each graduate school. It is for this reason that the scale of such schools is actively debated. And of course, Monbusho's policy decisions are directly related to the government's education budget.

There is thus a great difference between the two Councils in this regard. The University Council favours the expansion of PhD programmes, although it does not address how policy might cope with the anticipated surplus in demand. On the other hand, the Science Council argues that such an expansionist policy would lead only to higher unemployment. For the Science Council, the key point is the future demand in the private sector. If graduate schools fail to train students in a manner useful to industries, then the only possible measure against unemployment will be the postdoctoral fellowship programme. Moreover, such an expansion might be a signal promoting an increased excess of new PhD students.

Changes in the S&T labour market: some evidence

To fully understand these arguments and counter arguments it is best to examine the future trends in industry and the recent changes in the employment system. There have been notable changes in the Japanese employment system that have adversely affected the opportunities for new postgraduates.

First, fixed-term employment and temporary staffing in the S&T sector have superseded the tenure system and lifelong employment. Last year, according to a survey conducted by the author, fixed-term appointed researchers made up 0.4% of all personnel engaged in R&D in the private sector. Among newly recruited researchers, 0.6% were employed on a fixed-term basis, and among postgraduates generally, the rate was 9%. In the future, the amount of fixed-term employment is not expected to increase dramatically. However, it should be noted that the fixed-term employment system is more popular among postgraduates than among other types of workers. In the case of universities and public laboratories, a large number of younger S&T personnel today consist of non-tenure staff or part-timers.

Second, the survey highlights a growing trend of employing new postgraduates as research assistants. Among newly employed postgraduates, 20% are research assistants, and 80% are researchers. In an increasing number of cases, private firms are employing postgraduates who excel in a specific skill, and entrusting them almost exclusively with that task. These employees are not treated as independent researchers because, in the Japanese employment system, the labour force consists primarily of workers with generalised, broad-based skills, rather than specialists. For this reason, even if these workers held PhDs, they would probably be treated as assistants.

The third important change is that of the temporary staffing system. Japanese firms have increasingly utilised temporary staffing services. Interestingly, in the case of R&D, it is estimated that only 0.2% of researchers, but more than 16% of assistants, are temporary staff (no data on temporary staffing with doctoral researchers or assistants is available). On the other hand, according to our survey, many firms state that they do not intend to increase temporary staffing.

In fact, rather than using temporary research staffing, most Japanese companies seem to prefer making contracts or conducting joint research with external partners. It is thus expected that a majority of the newly recruited postgraduates will be utilised as regular, tenured staff. Nonetheless, it is important to watch future trends carefully, since the widespread use of fixed-term employment in universities and public research institutes might result in the spread of the fixed-term employment paradigm into the private sector. Finally, we should note the remarkable increase in recruitment of postgraduates by the information technology and communication industries. Though still representing only a fraction of total postgraduate recruitment, this trend is growing dramatically.

Discussion

Considering such changes in the labour market, our estimation of the postgraduate job market would still likely be inaccurate. Thus, the question remains are there too many PhD graduates or not?

If ongoing systems remain as they are, the possibility of an excess supply of postdoctoral labour cannot be excluded. As for demand from the industrial sector, shifting to an economy based on higher education might expand the skills and productivity of industries themselves. Even so, the present training of PhD students does not facilitate such a relationship. Because graduate-level students are presently taking charge of university research activities, they are more adapted to academic rather than industrial research. The mismatch between the skills of graduate students and the skills demanded by the industrial sector is quite substantial.

Furthermore, unless the government regulates the capacities of graduate schools, the distribution of students among the various research fields will tend to reflect the demands of the university, rather than those of industry. An important factor in PhD unemployment is that many postdoctoral students simply do not have the appropriate skills needed by industry. There is no path by which changes in social demands can be transmitted to the suppliers of educated labour, i.e. universities.

To rectify this situation, graduate training must first be released from the rigid organisation of the university, so that it can flexibly meet changes in social demand. Second, the mobility of S&T personnel must be enhanced so as improve their allocation.

In realising the latter goal, it will not be enough to enhance mobility among younger S&T personnel, since this group is already fairly mobile. Policy arguments concerning the training and securing of S&T personnel already tend to focus on younger people, and the excess supply of S&T personnel is also attributed to a lack of employment opportunities for this group. The corollary to this, however, is that S&T activities are increasingly being entrusted to older personnel. In the near future, older personnel will have to take charge in many science and engineering fields. The question arises: is this what society wants?

The S&T professions are already becoming characterised by a relatively elderly workforce, especially in universities and public institutes. But by forcing younger scientists and engineers to bear the difficulties of a depressed economy, one generation is effectively been favoured while another one is being neglected. To sustain development in the fields of science and engineering, the best policy may be to promote the retirement or mobility of elderly S&T personnel.

Over the last 40 years, the Japanese system of balancing the supply and demand of S&T personnel has matured, while at the same time becoming more and more inflexible. Today, a major reworking of this system must be considered.

D. LABOUR MARKET PERFORMANCE OF FRENCH PHDs: A STATISTICAL ANALYSIS

by

Daniel Martinelli, Céreq, Marseille, France

This document presents a statistical analysis of the supply and demand for PhD graduates especially those in science and engineering, in France. Drawing on surveys of recent graduates, it analyses the trend rise in higher education graduates in the 1990s and the underlying factors determining employment outcomes, in particular of PhD level graduates.

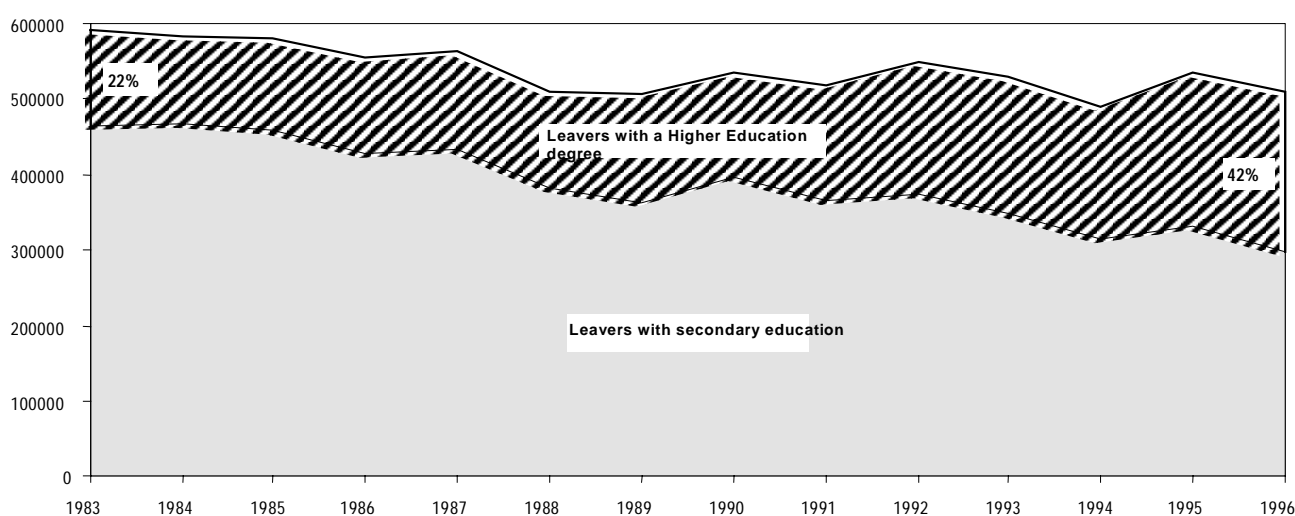
The supply of doctoral programmes is outstripping employment

Abrupt increase in Higher Education outflows

Between 1983 and 1996 outflows from the education system fell from 592 000 to 510 000, the number of departures being calculated at the end of the first three years on the labour market. At the same time, the number of Higher Education (HE) graduates rose sharply from 129 000 to 213 000: this increased the proportion of HE graduates among new arrivals on the labour market from 22% to 42%. Of all graduates leaving HE since 1983, the number of those with a *BTS (Brevet de technicien supérieur - Higher Technical Diploma)* increased the most. There was a considerable increase in the number of third-cycle graduates completing 'long' HE courses in the late 1980s.

Between 1980 and 1994, there was a particularly sharp rise in the number of graduates in engineering schools run by the Ministry of National Education and in private engineering schools; in fact, the number of graduates produced by both types of institution doubled during the period.

Figure 1. Number of labour market entrants by level of education (in employment after 3 years)



Source: INSEE. Extrapolated by Céreq.

Fourfold increase in the number of third-cycle graduates in natural sciences

University teaching in natural sciences benefited particularly from the rise in the number of students entering Higher Education. The number of those passing the baccalaureate has risen steeply since the early 1980s, with most students in a given age-band in the most recent cohorts reaching this level. Most of this growth took place among the general and technology baccalaureates, many of whom generally move on to Higher Education. HE courses have had to accommodate an increasing number of students as a result: some Higher Education courses recruit students by competitive examination or on the basis of personal files (the so-called ‘closed’ lists); others have to accept all those with the baccalaureate who wish to enrol (the so-called ‘open’ lists). Universities account for the majority of the latter category, and have therefore accepted a large proportion of people who have recently passed the baccalaureate.

The increase in the number of first-cycle enrolments has been accompanied by a rise in the examination passing rate and in a lengthening of the period of university studies. University studies have also become more common among graduates of the so-called ‘closed’ courses, particularly those holding the DUT (*Diplôme universitaire de technologie* – University Degree in Technology).

This has triggered an explosion in the number of students and in the outward flows of graduates; the increase has been greatest among those studying natural sciences. Students taking these subjects usually have a baccalaureate in mathematics or science (bac C or D); they also achieve better results, and undertake longer courses, than those with other baccalaureates. The number of graduates entering the labour market at the end of a second-cycle degree in natural sciences doubled between 1984 and 1994, while the number of those leaving after taking a third-cycle degree in natural sciences increased fourfold. Science students continued to remain in a minority among those leaving university at the end of the second cycle (9 100 out of a total of 39 900 in 1994), but they account for almost half of those departing on completion of a third-cycle degree (11 500 out of 26 400).

Substantial increase in the number of theses during the 1990s

The increase in the number of theses granted is illustrated by two data sources. The first is a survey by the Ministry of National Education’s *Direction de la Programmation et du Développement* (DPD – Planning and Development Directorate); the other is the work of the *Observatoire des flux et des débouchés* (Students Flows and Employment Opportunities Observatory); the latter body comes under the *Direction de la Recherche* (DR – Research Directorate). However, counting the number of doctorates granted has been made difficult by changes in the thesis system. Both sources contain figures on the increase in the number of theses after 1991¹¹.

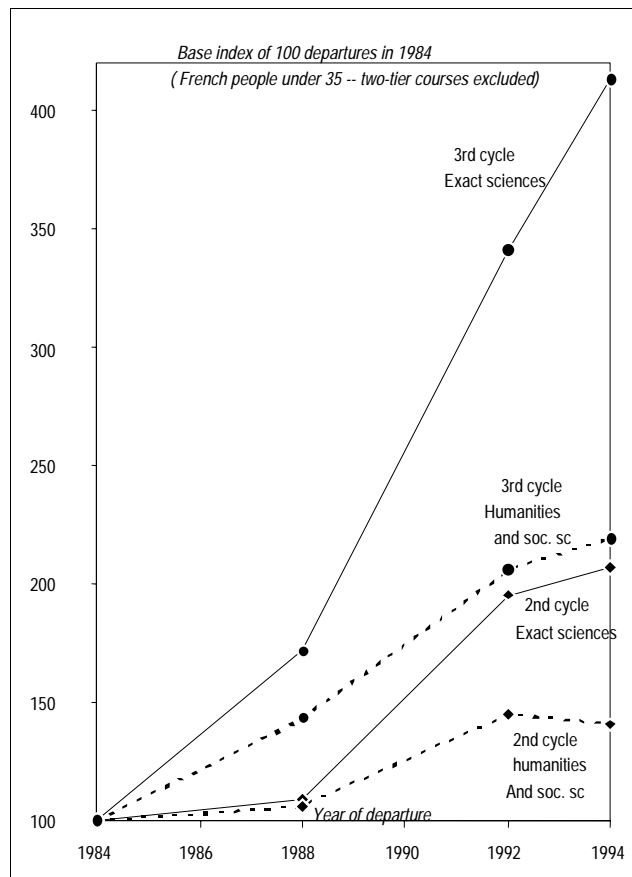
The number of theses remained relatively steady at around 5 000 during the 1980s, and even fell in the mid-1990s. Since 1992, however, the numbers have risen rather quickly and, according to the *Observatoire*, around 10 000 theses were submitted during 1994 and 1995. This doubling in the output of theses must be viewed in perspective, since the numbers of students and graduates of Higher Education also doubled during the same period.

During the 1980s, the number of theses in natural sciences grew to the detriment of those in letters/humanities and law and economic sciences. However, since 1990 the distribution of theses by

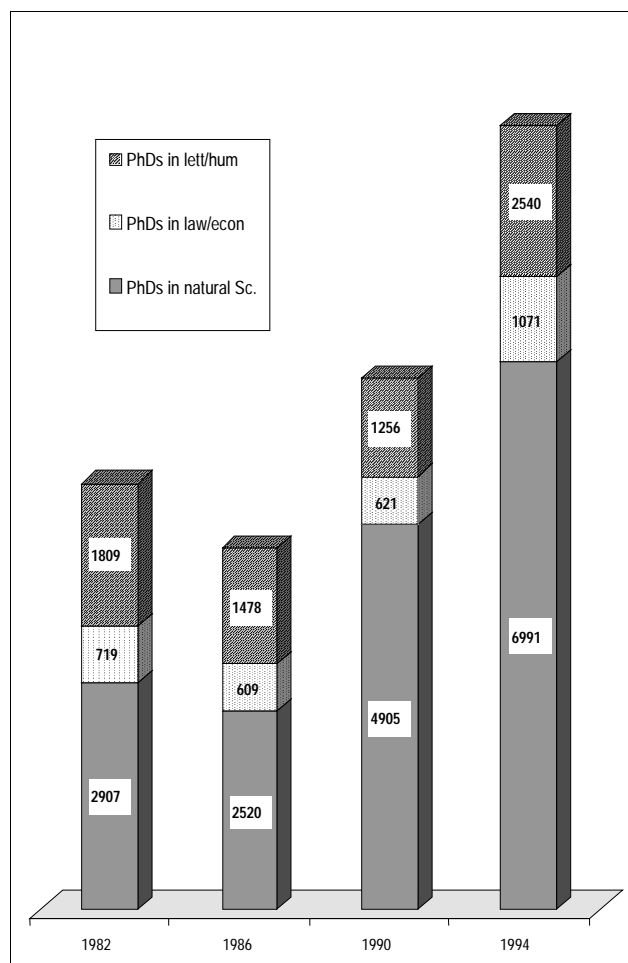
11 . We use DPD data up to 1989, and exclude ‘State’ PhDs. After that, we rely on data collected by senior DEA (*Diplôme d’études approfondies* – Degree in Advanced Studies) officials at the *Observatoire des flux et de débouchés*.

overall discipline has remained relatively stable, with two-thirds in natural sciences, a quarter in letters and humanities, and about 10% in law and economics.

Figure 2. Graduates entering the labour market on completion of the 2nd and 3rd university cycles



Source: Céreq.

Figure 3. Number of theses granted by discipline

Source: Ministry of National Education.

The scientific job market currently has less on offer

The main employment destination after completing PhD theses

As expected, teaching-research fellowships and engineering positions are the main job destination of graduates in exact sciences and humanities. Graduates in chemistry are an exception as this subject usually leads to employment in the private engineering sector. It should be noted that this discipline incorporates a large number of students undertaking doctorates in engineering.

PhDs in economics find positions both as teaching-research fellows and as managers in public administration and business. This includes managers of economic research units and in recruitment and personnel management, and manager-level posts in commerce, banking and insurance. Similarly, doctoral graduates in law usually find positions as teaching-research fellows, managers in administration, commercial companies and the public sector (including the post of Magistrate), and employment as lawyers. However, doctoral law graduates are few.

PhDs in letters and humanities often find employment in education; teaching-research fellowships are not the only outlet. Some PhDs in letters and humanities work in secondary education, even in primary education, and this indicates a relative decline in status in relation to the initial field of doctoral study. It should be noted that some PhD students in letters and humanities worked in primary and secondary education before completing their theses, and that a doctorate does not automatically open the door to higher education and research. It is likely that not all these teachers had a career plan when they were undertaking their theses. The average age on completion of theses in letters and humanities is often as high as 40.

Young graduates benefit less from the increase in the number of jobs for PhDs

Based on the above analysis, most PhDs become:

- Teachers and scientists in the public sector.
- Engineers and technical managers in enterprises.
- Managers in administration and in commercial enterprises.

In general, employment in these categories has grown at a similar pace. Although they are clearly expanding, it would appear that the increase has benefited younger graduates less since 1994. Employment among young graduates fell between 1994 and 1996, although it has picked up since. A survey of 1994 cohort of PhDs showed graduates did not benefit from the favourable economic upturn during their first two years of being on the labour market. Although the number of engineers employed by enterprises rose by almost 200 000 between 1984 and 1998, the recruitment of young university leavers fell dramatically in 1995/96 as a result of economic difficulties. This probably made it difficult for enterprises to recruit PhDs in natural sciences, but recruitment has subsequently revived.

There has been a rapid increase in the number of public sector jobs for scientists. Most of this growth is concentrated in teaching-research fellowship posts – a traditional destination for post-graduates – but there was particularly heavy recruitment in this category among young people between 1990 and 1994. Since then, employment among the under-30s group has stabilised at a level that is still quite high compared with the 1980s (14 000 teaching-research fellows under the age of 30 in 1996 and 1997, compared with 6 500 in 1984). Other scientific jobs in the public sector, which are of less appeal to PhDs, have increased in number at a similar pace, but the expansion has not automatically benefited younger people such as qualified and *agrégé* teachers, and engineers employed by the State and local authorities.

Labour market entry remains relatively positive

Job opportunities for higher education graduates in general level off

The number of graduates leaving higher education has risen sharply since 1990, 273 000 obtaining degrees in 1995 as compared with 184 000 in 1990, and there has been a particularly large increase among those who have pursued longer courses of study. Furthermore, since the early 1990s, the number of jobs in management and the intermediary professions, both traditional outlets for HE graduates, has risen more slowly. However, the fall in HE graduates finding employment that was observed in late 1994 appears to have been halted (Martinelli et al, 1997).

More positive developments

Three years after leaving higher education, members of the 1994 cohort found it slightly easier to find a job than their predecessors: their unemployment rate was 9.3% compared with 11.5% for the 1992 cohort. They were also more likely to find permanent employment and their salaries partly recovered from the steep fall that occurred in previous years. Moreover, their unemployment rate was twice as low as that of students with the baccalaureate, and almost four times lower than that of non-graduates. The share of higher education graduates in temporary employment (i.e. on fixed-term or temporary contracts, or working for agencies) fell sharply between 1994 and 1997. This number is still low as many graduates had managerial jobs on permanent contracts.

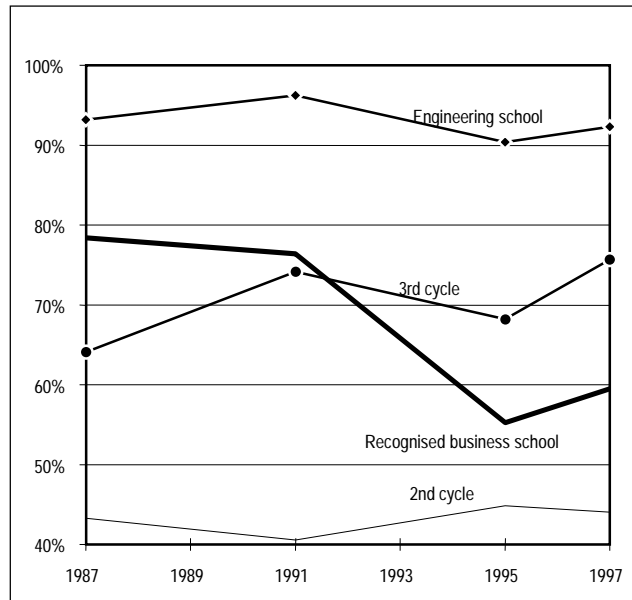
The salaries of HE graduates fell very substantially in 1992 and 1993, a time when the labour market was at a low ebb, but during periods of even quite modest economic upturn, pay levels recovered – as they did for the 1994 cohort. Salaries are now approaching the high levels achieved in 1991 at current rates. Higher Education graduates are also very likely to be recruited as managers (41% of them, including those holding a BTS (*Brevet de technicien supérieur* – Higher Technical Diploma) and or DUT (*Diplôme universitaire de technologie* – University Degree in Technology).

PhDs still find it relatively easy to find employment***PhDs quick to find jobs in the early 1990s***

In March 1991, Céreq conducted a postal survey of people who had completed HE degrees in 1988 (Martinelli, 1994). The exercise included a sample of young PhDs whose entry into employment could be compared with that of 1994 graduates. The 1988 cohort of PhDs found employment without much difficulty; this was due to the economic upturn and their relatively small numbers. French PhDs were as successful at entering the labour market as engineers (relatively low levels of unemployment, and satisfactory pay and employment levels); foreign PhDs were much less so. PhDs and engineers found employment most successfully on completing their Higher Education followed by graduates of recognised business schools, applicants holding the DEA (*Diplôme d'études approfondies* – Degree in Advanced Studies) or the DESS (*Diplôme d'études supérieures spécialisées* – Degree in Specialised Higher Studies), second-cycle university graduates, and those with a DUT or BTS.

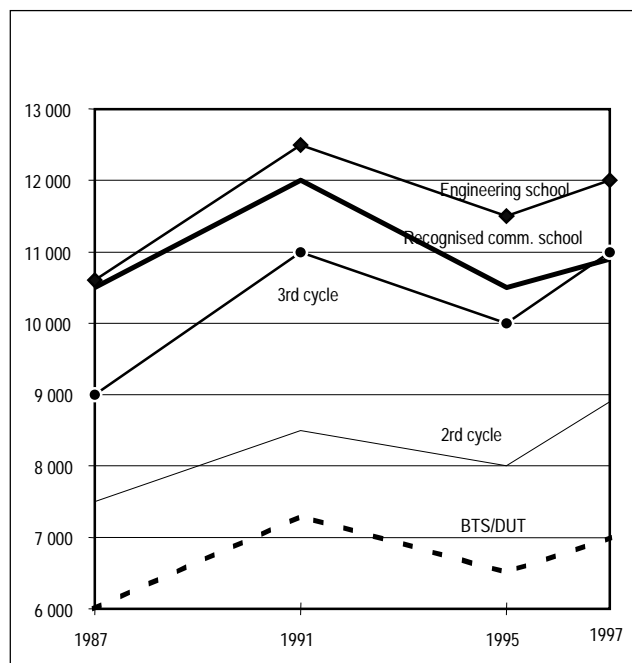
Engineering PhDs were the most successful in finding employment, their salaries and employment levels slightly surpassing even those of engineers. By contrast, PhDs who had received no more than a university education, and had not entered any public sector competitions prior to their doctorates, experienced some difficulties.

Figure 4. Median salaries three years after completing studies



Source: Céreq.

Figure 5. Median salaries three years after completing studies

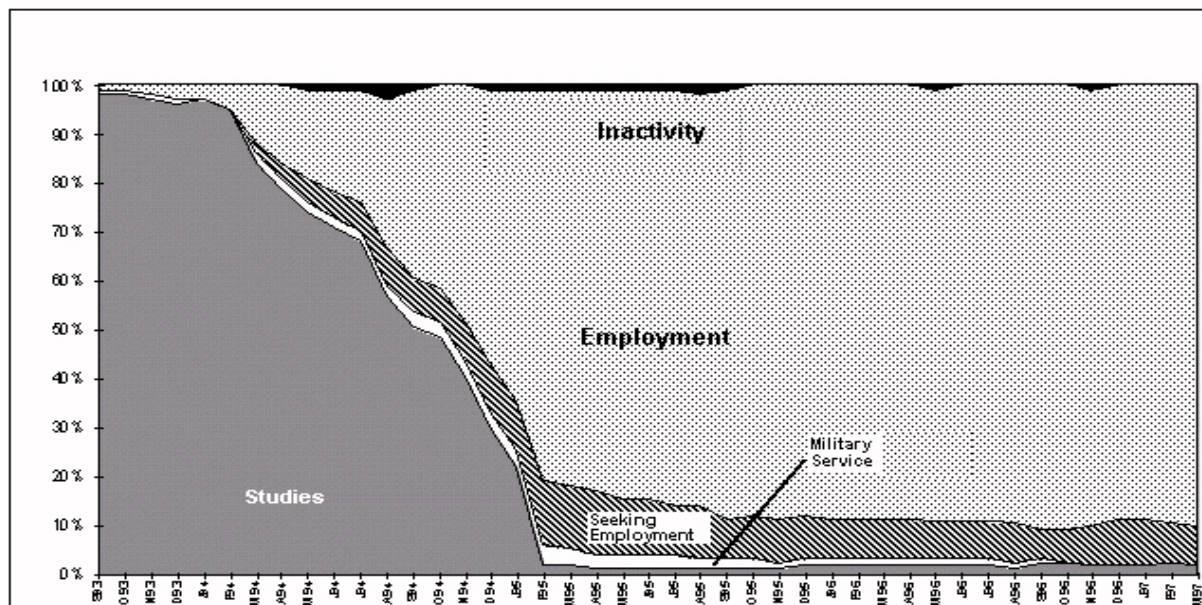


Source: Céreq.

PhDs still find employment more easily than other university graduates

The increase in the number of PhD theses and the standstill in recruitment meant that employment openings for PhDs, like those for other graduates, fell in the early 1990s. However, their situation remains favourable by comparison with that of other HE graduates. Only 8.5% of the 1994 cohort of PhDs were unemployed after three years on the labour market, as compared with 10.1% of holders of the DEA or DESS, and 12.3% of second-cycle graduates. PhDs found jobs more quickly than other university graduates, and spent less time out of work during the period under review (only 10% unemployed for more than six months before finding their first job). Figure 6 below shows the relative rates at which they found employment. It should be noted that only a tiny fraction of PhDs did their compulsory military service after finishing their theses. Their first jobs were more insecure than those of other university graduates: 41% accepted temporary employment as ATERs (*Attachés temporaires d'enseignement et de recherche* – Temporary Teaching and Research Assistants) and post-doctoral fellows. This instability is unpopular among PhDs, despite the fact that three years after graduation, the share of those in temporary jobs falls to around 21%.

Figure 6. Career paths of the 1994 cohort of PhDs (all disciplines)



Source: Céreq.

PhDs experienced slightly more unemployment than graduates of the *Grandes Écoles*. Although they seek employment for comparable periods of time, a slightly higher proportion of them were out of work after three years on the labour market (8.5% compared with 5% for engineering school graduates and 7% for business school graduates). *Grande École* graduates also take less unstable jobs than university graduates, in particular those with doctorates. However, PhDs and engineers enjoy the highest employment and pay levels upon completion of Higher Education (no PhDs in medicine were interviewed): three years after the end of their studies, 94% of PhDs had managerial-level jobs, for example as managers in the private or public sector, engineers, teachers and researchers. A large number of engineering school graduates also achieved manager-level status, but only 71% of job-seekers with the DEA or DESS and under 50% of second-cycle and business school graduates found employment at this level.

These differences in seniority explain the salary differentials between graduates. The net median salary of young PhDs in March 1997 was the same as that of engineers (FRF 12 000). Other graduates had substantially lower salaries (holders of the DEA or DESS: FRF 10 500; graduates of business schools: FRF 10 000; and holders of second-cycle university degrees: FRF 8 950). Few PhDs earned low pay; in fact, three quarters of them earned over FRF 11 000. Low salaries are much more frequently found among engineers, and particularly among graduates of business schools. A quarter of PhDs earn more than FRF 14 000, a high salary for the beginning of a career (see Table 1) .

Table 1. Job integration of PhDs compared with that of other HE graduates

	1 st insecure job	Insecure employ 1997	6+ months unempl. out of 33	6+ months unempl. before 1 st job	Unempl. March 1995	Unem- pl. March 1997	Managers March 1997	Salary * in 1 st quartile	Median salary*	Salary* in 3 rd quartile	Number
	(in %)	(in %)	(in %)	(in %)	(in %)	(in %)	(in %)				
PhDs in science	44.2	23.7	21.0	11.0	16.0	9.4	94.6	10 500	12 000	14 000	5 381
PhDs in hum/soc science	31.0	14.7	9.8	3.9	7.2	5.8	92.7	11 000	12 400	14 500	1 262
CIFRE	20.7	12.5	16.0	10.7	16.3	3.4	97.3	11 700	13 500	15 000	400
All PhDs	40.5	21.3	18.7	9.7	14.5	8.5	94.4	11 000	12 000	14 000	7 043
Engin.sch.grads	22.0	10.3	16.3	11.8	16.0	5.0	91.2	10 300	12 000	13 600	14 305
Business sch. Grads.	28.5	10.7	19.2	9.2	17.0	7.0	48.1	8 000	10 000	12 000	13 645
DEA-DESS	33.7	19.4	23.5	15.4	23.2	10.1	70.5	8 900	10 500	12 000	21 244
2 nd cycle univ. degree	34.3	22.9	21.4	12.3	21.7	12.3	44.8	7 200	8 959	10 500	46 492
DUT	51.2	30.5	27.1	14.5	27.6	13.9	5.8	6 000	7 000	8 400	12 913
BTS	45.3	29.4	23.9	14.4	21.7	7.6	5.0	6 000	7 000	8 000	44 830
Total higher education	36.8	22.4	21.8	13.1	20.8	9.3	41.5	7 000	8 860	11 200	172 373

* Net monthly salaries (all allowances included).

Source: Céreq.

Box 1. Survey Methodology

The survey on the labour market entry of PhDs focused on French PhDs (other than PhDs in medicine) who finished their degrees in 1994, were under the age of 35 in 1994, and were entering the labour market. A relatively high share of PhDs, particularly those in humanities were older and had been employed long before completing their theses.

The focus of the survey was exclusively on French PhDs for several reasons. First, it is virtually impossible to contact foreign PhDs when they have returned to their countries of origin and, moreover, interviewing those who stayed on would not be representative. Second, there were virtually no foreigners pursuing higher education in other fields. Accordingly, it was decided to compare the labour market entry of only French graduates.

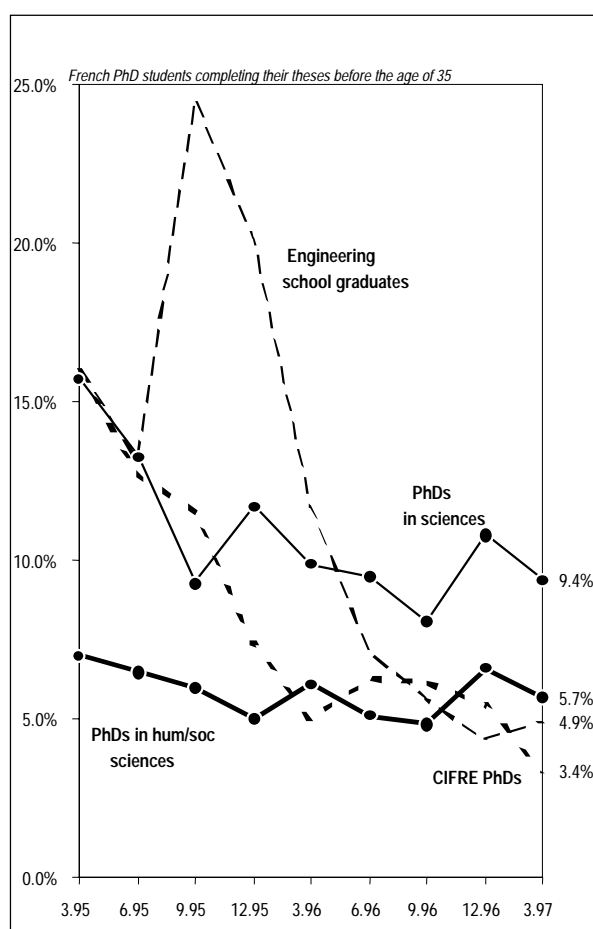
The survey was conducted by telephone between April and July 1997 using the computer-assisted telephonic interview (CATI) system. The interviews were carried out following an automatic and manual search of telephone numbers in the records of France-Telecom. Altogether 1 364 Doctors were contacted: 308 CIFRE (*Convention industrielle de formation par la recherche* – Industrial Agreement on Training through Research) PhDs, 515 non-CIFRE PhDs in sciences, and 541 non-CIFRE PhDs in humanities and social sciences. It is very difficult to contact these people, and the response rate reflected the accuracy of available address lists (ranging from 68% for CIFRE PhDs to 41% for PhDs in humanities and social sciences) Altogether, there were 926 questionnaires in which the age criteria were examined. The sample consisted of **274 CIFRE PhDs, 423 non-CIFRE PhDs in sciences, and 229 non-CIFRE PhDs in humanities and social sciences.**

CIFRE PhDs

CIFRE PhDs (PhD having participated in the Industrial Agreement on Training through Research) are most successful in finding employment, although it should be noted they are pre-recruited by enterprises, and that their theses often count as professional experience. After three years on the labour market, their unemployment rates were below 4% and their jobs rarely temporary. Moreover, salaries were above average because of work experience in the company. They also enjoyed employment conditions that were at least as favourable as those of engineering school graduates and they were better paid: FRF 13 500 for CIFRE PhDs compared with FRF 12 000 for engineering school graduates.

The ease with which PhDs enter the labour market varies according to their field of study. PhDs in humanities and social sciences (i.e. law, economics, letters and humanities) find employment a little more easily than those in science (apart from CIFRE PhDs); they also spend less time out of work, find jobs more quickly, and have less unstable employment. Their salaries are slightly higher than those of science PhDs. It is noteworthy that despite the age limit of the survey (under 35), some PhDs in humanities and social sciences had already worked, mainly in secondary education, prior to completing their theses. The success with which PhDs in humanities and social sciences find employment may also derive from the fact that there are so few of them (they account for only a third of all post-graduates). PhD graduates in law and economics did well at finding employment, whereas graduates in letters and humanities performed at the average.

PhDs in the ‘hard’ sciences such as mathematics, physics and information technology find employment more effectively than PhDs in life sciences (e.g. chemistry, biology, and life and earth sciences), and they also experience less insecurity and unemployment. PhDs in life sciences have greater difficulties (14% were still looking for a job after three years on the labour market), but their salaries are close to those of PhDs in ‘hard’ sciences.

Figure 7. Unemployment of graduates 1994-1997

Source: Céreq.

The public sector is the main destination of PhDs

Two thirds of PhDs find employment in the public sector. This is the highest proportion of public sector jobs observed to date on completion of Higher Education, but the traditional destination for students with theses is still teaching and research. No other university training leads so frequently to the public sector, although a significant proportion (45%) of second-cycle graduates enter the public sector via jobs in primary and secondary education. Taking all PhD graduates together, those in humanities most often opt for the public sector (85%). In addition a large number of graduates in letters and humanities at the second-cycle, DEA and DESS levels go into teaching. PhDs in sciences (excluding CIFRE PhDs) who do not work in the public sector are more likely to be in the tertiary market sector than in industry, especially engineering. Among PhDs, only the majority of CIFRE PhD graduates opt for the private sector. Following in the footsteps of engineering school graduates, they work in industry or in the services sector (i.e. business services).

Not all firms that recruit PhDs are large concerns. Since 1991, HE graduates have been increasingly hired by companies employing fewer than 500 staff and particularly by small enterprises with fewer than 50 employees. In this sense, the recruitment of PhDs differs from that of engineering school graduates in that a large proportion of the latter are still recruited by large firms. The jobs performed by PhDs are

closely linked to the sectors in which they seek employment; for example, almost 70% of CIFRE PhDs are engineers in firms, many of them becoming research engineers while other higher Education graduates rarely become production engineers.

It is less common for non-CIFRE PhDs to become engineers in firms; the majority find work as Senior Lecturers or Researchers. Most graduates with theses in 'hard' sciences become teachers, although PhDs in experimental sciences find work as researchers. PhDs in humanities and social sciences mostly move into the higher education sector, with a small share (11%) opting for research. A considerable proportion of PhDs in law and economics (15%) become administrative managers or commercial managers in firms, while post-graduates in letters and humanities who do not go into Higher Education or research become (or remain) first or second-level teachers, often with unstable employment (see Table 2).

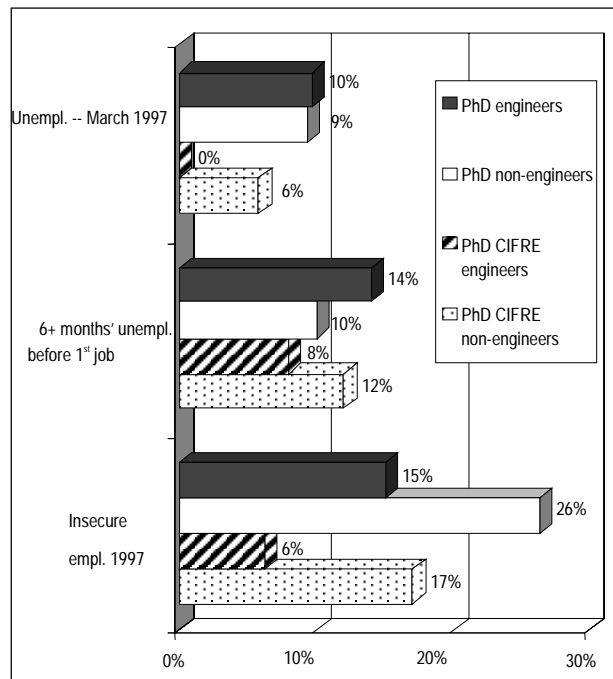
Table 2. Employment in March 1997 by size of employing institution

Degree	Size of institute	1-9 employees	10-49 employees	50-199 employees	200-499 employees	500 employees	Public sector	Total	Number
		%	%	%	%	%	%	%	NB
PhDs	Sciences	6.5	7.0	6.1	7.4	11.0	61.9	100.0	3 566
	Hum/Soc. Sc.	4.0	6.2	0.5	1.8	2.4	85.0	100.0	1 189
	CIFRE	5.1	11.3	12.6	14.2	25.5	31.4	100.0	373
	Total	5.8	7.2	5.3	6.6	10.1	65.1	100.0	5 128
Engin.sch.grad Business. Sch.graduate		5.1	13.2	17.0	17.1	38.7	9.0	100.0	12 765
		14.3	26.3	22.9	11.4	20.8	4.2	100.0	12 111
DEA-DESS	Sciences	7.4	11.7	16.3	10.4	23.8	30.4	100.0	5 609
	Law, econ.sc.	17.6	17.0	12.2	4.4	15.8	32.9	100.0	4 161
	Management	12.2	17.4	13.4	16.3	27.0	13.7	100.0	2 655
	Lett./hum.	8.9	8.9	9.5	2.5	7.4	62.9	100.0	4 829
	Total	11.0	13.1	13.0	7.6	17.8	37.5	100.0	17 254
Second cycle degree		10.8	17.7	10.7	4.4	11.2	45.3	100.0	31 060
DUT BTS		15.4	20.8	17.9	11.7	16.5	17.7	100.0	9 942
		26.4	24.6	15.2	9.6	12.5	11.7	100.0	37 862
Higher education total		15.4	19.0	14.3	9.1	16.5	25.7	100.0	136 195

Source: Céreq.

PhDs engineers outperform other graduates on the labour market

A substantial proportion of PhDs, particularly those with CIFRE theses come from engineering schools. This two-tier course is highly prized by enterprises, with PhD engineers performing better on the labour market than non-engineers. At the end of a typical natural sciences thesis, the rate of unemployment among engineering PhDs is similar to that of non-engineers, but there is much less insecurity. The salaries of engineering PhDs are higher, with half of them earning FRF 13 000 a month at the beginning of their careers. There are even greater differentials among post-graduates with CIFRE theses. Not one of the CIFRE engineering PhDs surveyed was unemployed three years on the labour market, temporary jobs were rare (6%), and salary levels were high. In March 1997, for example, the median salary of engineering PhDs was as high as FRF 14 000, compared with FRF 13 000 for non-engineers. Professional destinations varied slightly according to whether the PhDs were engineers or not; engineering PhDs being more frequently employed in the business sector, mainly in industry.

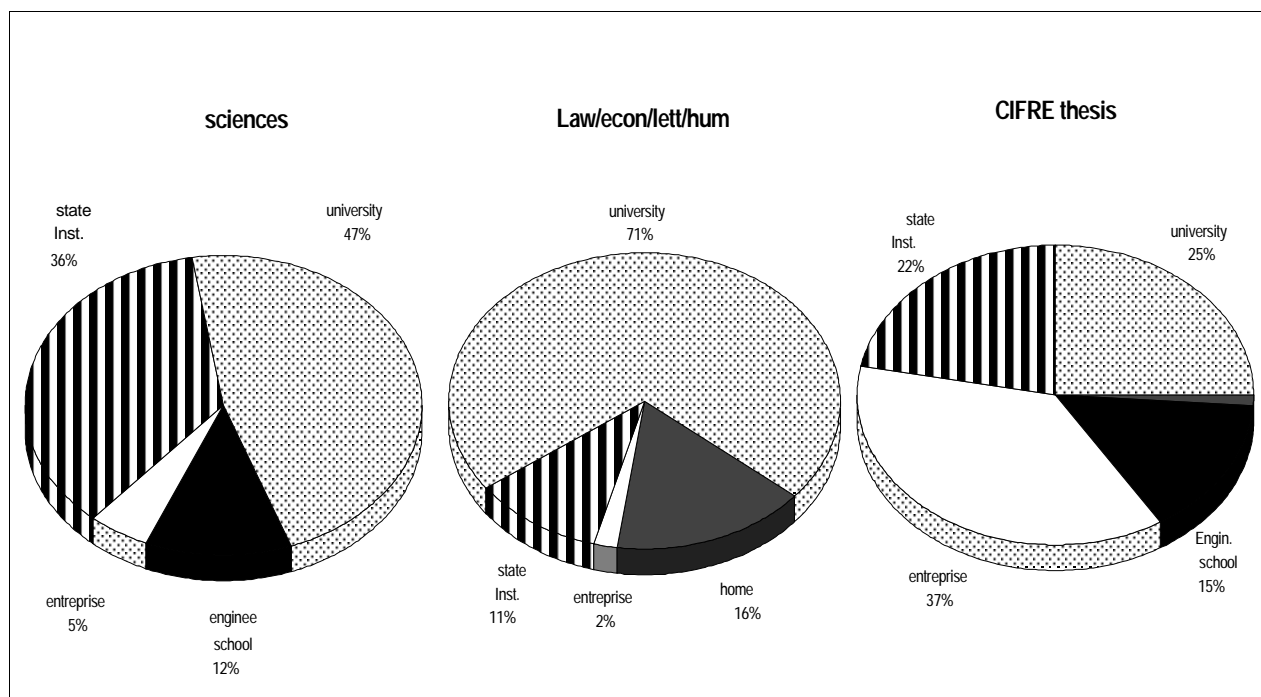
Figure 8. Labour market performance of PhD engineers

Source: Céreq.

The conditions in which a PhD is completed has a strong bearing on employment destination

The destination of PhD graduates is influenced by the funding source of the thesis, the institution of study, and the experiences gained while it is being written. Teaching while engaged on writing the thesis makes it easier for PhDs to move into the higher education sector. One option in this field open to them is the post of Graduate Assistant: a third of PhDs in sciences and 28% in humanities and social sciences surveyed held this job and, in so doing, obtained teacher training.

Carrying out part of PhD study in a firm can help PhDs establish a network of contacts that might be useful when seeking employment. Companies also look upon time spent with them as initial job experience. However, only a small proportion of PhDs surveyed worked in companies (14% in sciences, and 7% in humanities and social sciences). CIFRE PhDs were the exception: 82% of them carried out at least some of their theses in a firm. Universities are by far the most popular places in which to carry out a thesis. However, over a third of PhDs in sciences completed their theses in a state institution, and 16% in humanities and social sciences completed their theses at home; 37% of CIFRE PhDs completed their theses mostly in a firm.

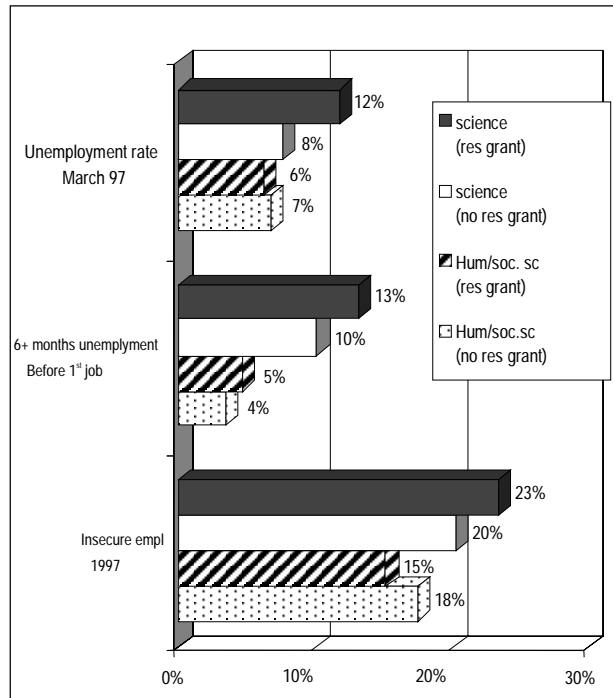
Figure 9. Distribution of PhDs by field of study

Source: Céreq.

One of the main differences between PhDs is the funding source of their theses. Having a research grant influences employment opportunities and encourages beneficiaries into research and higher education. Some 77% of one-time beneficiaries of a research grant worked in the public sector, compared with 58% of other PhDs, but the relative shortage of jobs in recent years appears to have blunted their employment opportunities. The unemployment rate and the amount of time spent looking for employment are both above average for recipients of thesis funding in sciences, and their salaries are lower than those of other PhDs irrespective of subject.

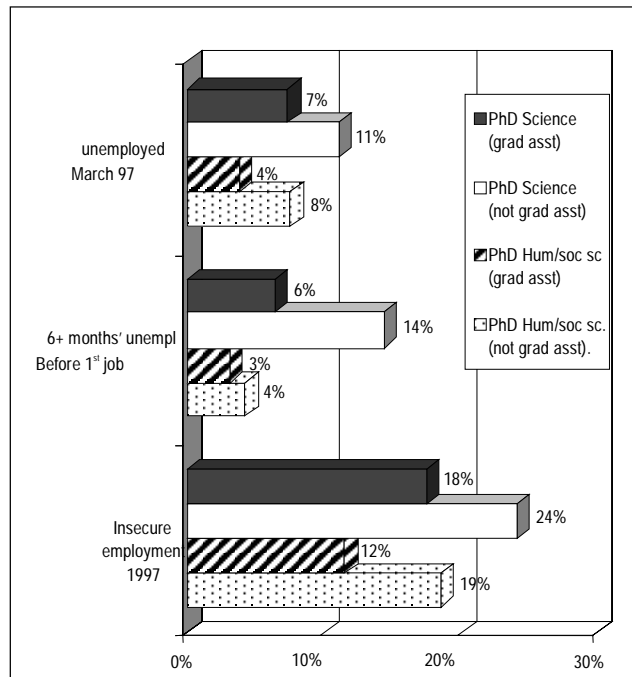
Former recipients of research grants become teachers in higher education more frequently than other PhDs. On completing the PhD theses in natural and exact sciences, half of the recipients of research grants go into teaching. The figure for those in humanities and social sciences is three-quarters. Having received a research grant does not help in finding employment as researchers. Of all recipients of research grants, graduate assistants enjoyed a more favourable situation in that much of them found employment in higher education and research. Few graduate assistants who completed their theses in natural sciences or in humanities and social sciences experienced unemployment or were in temporary jobs. They also spend very little time in the job search compared to those not having worked as graduate assistants, yet their salaries are slightly below average. This seems to suggest an ample supply of public sector jobs for graduate assistants. These jobs are a little less well paid in the early years. In summary, working as a Graduate Assistant leads to employment in higher education: 54% of Graduate Assistants teach after a thesis in natural sciences, and 81% do so after one in humanities and social sciences. It should be noted that Graduate Assistants are selected with this employment outcome in mind, and the teaching experience acquired during the thesis is likely to encourage their recruitment into higher education.

Figure 10. Labour market performance of PhDs by funding source



Source: Céreq.

Figure 11. Labour market performance of graduate assistants

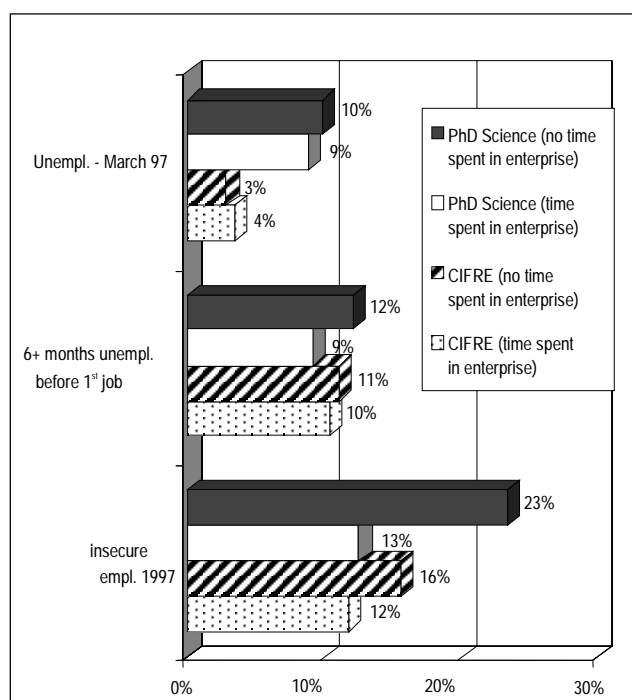


Source: Céreq

PhDs who completed at least part of their thesis in an enterprise were more likely (61%) to work in the private sector; they also had less unstable jobs than other PhDs and slightly higher salaries. PhD who did most of their theses in a firm found employment the easiest. Nearly all of them found a job within three years on the labour market: three quarters worked in the private sector, and earned relatively high salaries (about FRF 13 000). PhDs who did most of their theses in a state institution had more difficulty in finding a job, 61% of them went to work in the public sector, and their salaries were average (FRF 12 000). PhDs who did their thesis in a university were more effective at finding jobs in teaching and research than those from a state institution: they spent less time searching but their salaries (FRF 11 600) were slightly lower.

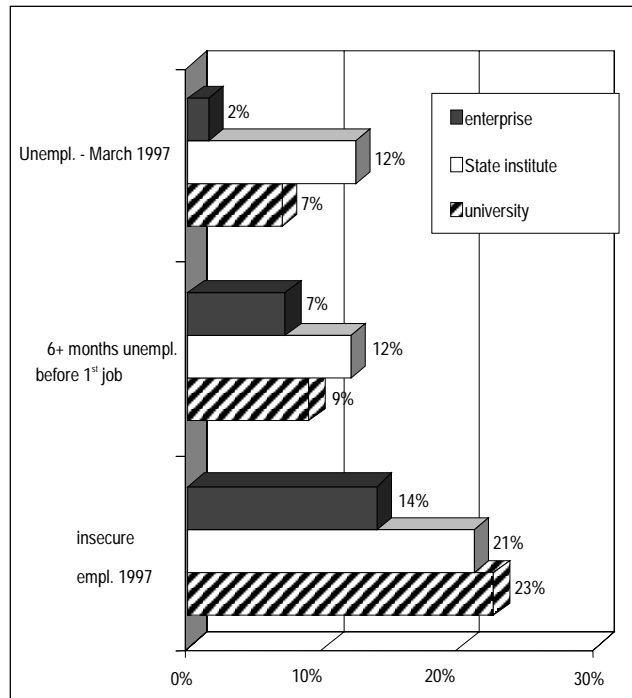
There is a correlation between the employment destination of PhDs and the institution in which they completed their thesis. Those who completed it in an enterprise became engineers in the private sector (63%), while those who carried it out in a university went on to teach in higher education (49%) or worked in the public research sector (17%). The employment destinations of PhDs from a state institution are less influenced by where they completed their thesis: one third worked in the public research sector while another third worked as engineers in firms, and 17% taught in higher education. The sample contained few PhDs who completed their theses in an engineering school. Their outcome appears to be similar to those of PhDs who came from state institutions, albeit with a higher share of teachers.

Figure 12. Employment status and prior work experience in firms



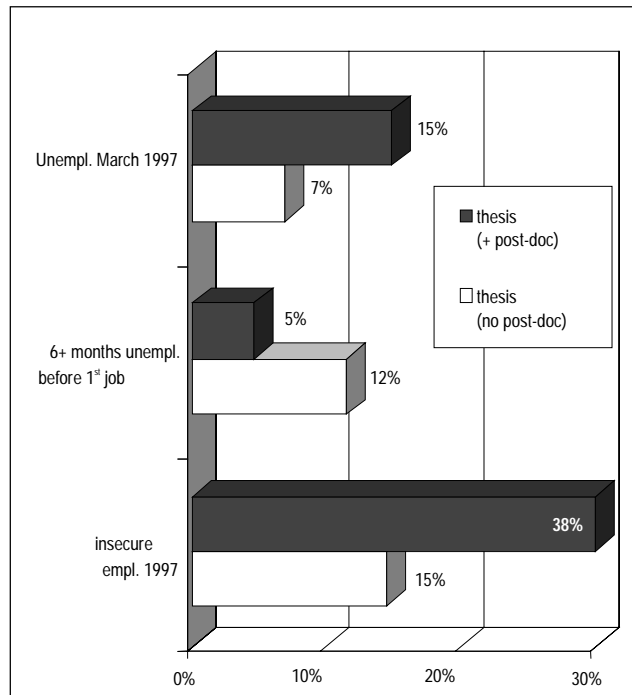
Source: Céreq.

Figure 13. Labour market status by institution of theses completion



Source: Céreq.

Figure 14. Employment status of post-doctorates



Source: Céreq.

Post-doctoral fellows do not seem to be better prepared

Post-doctoral fellowships are mostly taken up by non-CIFRE PhDs in natural sciences: in fact, almost one PhD in three in this discipline accepts these fellowships. Post-doctoral fellowships are less common among CIFRE PhDs (13%) and those with doctorates in humanities and social sciences (6%). Post-doctoral fellowships are usually taken up abroad (78%), in Europe (39%) or the United States (23%).

The career path observed in the survey (three years) made it impossible to assess the effects of post-doctoral fellowships on employment. Indeed, some PhDs were still working as post-doctoral fellows in March 1997, or had only just finished. Post-doctoral fellowships do not appear to improve job prospects; they avoid a long search for work, but PhDs who had taken this option faced more unemployment three years after their theses as well as unstable and less well paid jobs. These fellowships have given little boost to employment in public-sector research: 71% of PhDs who had completed such post-doctoral work left for employment in the public sector, compared with 65% of other PhDs.

This is not due to the fact that PhDs who find work the easiest are also more likely to undertake post-doctoral fellowships. In fact, post-doctoral fellows generally find it harder to find employment irrespective of their subject. Although post-doctoral fellowships do not help with finding a job in the short term, they do lead to research jobs. PhDs who have not taken such fellowships are more likely to become teachers in higher education.

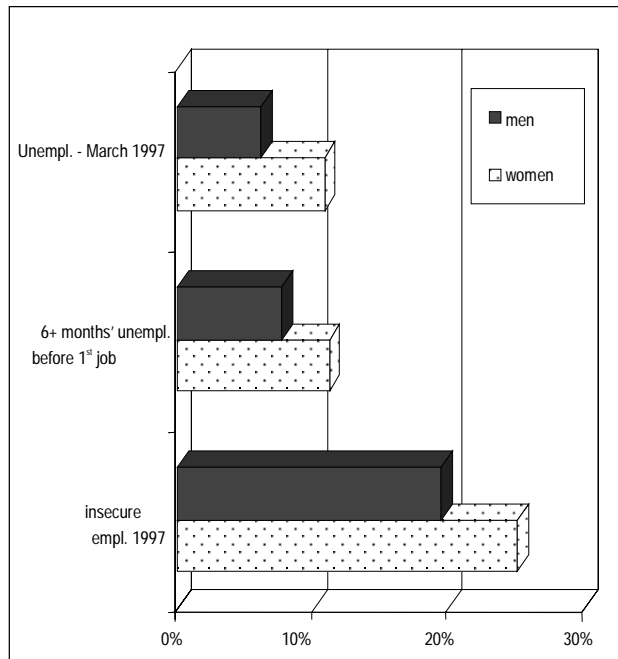
Individual characteristics of PhDs also influence the jobs they take

Persistent disparities between men and women

The share of women falls on completion of university studies and as the level of degrees rises. Women often perform better academically, but they pursue their studies for a shorter period. There are fewer women, for example, in natural sciences, traditionally the longest courses (sciences include a minority of second-cycle leavers, but as many as two thirds of all graduates with a thesis). Women represent 37% of all university PhDs but they account for a smaller percentage of PhDs in natural sciences or CIFRE PhDs than humanities and social sciences. Even at the very highest levels of higher education, there are employment and salary disparities between men and women. They are very small among those leaving state-recognised engineering and business schools, but greater at the end of courses at non-recognised universities and business schools. Among PhDs in natural sciences, CIFRE PhDs, and humanities and social sciences, women performed less favourably than men did. Women completing a thesis in natural sciences took longer to find employment than men did and, although their salaries were on a par, unemployment was higher among women (12%) after three years on the labour market.

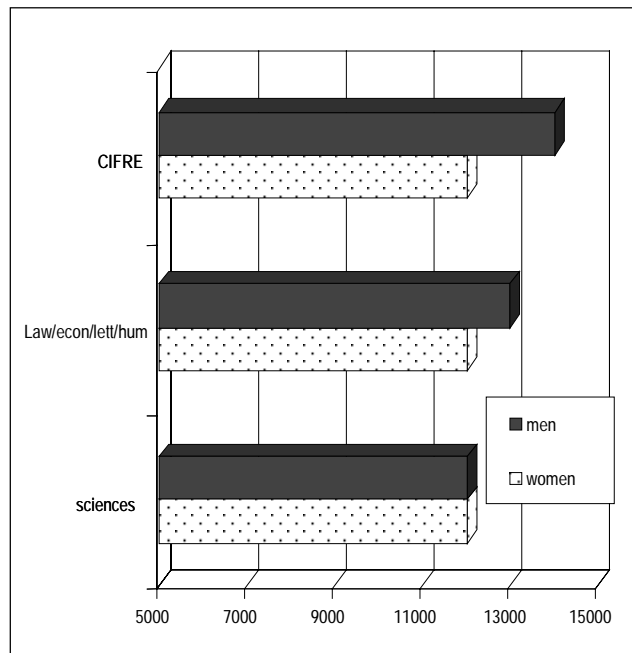
Women PhDs in humanities and social science also had higher unemployment rates than men and were less well paid (FRF 12 000 as compared with FRF 13 000 for men). While there are not many job seekers among CIFRE PhDs, women were slightly more unemployed and earned substantially lower salaries than men (FRF 12 000 as compared with FRF 14 000 for men). These disparities do not exist because women are more likely to seek employment in the public sector; indeed, the proportion of women PhDs working in the public sector (68%) is not much higher than that of men (64%).

Figure 15. Labour market status of the 1994 cohort of PhDs by gender



Source: Céreq.

Figure 16. Median salary of the 1997 PhD cohort by gender



Source: Céreq.

PhDs come from favourable socio-economic backgrounds

The level of higher education attainment is typically linked to socio-economic background: the higher the level of degree, the higher the parents' social category. Survey results show that the fathers of 57% of business school graduates were managers; followed by engineering school graduates and PhDs (53%). The social background of PhDs is not related to the subject of study. The father's academic level is also highest among business school graduates; followed by engineering school graduates and PhDs. The father's academic level is very similar among PhDs, irrespective of the field of study. PhDs whose fathers are managers, or had attained higher education, find employment most easily. Although social background has little impact on salaries, it does affect disparities with regard to unemployment and job insecurity.

PhDs holding a baccalaureate in mathematics ("bac C") find employment more easily

Among PhDs, the clear majority held either a mathematics baccalaureate C (57% of the total) or a baccalaureate in science (bac D) (26%). Only PhDs in humanities and social sciences held a baccalaureate A or B and 50% of these graduates held such baccalaureates. The following analysis thus focuses on the different experiences of the baccalaureate C and D holders in finding employment. This group accounts for the majority of PhDs, all fields of study combined. PhD graduates with a baccalaureate C found work most easily. They also spent less time looking for work, faced lower unemployment, and their jobs were more stable. By contrast, 39% of students with a baccalaureate D were still in unstable employment three years after completing their theses. PhDs with a 'bac C' had slightly higher salaries (FRF 12 500) than those with a 'bac D' (FRF 12 000). There was only a small sample of PhD graduates who held a baccalaureate A or B. Still, they seem to find jobs more easily than those with D baccalaureates. The labour market success of PhD graduates with B baccalaureates is boosted by the general success of PhDs in economics while PhD graduates holding baccalaureate D tend to fare less well due to the same difficulties facing PhDs in life sciences.

Regional analysis: labour market performance of PhDs tends to be better in the Île-de-France region

Outcomes are calculated based on the place where the thesis was completed. As a large number of graduates found employment in the regions where they were trained, these figures are influenced by the situation of the regional labour market. Outcomes are nearly always better in *Île-de-France* insofar as the region accounts for almost half of France's managerial positions and a large amount of the research; salaries are also higher there than elsewhere. Previous studies have shown that job seekers in *Île-de-France*, whether they hold the DUT or BTS or are university graduates, enjoy a clear advantage in finding employment (Martinelli, 1994). PhDs surveyed in 1997 were no exception to this rule. PhDs in sciences who were trained in *Île-de-France* experienced substantially less unemployment than their colleagues in the provinces (their unemployment rate was half as high after three years on the labour market), their jobs are a little less unstable, and their salaries are slightly higher. In contrast, PhDs in humanities and social sciences from *Île-de-France* had only a slight advantage in terms of unemployment and job insecurity compared to their peers in the provinces. Their salaries, however, were clearly higher (FRF 13 500 compared with FRF 12 000 for PhDs trained in the provinces). Regional differentials are smallest among CIFRE PhDs. Generally speaking, CIFRE PhDs face few problems, although there are small disparities in time spent on the job search and in salary, with those trained in *Île-de-France* enjoying a slight advantage.

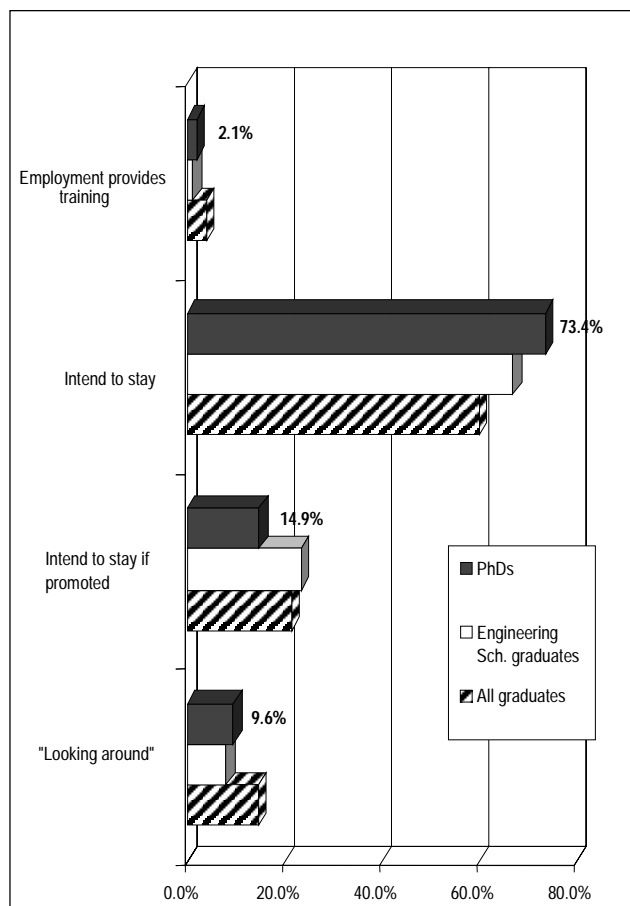
Job satisfaction is higher among PhDs than other higher education graduates

Of all higher education graduates, PhDs were the most satisfied with their jobs in 1997. Three quarters found their jobs interesting and intended to continue working for their present employer. In contrast, only

67% of engineering school graduates and 53% of business school graduates shared this view. Of other higher university education graduates, about 60% found their job interesting. While less than 10% of PhDs stated they were in their current job awaiting a better opportunity; up to 15% of those leaving higher education chose this response.

Among all categories of PhDs identified in this study, CIFRE PhDs were slightly more satisfied with their jobs than other PhDs and 74% of them intended to stay in their current job. However, job satisfaction of PhDs differs when their jobs are unstable (i.e. temporary). Half of them stated they were 'looking around', or that they would only stay if they got promoted. This confirms the very negative perception that PhDs have of the insecure employment conditions they sometimes face. Job satisfaction also varies according to sector of employment. The most satisfied PhDs worked in the public sector. Most of those employed in the tertiary market sector (e.g. engineering) intended to stay (64%), but a quarter stated they would only do so if they were promoted. PhDs working in industry were most likely to seek a higher position: only half stated they intended to stay and a third were seeking a promotion. It is noteworthy that salary had little influence on the job satisfaction of PhDs.

Figure 17. Job satisfaction of PhDs in 1997



Source: Céreq.

BIBLIOGRAPHY

MARTINELLI, D. (1994)

Diplômés de l'université. Insertion au début des années 1990, Document N° 100, 'Observatoire' Series, Céreq, October 1994.

MARTINELLI, D. (1997)

Diplômés de l'enseignement supérieur. L'insertion professionnelle se stabilise mais les écarts s'accroissent, Bref N° 134, Céreq, September 1997.

ANNEX

Labour market integration of foreign PhDs in the sample living in France in 1997

As the last survey carried out in 1991 showed, the situation of foreign PhDs in France is very unfavourable. We were unable to interview those who had returned to their countries of origin as it proved very difficult to contact them. The size of the sample prevented us reaching definitive conclusions, but the disparities are so substantial that these outcomes are sufficiently reliable. They do not prejudice the overall situation of foreign PhDs, as those who returned to their countries of origin may have been better off.

The overwhelming majority of the foreign PhDs that we did manage to interview are not from the European Union. There is a high incidence of unemployment and unstable employment among them, and unemployment has a tendency to rise at the very time that it is falling among other graduates. Salary and employment levels are also below average for the most part. Those in the most unfavourable situation are foreigners who do not come from the European Union and who remain in France.

Table 1. Job integration of foreign PhDs in the sample living in France (63 questionnaires)

Labour market integration indicators	All foreign PhDs
1 st insecure employ	60%
Insecure empl. 1997	38%
6+ months unempl.(out of 33)	38%
6+ months' unempl. before 1 st job	17%
Unempl. rate March 1995	24%
Unempl. rate March 1997	35%
Managers in March 1997	77%
Managers + interm. profs in March 1997	95%
Salary in 1 st quartile	8500
Median salary*	10000
Salary in 3 rd quartile	13500

Source: Céreq.

E. HUMAN RESOURCES IN SCIENCE AND TECHNOLOGY IN SPAIN: A REVIEW OF THE INFORMATION SOURCES

by

Ms. Carolina Cañibano, Assistant Professor, *Alfonso X University of Madrid*
Dr. Paloma Sánchez, Professor of Applied Economic, *Autonomous University of Madrid*

Overview

This paper attempts to make a methodological analysis of the Spanish statistical data that may provide information about the human resources in science and technology labour markets. A thorough review is made of the questionnaires in different surveys and the results. One of the main findings is that although none of the sources has been created with the purpose of providing information about these human resources, the information is quite extensive and its analysis could lead to important improvements in policy design. Some suggestions are provided in the paper to ameliorate the analytical capacity of the data sources, first by making additional use of the existing raw material in the questionnaires, and second by suggesting further issues to be incorporated.

Introduction

The object of this paper is to review the existing statistical sources in Spain that may provide information on the human resources in science and technology. The analysis of these sources will be made allowing for possible use of existing data to explain the characteristics of the labour markets of that portion of population in order to better define policy measures.

The rationale of this analysis is very clear. We live in a knowledge-based economy, which means that knowledge has become an important factor of production, completely changing the characteristics of the production process. In this new situation competitiveness and growth are increasingly based more on brains than on material resources. To determine the level, qualifications, dynamics, etc. of human resources, the brain-intensity of a country, is without doubt a key political issue. Future wealth will be largely based on the existence of sectors of population which are well trained with the appropriate skills to undertake the challenges of the new millennium.

The remainder of this paper is organised as follows. The point of departure is the concepts and definitions of the Canberra Manual (OECD, 1994). Section 2 is devoted to defining the scope of the analysis taking into account the different categories established by the Manual. A detailed description of all existing data sources in Spain is made in Section 3. All of them are enumerated and described, distinguishing between primary and secondary sources. The following information is provided for every source:

- Institution responsible for the data.
- Date of first and last data available.
- Data frequency.
- Main information provided.

Particular attention is paid to the following:

- Existence of detailed raw data related to S&T human resources (included in the questionnaires) but not yet used in the tables. Additional analysis of existing data that would supply further information on such resources.
- Need for more raw data and therefore a redefinition of the questionnaires.

Some of the methodological and factual difficulties in addressing mobility are addressed in Section 4. Section 5 is devoted to highlighting the main advantages and shortcomings of the existing data to build adequate indicators for policy making, and finally, Section 6 presents some conclusions.

Scope of the analysis on the Canberra Manual bases

As is well known, the OECD Group of National Experts on Science and Technology Indicators (NESTI) finished in November 1994 a Manual on the Measurement of Human Resources devoted to Science and Technology, referred to hereafter as the Canberra Manual. This Manual is an important attempt to provide useful international guidelines to measure a crucial subgroup of all human resources, which is in one way or another connected to scientific and technological activities.

The Manual takes a broad view considering Human Resources devoted to Science and Technology (HRST) as those who fulfil one or other of the following conditions:

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

We will keep closely to these definitions in this paper and will therefore use the two following categories:

- Human resources with a third level education in Science and Technology studies: HRSTE.
- Human resources occupied in Science and Technology activities: HRSTO.

The intersection of these two groups will be the main category of human resources and refers to people with third level education *and* employed in an S&T occupation. It is one of the important groups for policy purposes (see Figure 1).

According to the above definitions two issues have to be defined:

- Science and technology studies.
- Science and technology activities.

In the first case the Canberra Manual distinguishes between Core Coverage, Extended Coverage and Complete Coverage. Table 1 below shows how they are defined.

Table 1. Coverage for data collection, by field of study and level of education

Field of Study	ISCED-76 Level		ISCED-97 Level	
	6/7	5	5A/6	5B
Natural sciences	Core	Extended	Core	Extended
Engineering and technology	Core	Extended	Core	Extended
Medical sciences	Core	Extended	Core	Extended
Agricultural sciences	Core	Extended	Core	Extended
Social sciences	Core	Extended	Core	Extended
Humanities	Extended	Complete	Extended	Complete
Other fields	Extended	Complete	Extended	Complete

Source: OECD, 1994; 25 and OECD, 1999b; 14.

Levels 5, 6 and 7 are all within the third level of education (technical plus university level qualifications) according to the International Standard Classification of Education (ISCED-76), which is the classification followed by the Manual. However, Table 1 shows also the coverage for data collection following the new ISCED-97 classification, which will be implemented in OECD countries in the coming years.

In principle, we are going to consider all suggested coverage. Thus HRSTE are all human resources with third level education in whatever field of study. This approach is taken mainly for practical reasons. As we will see in the next Section, some sources reveal the level of education a person has achieved (and therefore permit us to place them above or under the third level), but not the field of study in which that level has been attained.

However, for political purposes we believe that humanities and other fields at any educational level should be left out, otherwise data gathering and analysing would increase without providing a useful tool for policy. The fact is that the number of humanities graduates in Spain is larger than the number of graduates in sciences and engineering, which is probably a shortcoming if the innovative capacities of the country are to be increased.

In relation to coverage in terms of occupation, the Manual follows the International Standard Classification of Occupations (ISCO). We will adhere to the coverage suggested, considering as S&T occupations Professional Technicians and Associate Professionals, and Managers. Recent reviews suggest excluding the Manager's group (OECD, 1999) but as this is just a methodological analysis of the sources we prefer to have the broadest possible perspective. When actually gathering the data to build indicators a selection of those with more explanatory capability and usefulness for policy may be made.

Table 2 shows clearly the equivalence between ISCO classification and the Spanish definitions. Two important ideas from the Manual are kept in mind in particular when analysing the Spanish data sources. The first one is that there are a number of data sets that contain information about HRST, but they have neither been collected nor used for S&T policy. In fact S&T policy makers do not take these data into consideration. The second is that the Manual itself has yet to be implemented in practice. It is necessary to see whether it is sufficiently utilitarian and relevant to policy and analytical needs.

Taking these two ideas together, the main objective of this paper is to: analyse the data sets in Spain which, although not built for that purpose, provide information about HRST, and to assess whether the categories and concepts established in the Manual can be found in the Spanish statistical data and whether they are useful in terms of shaping S&T policy.

On the basis of the Canberra Manual, in 1995 the OECD produced a very important paper: *Basic Indicators for describing the stock of Human Resources in Science and Technology* (OECD, 1995). In the

paper a set of 10 main indicators to be calculated by all countries is suggested. The availability of these indicators would allow interesting international comparisons.

In this paper, we consider whether the Spanish data permits the construction of such indicators, and in some cases, additional ones are suggested.

Description of the data sources

The following sections describe in detail the data sources analysed.

Active Population Survey (Encuesta de Población Activa – EPA) (INE, 1998a.)

- Institution responsible for the data set: National Institute of Statistics (INE).
- Date of first and last data: 1987/third quarter 1998.
- Publication frequency: Quarterly.
- Sample: 64 000 family units¹² surveyed every quarter.

The Spanish Active Population Survey (EPA) provides useful information about the conditions of the labour market. The data are classified in four main categories: 1) Occupied; 2) Unemployed; 3) Active (Occupied + Unemployed), and 4) Inactive. All of them are analysed below.

The classification of occupations used in the two first categories follows the National Classification of Occupations (CNO-94), which is the most recent Spanish adaptation of the International Standard Classification of Occupations (ISCO-88). Thus the EPA provides HRST data, in terms of occupation according to the definitions outlined in the Canberra Manual.¹³

The equivalence between ISCO-88 and Spanish CNO-94 is shown in Table 2.

Table 2. ISCO-88 and CNO-94 Equivalence for S & T Occupations

ISCO-88	CNO-94
Major Group 2: Professionals	Major Group 2: Technicians, Professionals, Scientists and Intellectuals.
Major Group 3: Technicians and Associate Professionals	Major Group 3: Support Technicians and Professionals.
Major Group 1; Subgroup 122: Production and Operations Department Managers and subgroup 123: Other Department Managers	Major Group 1; Subgroup 11: Executive Managers of companies with 10 or more employees.
Major Group 1; Subgroup 131: General Managers	Major Group 1; Subgroups 12, 13, 14, 15, 16 and 17: Managers

Source: Authors.

12. The unit of analysis is the group of people living in the same house.

13. “All people employed in occupations which are classified in ISCO-88 major groups 2 or 3, or in the management subgroups 122, 123, or 131 are considered to be employed in an S&T occupation” (OECD, 1994; 27).

Information about the active population

The EPA section, which corresponds to the employment survey, provides substantial information on the stock of HRST employed in an S&T occupation (HRSTO). The quarterly publication of the INE includes the following breakdowns for each one of the major groups mentioned above:

- Gender.
- Age.
- National Origin (grouped by large geographical or political areas, i.e. European Union, America, etc.).
- Economic Sector of Employment.
- Labour force status: Full time or part time permanent staff, short-term contract staff, etc.
- Time spent in the present employment.
- Type of working conditions (work on weekends, work at home, work by night, etc.).
- Level of education (classification comparable to ISCED).
- Current studies.

As the level of education is provided for all HRSTO, the EPA allows for differentiating between two of the three main categories of HRST defined by the Canberra Manual. Thus:

- HRST without third level education but employed in an S&T occupation.
- HRST with third level education and employed in an S&T occupation.

It should be noted, however, that the source we are analysing here allows for breakdowns only for the different occupation levels and disregards the different educational levels. So, for example, a gender analysis here can be made for HRSTO, but not for HRSTE.

Moreover, using the information on the Current Studies of HRSTO, we obtain the flow of HRST going from a) to b), which represents people employed in an S&T occupation who are now receiving third level education. The EPA results are only published at aggregated level. This means that only data about the major groups of occupations are disclosed, even though raw data exists on the subgroups and could be obtained and analysed on request. In summary, the Spanish Survey of the Active Population allows for the preparation of a well defined profile of those employed in an S&T occupation, according to the definitions and analysis of the Canberra Manual.

Information about the unemployed and inactive population

Unemployment figures broken down into major groups of occupations provide information about people who are unemployed at the time of the survey, but who held an S&T occupation in the past. The different analyses show how long these people have been unemployed, their gender, age and the reason for leaving their last employment.

The source also provides information on those HRST who are inactive, and in this case the duration of their last employment is also provided.

The EPA then permits us to determine the profile of the stock of human resources who had an S&T occupation in the past and who are, at the time of the survey, unemployed or inactive. This profile,

according to the published data, is not as detailed as that of the employed, although the raw data exists and analysis could be made as thorough as that related to the occupied population. In addition, a follow up to the quarterly results of the EPA would enable us to obtain information about the flows of HRSTO from employment to unemployment and inactivity. The reasons for leaving an S&T occupation could also be studied, as well as other aspects concerning the dynamics of HRSTO. Thus we have a very useful source of information which can be better exploited. As most OECD countries produce something similar, comparisons between countries could be made.

Population Census (Censo de Población) (INE, 1996)

- Institution responsible for the data: National Institute of Statistics (INE).
- Date of first and last data set: 1857/1991.
- Publication frequency: Every 10 years.
- Sample: Exhaustive.

The population census can be a very useful instrument to measure the stock of HRST both in terms of education and occupation. It provides information on the level of education for the whole Spanish population and specific details about the occupations of the employed population.

However, the latter are classified following the National Classification of Occupations of 1979 (CNO-79), which presents differences with CNO-94 used for more recent surveys like the EPA. Besides this, the classification breakdown is made only into major groups, which do not permit us to distinguish the subgroups of major group 1 as suggested by the Canberra Manual.

The INE publication of the National Results (INE - 1996) of the Census presents the following relevant breakdown:

- Total population with third level education broken down into age groups, gender, level of completed education and occupation.
- Active and Inactive Population with third level education.
- Employed broken down into level of education, economic sector of activity, age and labour situation (paid or self-employed, permanent versus short-term contract, full time versus part time, etc.).
- Unemployed by level of education, gender and age groups.
- Migration between regions (Autonomous Communities), broken down into level of education.
- Foreign population analysed by the level of education, gender and age groups.
- Foreign studying population.
- Immigrants during the last decade broken down into level of education, gender, age and size of arrival city.

As the Census is related to the entire population and not to a sample it provides exhaustive information about the HRST stock. The data allow the analysis of different HRST subgroups as well. The specification of the completed education level makes it possible to separately analyse the situation of those included in the different ISCED categories. The data, for example, would determine the number of working women holding a postgraduate degree as a proportion of all graduates. Even if the publication analysed does not

present a classification in terms of fields of study, the Census questionnaire contains a specific question related to it. Thus, a conclusion concerning the stock of HRST to be highlighted at this stage is that the Population Census gathers enough data to study in detail both HRSTE and HRSTO.

With regard to the flows, the breakdowns mentioned show that the Census contains information on the internal mobility of HRSTE, general data on the inflows of foreign HRSTE and special data on inflows of foreign students who may be HRSTE in the future. This means that some indicators describing the mobility of HRSTE could be produced.

The population Census appears thus to be a useful instrument for gathering statistical information on HRST. However, it is important to underline that the survey is conducted every ten years and that the methodology used to prepare each census usually changes, which makes dynamic analysis more difficult. The last Census produced in Spain dates back to 1991 making the data obsolete. For any future studies of the Spanish HRST, the 2001 Census should be taken into account (INE, 1998-d.).

Social-demographic survey (Encuesta Sociodemográfica) (INE, 1994-b.)

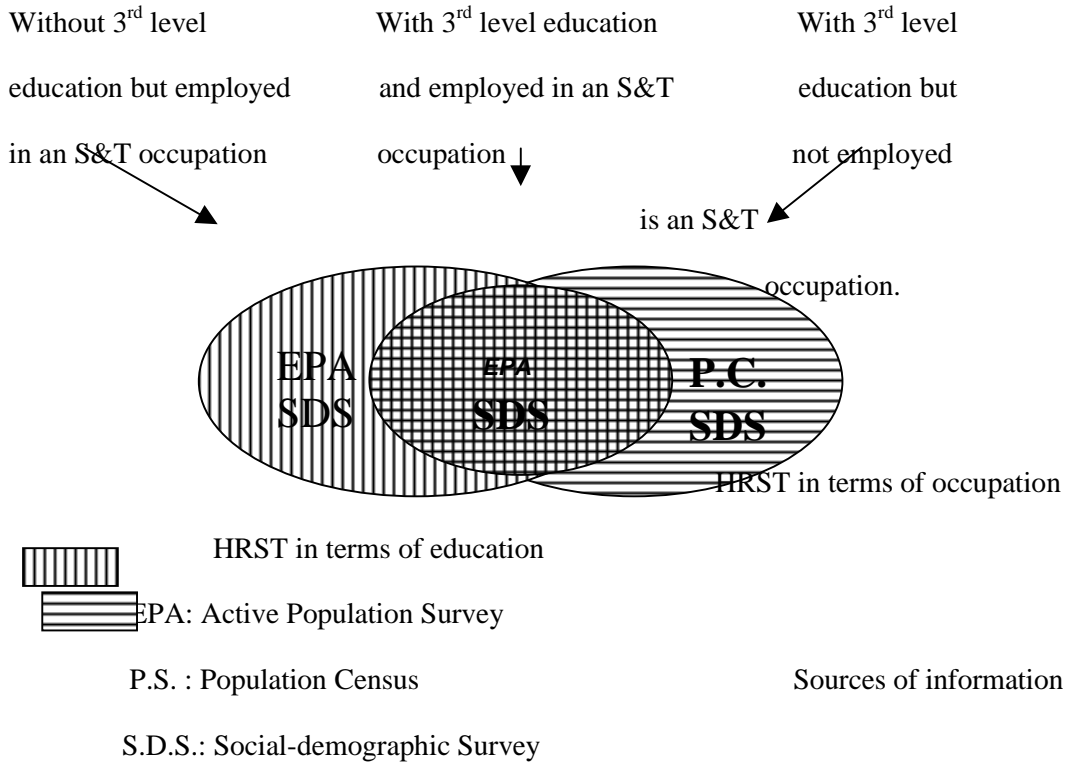
- Institution responsible for the data: National Institute of Statistics (INE).
- Date of first and last data set: 1991.
- Publication frequency: Singular source.
- Sample: Population aged 10 or over, living in family units and registered in the 1991 Population Census.

This source is the result of an exhaustive and very detailed data collection made in 1991 in order to increase knowledge of the individual characteristics of Spanish residents provided by the Population Census. The statistical survey focuses on the changes which have occurred in individuals' lives. For example, the reasons for changes in occupation and type of work, as well as changes of residence and their cause. Special attention is also paid to the particular family circumstances of the surveyed person, providing detailed information on their social and cultural origins.

In relation to the educational level, the survey provides an in depth analysis of the "education life" highlighting, for example, the reasons for interrupting and adjourning studies. It also provides information on the labour activities: all the occupations held, the reason for changes, unemployment spells, etc. The classification of occupations follows the CNO-79, the same as the Population Census, and the educational levels may be classified in the ISCED categories (see Table 3). Thus, this source of information contains data on all the HRST stock, making it possible to distinguish between HRSTE and HRSTO. Besides giving special attention to trends and changes, the information on flows and mobility is also relevant. It is important to notice that a specific questionnaire was produced for foreigners living in Spain, providing many details concerning their education and labour characteristics. The list of breakdowns provided by this source, which are useful to the HRST study, would be too large. Therefore we advise the interested reader to go to the original source (INE, 1993). The social-demographic survey has been an extremely useful source to produce monographs concerning different characteristics of Spanish society since its publication. In our opinion a special one on HRST could also be made, especially if new surveys with similar characteristics are going to take place.

As the three above-mentioned sources are probably the main ones which may be used for the analysis of HRST, they could be integrated in order to achieve what the Canberra Manual calls "principal categories of HRST", which may be represented by the following figure:

Figure 1: Principal categories of HRST



Third level education

There are two sources for third level education statistics, the first is the annual survey on higher education provided by the National Institute of Statistics (INE) and the second a special annual report from the University Council. We shall analyse both of them separately.

Higher education statistics (INE) (INE, 1998-c.)

- Institution responsible for the data: National Institute of Statistics (INE).
- Date of first and last data: 1989/1990 and 1995/1996.
- Publication frequency: Annual.
- Sample: Exhaustive.

The information presented in this annual publication is related to HRST covered in terms of education (HRSTE); it provides an exhaustive survey of higher education centres. Before analysing in detail the information provided by the data, it is important to establish the equivalence between the categories of the ISCED (International Standard Classification of Education used by the Canberra Manual) and the third level Spanish diplomas. Table 3 summarises such equivalence:

Tables 3A and 3B. Allocation of Spanish education levels to ISCED-76 and ISCED-97

Table 3A

ISCED-76	Spanish Diplomas
Category 5: First stage, does not lead to an award equivalent to a first university degree.	- High level Technician. High level professional training.
Category 6: First stage, leads to a first university degree.	- University Diploma. First cycle University education (2 to 3 years). - University Graduate. Second cycle University education (4 to 6 years).
Category 7: Second stage, leads to a postgraduate university degree or equivalent.	- Postgraduate: Doctoral and master studies.

Table 3B

ISCED-97	Spanish Diplomas
Category 5B: Practical/technical/occupationally oriented programmes, minimum two year programmes.	- High level Technician. High professional training.
Category 5A: more theoretically oriented programmes than level 5B; minimum three year programmes, usually lead to a university degree.	- University Diploma. First cycle University education (2 to 3 years). - University Graduate. Second cycle University education (4 to 6 years). - Postgraduate: Master studies.
Category 6: Programmes devoted to advanced study and original research, usually three year theoretical programmes.	- Postgraduate: doctoral studies.

Source: Authors and OECD, 1999b: 107.

The survey provides detailed information on the development of the stock of HRSTE indicating the number of students graduating each year in the different categories described above. In addition, the data on the students enrolled in the different categories every year enables us to predict what the HRSTE stock will be in future.

The data are classified according to the ISCED classification with the following breakdowns:

Higher non-university education; ISCED category 5

- Students enrolled in centres of higher education analysed according to:
 - Type and field of study.
 - Autonomous Community and province.
 - Character of the centre: public/private.
 - Gender.
- Students who finished their studies the year before the survey, and categorised in the same way as enrolled students.
 - There are also annual series available concerning these two categories which show enrolment and graduation trends since 1986 broken down by field of study.

University education, first stage, 1st and 2nd cycle; ISCED-76 category 6

- Students enrolled at Spanish universities analysed according to:
 - University.
 - Field of study.
 - Gender.
- Students who finished their studies the previous year and categorised according to the same variables as enrolled students.
 - Similarly, there are also annual series available concerning these two categories which reflect enrolment and graduation trends since 1986 broken down by field of study.

University education, second stage, 3rd cycle; ISCED-76 category 7

- Students enrolled in doctoral programmes at Spanish universities broken down by:
 - University.
 - Field of study.
 - Gender.
- Doctoral thesis approved during the last year and categorised in the same way as enrolled students.
 - Information on annual series for graduate students and approved thesis broken down by field of study from 1986/87 is also available.

One of the first conclusions to be highlighted at this stage is that this source of data will permit us to differentiate, when analysing the HRSTE stock, between the three coverage levels (Core Coverage, Extended Coverage and Complete Coverage (see Table 1). These were established by the Canberra Manual (1994; 25) for data collection by field of study and level of education.

In addition to the distinction between the Core and the Extended Coverage, the information provided by the Education Statistics facilitates a detailed study of a crucial subgroup within the HRST: the PhD

holders. The Canberra Manual states that the proposal to create a third category, PhD level HRST, was in fact only abandoned on practical grounds (OECD 1994; 12). In our opinion this subgroup should be analysed whenever possible and its labour market be taken into consideration for policy purposes. The availability of Spanish data concerning postgraduates allows us to be more optimistic about overcoming the practical problems.

The source contains the following information concerning doctoral studies:

- Stock of doctors and dynamic trends since 1986 broken down by field of study.
- Number of doctoral dissertations read during the year, classified by field of study, universities and gender of the reader.
- Number of PhD students broken down by university and gender.

As a consequence, the following indicators concerning PhD Spanish holders could be made up as follows:

- Stock of doctors as a proportion of all the HRSTE.
- Stock of doctors as a proportion of the Core HRSTE; broken down by fields of study.
- Number of doctoral dissertations read in the year as a proportion of enrolled PhD students. This indicator would give an idea of the efficiency of Spanish universities when generating highly qualified HRST.

The survey also provides information about teachers, which corresponds to HRSTO. There are for example annual series for the number of teachers, broken down by fields of study. Nevertheless, it should be borne in mind that the useful information from this source refers mainly to education (HRSTE) and not occupation (HRSTO). As can be gathered from the above, this statistical source provides information not only about the HRSTE stock but also about its flows, as it contains annual series over a period of years. In conclusion, this source of data provides useful information about PhD holders in Spain and about the dynamic generation of new HRSTE every year. This information is crucial for education policy design.

University statistics (University Council, 1995)

- Institution responsible for the data: University Council General Secretary.
- Date of first and last data set: 1989/1990 and 1993/1994.
- Publication frequency: annual.
- Sample: Exhaustive.

The information contained in this annual publication is also related to HRST covered in terms of education (HRSTE); it provides an exhaustive survey of university statistics.

Although it is a primary source, the information is very similar to that contained in the Statistics of Higher Education described earlier. Thus, this section only analyses the difference between both sources, rather than making a review similar to the one contained in the preceding paragraphs.

The Annual Report on University Statistics naturally contains no data on non-University Higher Education and so excludes students enrolled and graduates in ISCED level 5. As a consequence the information in this Annual Report only covers Core Coverage in terms of education. The data concerning students at ISCED level 6, which includes university students of 1st and 2nd cycle, is provided in more detail than those contained in the Higher Education Statistics provided by the INE. All analysis of the information presented

for the latter is also presented in the Annual Report. In addition it also breaks down data concerning enrolled students and graduates according to the following categories:

- Age.
- Duration of studies (1st or 2nd cycle).

Concerning the enrolled students there are three breakdown categories that provide certain information on mobility:

- Nationality: Distinction between Spanish students and foreign students.
- Province of the family residence.
- Province of the university of enrolment.

Other distinctions make it possible to determine the social origin of the students:

- Educational level of the student's father.
- Occupation of the student's father.
- Occupation of the student's mother.

The three latter categories concern social rather than regional mobility. This could be an interesting point, since certain analysis could be made to see whether children of the no HRST population become part of the HRST population. Similarly, the likely hypothesis that children of the HRST population also tend to be part of such a population at least in respect to the educational level could be verified.

The Annual Report also goes further than the INE report in the analysis on graduates, providing information about their labour market situation as follows:

- Graduates in the active population during the year before the survey, broken down according to duration of studies, gender and age.
- Graduates in the active unemployed population the year before the survey, broken down according to duration of the studies, gender and age.

The above-mentioned differences between the two sources (INE and University Council) refer only to students and graduates at ISCED-76 level 6, while data concerning postgraduate studies (ISCED-76 level 7) are basically the same in both sources.

Finally the Annual Report also gives more detailed information on R&D personnel at universities broken down into fields of study. The 1994 Report provides information on this stock since 1985, indicating the percentage of women and scholarships in the total stock. This is clearly related to HRSTO (employed in an S&T occupation) and it is the only information concerning HRSTO contained in the document.

As a conclusion Table 4 summarises the advantages and shortcomings of the last two analysed sources in order to build a profile of Spanish HRSTE:

Table 4. Advantages and shortcomings of education statistics sources

	Advantages	Shortcomings
Source: INE	Earlier availability. Last data = 1995/96 Data about all HRSTE, including ISCED level 5	Less detail concerning ISCED level 6.
Source: University Council	More detailed information concerning ISCED level 6. Data on: Age / Nationality / Social Origin / Regional Mobility / Labour market situation.	Data for years 94/95 and 95/96 are not yet available. No information on ISCED level 5.

Source: Authors.

R&D Statistics

National level (INE, 1998-b.)

- Institution responsible for the data: National Institute of Statistics (INE).
- Date of first and last data set: 1973/1996.
- Publication frequency: annual.
- Sample: approximately 5 000 statistical units: 4 000 companies; 500 governmental institutions; 45 universities; 200 private non-profit institutions.

This source provides HRST information covered in terms of occupation (HRSTO). One of the objectives of the survey is to record the number of working hours devoted to Research and Development activities in Spain. The methodology used follows the OECD Frascati Manual and takes the Full Time Equivalence (FTE) approach to prepare the data. This leads to difficulties when comparing these data to those extracted from other sources. The R&D statistics provide the only analysed Spanish source using this approach.

The R&D personnel (FTE) information is broken down into occupation according to the three following categories: researchers; technicians and other support staff.

The following breakdowns are also provided concerning R&D personnel:

- Sectors: Business Enterprise, Government, and Higher Education Institutions.
- Occupation according to the classification mentioned above: researchers, technicians and other support staff.
- For the Business Enterprise Sector, there is also a breakdown of economic activity, which is in accordance with the National Classification of Economic Activities (CNAE), the Spanish equivalent of the International Standard Industrial Classification.
- For the Governmental Sector the survey provides a breakdown of the field of study.

Although it is not specifically stated in the document, it is very likely that those in the researchers' category have an education level equivalent to ISCED categories 6 and 7. As a result, findings contained in the survey provide information on the total number of people with 6 and 7 education levels who are effectively working as researchers in companies, research institutions and governmental agencies.

The problem, once again, is that data are provided in FTE. This Full Time Equivalence has to be calculated by taking into consideration first the total number of people related to research independently of the number of hours each one devotes to such activity. Therefore, the problem would be solved by asking for a head count of researchers, technicians and other support staff.

Once the head count data is available, the statistics could be crossed with the data from other sources to obtain indicators such as:

- Researchers working in companies as a proportion of all HRSTE with ISCED 6 and 7 education levels.
- Researchers working at universities as a proportion of all HRSTE with ISCED 6 and 7 education levels.
- Researchers working for the Government as a proportion of all HRSTE with ISCED 6 and 7 education levels.

Nevertheless, the survey would be much more useful if it indicated the education level of the employees. We must insist that it has been assumed that researchers have 6 and 7 education levels but that this information is not stated in the document. Were the information about the educational level of R&D support staff available, we would know, for example, the number of people who are not HRSTE but who have an S&T occupation and where they work.

It is interesting to recall that the Active Population Survey also gives information about HRSTO who are not HRSTE but does not specify the sector (company, university, Government). Once such problems are solved, the information concerning HRST from this source would be useful in analysing a large part of the Spanish HRST labour market, that of people actually working on S&T activities.

Regional level sources

Basque Country (EUSTAT, 1997)

- Institution responsible for the data: EUSTAT (Basque Country Institute of Statistics).
- Date of first and last data set: 1990/1995.
- Publication frequency: annual.
- Sample: No information available.

This source provides HRST information covered in terms of occupation (HRSTO). The information contained in the document concerns the same subjects as those dealt with in the previous section. The difference lies in the geographical scope of the analysis. The present source provides R&D statistics, which concern only the Basque Country, an Autonomous Community in northern Spain.

The reason this document is interesting is that its HRST data are more precise than those contained in the national R&D Survey. The presentation of the information follows the same schema. There are different tables devoted to R&D personnel, which are classified as before into three categories: researchers, technicians and other support staff. The sector classification is also the same.

However, it is important to stress that all data concerning personnel are presented both in Full Time Equivalence and in Head Counts. The breakdowns provided by the tables concerning R&D personnel are as follows. The words in bold correspond to the categories which are not available in the national survey.

Business enterprise sector

R&D personnel broken down into:

- Economic activity (i.e. very precise information), broken down according to occupation (researcher, technician) and gender.
- Field of study (Natural sciences; Engineering and technology; Health sciences; Agricultural sciences, Social sciences and Humanities) and occupation.
- Size of the company, by occupation and gender.
- Total “in-house” R&D expenditure broken down into the total number employed in R&D and by the nature of expenditure (researchers’ salaries, other personnel’s salaries).
- Total “in-house” R&D expenditure broken down into the total number of researchers and by the nature of the expenditures.

The information concerning companies also provides the following annual series:

- Number of companies broken down according to the number of R&D personnel from 1989 to 1995 (only available in FTE).
- Number of companies broken down according to the number of researchers employed from 1989 to 1995 (only available in FTE).
- R&D personnel broken down by sector of economic activity from 1993 to 1995 (available in FTE and Head Count).
- R&D personnel broken down by occupation from 1989 to 1995 (FTE and Head Count).

Governmental institutions

R&D personnel broken down into:

- Field of study (same classification as for companies), occupation and gender.
- Full or part time occupation, broken down by field of study, occupation and gender.
- Education level: Doctor, graduate, engineer, high school level, others; broken down by field of study.

Higher Education Sector

R&D personnel broken down by:

- Field of study, occupation and gender.
- R&D expenditure, broken down according to type.

As a consequence the breakdowns described allow for a much more detailed analysis than the national survey and could prove most useful if used at a national level as well.

Madrid (Comunidad de Madrid, 1998)

- Institution responsible for the data: Madrid Autonomous Community Government.

- Date of first and last data set: A monograph produced in 1998.
- Sample: Exhaustive.

It is important to mention this survey because it is the only recent study we have found that contains a special analysis on Human Resources in Science and Technology. Its second chapter is devoted to HRST in the Madrid Autonomous Community, analysing the human resources employed in Madrid Universities, and Research Institutions. For each institution the document presents the proportion of doctors, graduates, scholars, and “others” employed. There is also a breakdown of human resources by field of study, university and education level. The analysis is not very detailed, but it represents a first step towards the study of HRST as being of public interest.

Other sources

Annual Summary of the Occupation Observatory. Labour Market Information (Resumen Anual de los Datos del Observatorio Ocupacional. Información sobre el mercado de trabajo) (INEM, 1996).

- Institution responsible for the data: INEM (National Institute of Employment).
- Date of first and last data: Unknown/1995.
- Publication frequency: annual.
- Sample: Exhaustive.

This source covers a subgroup of HRST made up of people who register themselves at the INEM (National Employment Office) as unemployed. In Spain, anyone receiving an unemployment subsidy has to be registered at this office. Registration is also useful for those not receiving a subsidy since INEM is an intermediary between labour supply and demand. It also provides training courses for re-skilling and specialisation for the unemployed.

One of the main objectives of the publication is to show how these training courses help the unemployed to obtain a new job. With regard to HRST, the information that this source provides is, firstly, unemployed educated at the third level as a proportion of all those registered throughout the year, broken down by age and gender. In 1995 this proportion was 8%, which was the smallest category registered at the INEM.

The publication also contains information on the new contracts for people registered during the year, broken down into “professional families”. Only two of these categories require an education level above ISCED level 5, which are Teaching and Research and Health related occupations. Nevertheless the Teaching and Research category takes in only a few occupations, and some of these which are not related to HRST such as driving instructors. As mentioned, most of the information from this source is related to the results of the training courses. It should be noted however that most courses correspond to a low skill level.

In summary, this source is only useful to measure the HRSTE who are registered at the INEM as a proportion of all unemployed HRSTE. It is very likely this proportion is very small. The rest of the INEM information concerning unemployed HRST will not be very relevant for our purposes.

Analysis of the University Graduate Women Labour Market (Estudio sobre la Inserción laboral de las tituladas universitarias en el mercado de trabajo) (INEM, 1993).

- Institution responsible for the data: INEM (National Institute of Employment).
- Date of first and last data set: A monograph made in 1993.

- Sample: 2 100 women in 14 different provinces.

This publication presents the results of a survey made to a sample of women who graduated in humanities from different Spanish universities in the period 1988-91. The most useful information concerns the proportion of employed and unemployed woman and their contribution to the university teaching staff.

However, this source is of little interest when analysing Spanish HRST as it concerns only humanities, which do not belong to the core HRST and is a relatively small sample. Nevertheless it would be interesting to see the proportion of these 2 100 women graduates on the total new HRSTE women for the surveyed year.

Differences between S&T stocks and flows: the problems of assessing mobility

According to the Canberra Manual two types of HRST mobility may be analysed: the external mobility, which takes in the inflows and outflows of the HRST stock, and the internal mobility, which reflects changes within the stock.

All the sources described in the previous section focus mainly on information on stocks. However as we have mentioned at different points, some information about mobility can also be obtained. Apart from this there are other sources that, without giving much information on the characteristics of the persons involved, provide specific information on mobility, for example as to the scholarships granted from different institutions or the Governmental international agreements that support mobility.

The mobility programmes could be structured into two groups:

- Mobility to and from foreign countries.
- Mobility within Spain.

In relation to the first group, scholarships are provided mainly by the Ministry of Education and Culture, some Autonomous Community Governments and some private institutions. Information concerning the participants in these mobility programmes is not easily available. We have only obtained some statistics from the Ministry of Education, which provide information on the following issues, for years 1994-1998:

- Spanish researchers abroad.
- Foreign researchers in Spain.
- Spanish professors abroad.
- Incoming researcher contracts: this data concern researchers who received a scholarship for research abroad and are engaged by a research institution on return.
- Short stays and congresses attended by Spanish researchers.
- Sabbaticals abroad.

This information is broken down by province, gender and age (over or under 25). Other important details for the analysis such as field of study, duration, country of origin or destination, are not included in the information provided which does not mean that it does not exist. These additional aspects are probably known by the Ministry and may be used for policy purposes.

Additional details about migration abroad can be found at the Ministry of Foreign Affairs. The Government has signed agreements for scientific and technological co-operation with several countries, which encourage the flows of researchers. Every agreement names a Joint Commission to supervise and

follow up on the results. Although unpublished, these Joint Commissions may have data about the actual movements.

Another governmental initiative to promote mobility is led by the R&D National Plan: in the goal of the programmes is internal mobility. There is a specific measure to foster hiring of PhDs by companies (*Acción IDE*) and another one to encourage young researchers to carry out their research in companies and technological centres (*Acción MIT- Becas*). The information concerning the participants is not published, and therefore not easily available.

The different mobility categories could be structured in the way shown in Table 5. The left-hand side of the table defines the categories and the right-hand side indicates the sources where information about them may be found.

Table 5. Available information sources for the study of HRST mobility

MOBILITY CATEGORIES	INFORMATION SOURCES
HRST EXTERNAL FLOWS:	
HRST inflows¹⁴	
a) Persons qualifying at ISCED level 5 or above for the first time.	a) Higher education statistics (INE).
b) Persons without a qualification at ISCED level 5 or above being employed in an S&T occupation.	b) Not much information available. The INEM registers only some of them.
c) Qualified immigrants.	c) Census and Social-demographic survey for the general population; University Council for students.
HRST outflows	
d) Persons without a qualification at ISCED level 5 or above leaving their S&T occupation.	d) EPA and Social-demographic survey.
e) Emigrants.	e) Ministries of Education and Foreign Affairs for temporary movements.
f) Deaths.	f) Not available.
HRST INTERNAL FLOWS	
g) Persons with a qualification at ISCED level 5 or above leaving their S&T occupation (going unemployed or inactive).	g) EPA.
h) Persons with a qualification at ISCED level 5 or above, unemployed or inactive, finding an S&T occupation	h) Very little information at the INEM and Ministry of Education and Culture (incoming researchers' contracts.
i) Persons with a qualification at ISCED level 5 or above, changing their occupation	i) Available for 1991: Social-demographic survey.
j) Persons without a qualification at ISCED level 5 or above, moving from one S&T occupation to another.	j) Available for 1991: Social-demographic survey.
k) Persons with an S&T occupation who increase their qualification level.	k) Social-demographic survey and EPA.
l) Persons within the HRST stock that move from one region to another.	l) Some information in Education Statistics and in Social-demographic statistics for 1991.
INTERNAL/EXTERNAL FLOWS¹⁵	
m) HRST persons moving temporarily to another country.	m) Ministry of Education and Culture and Ministry of Foreign Affairs.

Source: Authors.

14. OECD (1995; 9).

15. The international temporary mobility could be considered both an external and an internal movement. If considered external the immigrant/emigrant notion could be extended to include not only those people who change their residence but also those who move for a few months (training courses, exchange programmes, etc.). On the contrary if considered internal the underlined hypothesis would be that maintaining their own residence keeps them within the national stock of HRST.

Several general conclusions can be drawn from the available information on mobility. First, the information is rather dispersed. Different institutions and programmes are involved, each one with different procedures. Second, the information is not published. The institutions do not prepare it for distribution and it has to be obtained on request. It is heterogeneous as the different programmes provide different data and for some of the sources on flows the data needed to compare them with those of the stocks do not exist. Third, the information does not seem to be used in a coherent manner for policy purposes. Nevertheless the mere existence of mobility programmes suggests that there is a political concern about mobility, particularly when it affects the mobility of highly educated people. Most of the programmes are targeted for graduates and PhDs.

It is worth mentioning that geographical mobility in Spain has little social support. The attachment to the place of origin is high and students prefer, in general terms, to study in the area where their family lives, and workers seldom move during their working lives. This situation is not desirable for a global competitive economy where jobs appear in some activities and regions and disappear in others. Therefore, mobility is an important political issue at the moment and new programmes and activities are likely to be launched in the near future. In our opinion, these activities should be launched in parallel with the corresponding evaluation designs. This implies defining a certain degree of homogeneity in the data to be gathered, and taking stock of all the information related to those programmes in a particular place, to facilitate analysis and feedback into policies. It could also be useful to gather the information corresponding to private institutions, to allow public policy to act on a subsidiary or complementary basis.

Usefulness of existing data to build indicators

The OECD document entitled *Basic Indicators for describing the stock of Human Resources in Science and Technology* (OECD, 1995) suggested a list of ten main HRST stock indicators. One of the objectives of this section is to develop a set of the different suggested indicators on the basis of the information provided in the description of the data sources. The following list provides this information, including comments on the cases when data do not permit us to create the proposed indicator but provide enough information to produce a similar one.

Basic Indicators for describing the stock of HRST which can be drawn from:

a) The EPA

Using the published results of the EPA, and the unpublished raw data on ISCO-88 groups 122, 123 and 131, the basic indicators concerning the stock of HRST employed in an S&T occupation which can be calculated are the following:

- *Main indicator 3:* HRST with an S&T occupation as a proportion of the employed; analysed at level of education, occupation, age group, and gender.
- *Main indicator 4:* Core of the HRST stock (equal to people with third level education and employed in an S&T occupation) as a proportion of all employed; broken down by type of third level education. The rest of the breakdowns suggested for this indicator (field of study, occupation and age group and gender) are not directly available. However, considering that respondents surveyed are asked about all these issues, an ad-hoc analysis of the questionnaire would allow us to build the indicator.
- *Main indicator 6:* HRST employed in an S&T occupation without third level education as a proportion of all employed. Producing the suggested breakdowns presents the same difficulties as Main indicator 4.

- Related to *Main indicator 9*: HRSTO potential (unemployed or inactive) as a proportion of all third level HRST. The proportion suggested may not be easily obtained; however the EPA enables us to calculate the HRSTO potential as a proportion of all HRSTO, that is people who had an S&T occupation in the past as a proportion of people who have an S&T occupation at present. A useful breakdown would be to distinguish between unemployed S&T and inactive S&T.

b) The Census

- *Main indicator 1*: The HRST total stock as a proportion of the population aged 18 years or above; broken down by level of education, age group and gender.
- *Main indicator 2*: The HRST educated at the third level as a proportion of the population aged 18 years or above; broken down by level of education, age group and gender.
- *Main indicator 3*: HRST with an S&T occupation as a proportion of the employed; analysed at level of education, occupation, age group, and gender.
- *Main indicator 4*: Core of the HRST stock (equal to people with third level education and employed in an S&T occupation) as a proportion of all employed; broken down by type of third level education, field of study, age and gender.
- *Main indicator 7*: Unemployed HRST (with third level education) as a proportion of all level educated HRST; broken down by type of third level of education, age group and gender. The Census information does not permit analysis of data regarding the field of study, as suggested in the definition of this indicator by the Canberra Manual.
- *Main indicator 8*: Inactive HRST (with third level of education) as a proportion of all level educated HRST broken down into type of third level of education, age group and gender. As mentioned above the analysis attending the field of study is not possible.
- *Main indicator 9*: HRST potential (unemployed or inactive HRST) as a proportion of all level educated HRST; analysed by type of third level of education, age group and gender. Again, the breakdown by field of study is not possible.

c) The social-demographic survey

All indicators suggested in the OECD document may be calculated, given the large quantity of data provided by this source.

d) INE statistics on higher education

- *Main indicator 2*: The HRST educated at the third level as a proportion of the population aged 18 years or over; broken down by level of education, field of study, age group and gender. This source does not enable us to calculate all the proportions proposed in the OECD document (OECD, 1995; 29-30) as it contains no information about the entire Spanish graduate population. Nevertheless, some figures related to this main indicator could be very interesting. Here are some examples:

Example 1: HRST who obtained a first cycle or 2nd degree in 1994

Graduates having completed 3rd level education in 1994

= New HRSTE at ISCED level 6 1994

New HRSTE 1994

Example 2: New HRSTE in Natural Sciences in 1994

- Related to *Main indicator 9*: A new basic indicator could be worked. This indicator may be called HRST future potential. The number of students attending third level education, as a proportion of the population aged 18 or more (Population Census), for example, would give an idea of the HRST who would be available in the future.

e) University Council Annual Report

- Related to *Main Indicator 2*: The comment made in relation to this indicator in paragraph c) above could be reproduced here. The examples concerning possible new indicators could be similar in this case.
- Related to *Main Indicator 9* (HRST potential): This source would permit us to make a more dynamic analysis than the analysis allowed by the suggested indicator in OECD (1995). Two interesting indicators to build would be:
 - New active population educated at ISCED levels 6 and 7 in year X, as a proportion of all university graduates in year X.
This indicator would show the proportion of new graduates who enter the labour market immediately after graduation.
 - New unemployed population graduated at ISCED level 6 and 7 in year X, as a proportion of new active graduates at the same levels and in the same year. This proportion would inform us of the difficulties new graduates encounter in finding employment.

f) INE R&D Statistics

The survey does not permit us to calculate the indicators suggested by the OECD document for several reasons. First of all, the categories of HRSTO defined in the publication (researchers, technicians and support staff) do not follow the occupation classification used by the rest of the sources. However, it is easy to deduce that everybody included in the survey as R&D personnel is HRSTO.

Two additional problems when working with this data source have been mentioned before: the data follow the FTE criteria and they provide no information about the educational level of R&D personnel.

Should these two problems be solved (i.e. by adding two questions to the questionnaire) the following indicators could be calculated, related to the subgroup of HRSTO defined as R&D personnel.

- Related to *Main indicator 3*: R&D personnel as a proportion of all employed (source: EPA), broken down by level of education, type of occupation (researcher, technician or support) and place of employment (company, university or Governmental institution).

- Related to *Main indicator 4*: Core of the HRST stock (ISCED level 6 and 7 of education included in R&D personnel) as a proportion of all employed (source: EPA) broken down into level of education, type of occupation and place of employment.
- Related to *Main indicator 6*: HRST employed in an S&T occupation without third level education as a proportion of all employed (source: EPA) broken down into type of occupation and place of employment.

g) EUSTAT R&D statistics

The comments above are also valid for the present source. However, it is important to insist on the fact that one of the problems faced when working and comparing the R&D data from the INE is solved in this case, and that is that data are presented both following the Full Time Equivalence and the Head Count criteria. In addition, many more indicators could be produced, for example:

- Salaries of researchers as a proportion of all the R&D expenditures by companies.
- The number of companies employing more than X researchers as a proportion of the companies with more than Y employees.
- The number of doctors working in governmental institutions as a proportion of all R&D employees in this sector.
- The number of woman employed as researchers in companies as a proportion of all women researchers employed in the whole economy.

As the reader might conclude, the statistical exploitation that could be made using the data from this source is very wide and would provide in-depth knowledge of the HRSTO in the Basque Country. This methodology might also be applied at national or other regional level.

Table 6. Sources of statistical information available to build main HRST indicators

Main Indicators	Sources of data
1: HRST stock proportion	Census EPA
2: HRSTE stock proportion	Social-demographic survey Census Social-demographic survey INE statistics of education University Council
3: HRSTO stock proportion	EPA Census Social-demographic survey INE R&D statistics with the suggested changes + EPA (some problems may also appear when crossing the data).
4: Core of the HRST stock	EUSTAT R&D statistics + EPA: regional indicator. EPA Social-demographic survey INE R&D statistics: reliable source only after adding to the questionnaires questions concerning the level of education of the employees
5: HRSTE employed in a non S&T occupation	Social-demographic survey
6: HRSTO who are not HRSTE	EPA Social-demographic survey INE R&D statistics (after changes: education and head count) + EPA
7: Unemployed HRSTE	Census Social-demographic survey
8: Inactive HRSTE	Census Social-demographic survey
9: HRST potential	Census Social-demographic survey EPA: with some changes INE education statistics University Council
10: HRST reserve	Social-demographic survey

Source: Authors.

Some interesting conclusions are as follows:

- All the indicators can be produced. However, some of them may not be updated because data are obsolete.
- Apart from the indicators suggested by the OECD document others may be calculated on the basis of the information provided by the sources.
- EPA, Census and Social-demographic survey appear as three very useful instruments to provide statistical information about HRST.
- INE R&D statistics could also be a good instrument once minor changes are incorporated.
- According to the table, education statistics do not seem to provide much information. However, their utility lies in the information that they store about flows and future HRST potential.

Policy conclusions

Bearing in mind that the above discussion is related to methodological issues of the existing Spanish data set, the policy conclusions can only refer to generic and methodological policies. The main characteristic of the current situation is probably lack of awareness. There is no coherent set of data about HRST which would inspire education and labour market policies, or scientific and technological policies. The efforts OECD makes to integrate data so as to give a coherent perspective are not followed up at national level. It would not be wise to undertake the gathering of specific data on HRST. On the contrary our conclusions suggest a better and more effective use of existing ones. The specific suggestions are as follows:

1. Data should be gathered and considered as a whole and not in a dispersed manner as at present. For that purpose an administrative unit could be created, for example, at the National Institute of Statistics (INE) to take into stock the data from all the already existing sources and produce a coherent analysis of all of them. Duplications and shortages will then appear and solutions could be implemented.
2. Studies about the functioning of HRST labour markets are sorely needed. The variables affecting supply and demand of those human resources are almost unknown. If not grounded in true and reliable information the best designed policy can fail.
3. Although the extended and complete coverage in terms of field of studies could be made, our suggestion is to concentrate efforts in the key areas. These are in our opinion: Natural sciences, Engineering and technology, Medical sciences, Agricultural sciences, and Social sciences for educational levels 6 and 7, and Natural sciences and Engineering and technology for level 5. Particular analysis should also be made of PhDs (part of level 7) in all the mentioned fields.
4. To change supply and demand trends in education is a long term and inflexible process. Public efforts to modify those trends and to match supply and demand both in education and labour markets should therefore be well thought out. This means that all actions or programmes undertaken should be accompanied by their own evaluation procedure. The design of any programme should be made together with the evaluation design, so as to continuously feed back into the process.
5. Particular policies to encourage mobility should continue. However, a previous analysis of the results of existing programmes both at public and private level should be made. Again all new action should encompass a permanent evaluation process.
6. In relation to the existing data sources, all questionnaires should be revised for the next survey to be made. As we have explained in the paper, only minor modifications could enormously improve the analytical capacity of the data. In some cases a few additional questions could be included.

ANNEX. MAIN SUGGESTED INDICATORS

1. The total HRST stock as a proportion of the population aged 18 years or above; broken down by level or education, age, group and gender.
2. The HRST educated at the third level as a proportion of the population aged 18 years or above, broken down by type of third level of education, field of study, age group and gender.
3. HRST with S&T occupation as a proportion of the employed; broken down by level of education occupation, age group and gender.
4. Core of the HRST stock (third level education and employed in an S&T occupation) as a proportion of all employed; broken down by type of third level of education, field of study, occupation, age group and gender.
5. HRST (with third level education) employed in a non-S&T occupation as a proportion of all employed broken down by type of third level of education, field of study, age group and gender.
6. HRST employed in an S&T occupation without third level education as a proportion of all employed broken down by occupation, age group and gender.
7. Unemployed HRST (with third level education) as a proportion of all level educated HRST; broken down by type of education, field of study, age group and gender.
8. Inactive HRST (with third level education) as a proportion of all third level educated HRST: broken down by type of third level of education, field of study, age group and gender.
9. HRST potential (unemployed or inactive HRST) as a proportion of all third level educated HRST; broken down by type of third level of education, field of study, age group and gender.
10. HRST reserve (= unemployed, inactive or HRST employed in a non S&T occupation) as a proportion of all third level educated HRST; broken down by type of third level of education, field of study, age group and gender.

REFERENCES

COMUNIDAD DE MADRID (1998)

Investigación y Desarrollo en la Comunidad de Madrid: Tres estudios sobre los recursos, producción y distribución de la actividad científica madrileña. Consejería de Educación y Cultura. Madrid.

CONSEJO DE UNIVERSIDADES (1995)

Anuario de Estadística Universitaria 1993/1994. Ministerio de Educación y Cultura. Madrid.

EUSTAT (1997)

Estadística sobre actividades en investigación y científica y desarrollo tecnológico (I+D) 1995. Bilbao.

INE (1991)

Encuesta de Población Activa. Descripción de la encuesta, definiciones e instrucciones para la cumplimentación del cuestionario. Madrid.

INE (1993)

Encuesta Sociodemográfica 1991, Metodología. Madrid.

INE (1994-a.)

Clasificación Nacional de Ocupaciones 1994 (CNO-94). Madrid.

INE (1994-b.)

Encuesta Sociodemográfica 1991. Tomo I: Principales Resultados (Informe básico). Tomo II: Resultados Nacionales. Madrid.

INE (1994-c.)

Metodología, Censos de Población y Viviendas 1991. Madrid.

INE (1996)

Censo de Población de 1991. Tomo I: Resultados Nacionales. Características Generales de la Población. Madrid.

INE (1998-a.)

Encuesta de Población Activa. Resultados Detallados, Tercer Trimestre 1998. Madrid.

INE (1998-b.)

Estadística sobre las Actividades de Investigación y Desarrollo (I+D). Indicadores Básicos 1996. Madrid.

INE (1998-c.)

Estadística de la Enseñanza Superior en España. Series de todos los niveles, Curso 1995-96. Madrid.

INE (1998-d.)

Anteproyecto de los Censos Demográficos del 2001. Documento de Trabajo. Madrid.

INEM (1993)

Estudio sobre la inserción laboral de las tituladas universitarias en el mercado de trabajo. Situación actual y nuevas posibilidades de recualificación y empleo en las titulaciones de filología, historia, geografía, pedagogía, psicología y profesorado de EGB. Observatorio Ocupacional. Madrid.

INEM (1996)

Información sobre Mercado de Trabajo. Resumen anual de datos del Observatorio Ocupacional 1995. Madrid.

OECD (1995)

Manual on the Measurement of Human Resources devoted to S&T “Canberra Manual”.

OECD (1999a)

Background Report on Science and Technology Labour Markets in this report.

OECD (1999b)

Classifying Educational Programmes. Manual for ISCED-97 Implementation in OECD Countries, Paris.

MOBILITY OF SCIENCE AND TECHNOLOGY PERSONNEL

A. THE CAREER TRAJECTORIES OF KNOWLEDGE WORKERS

by

Mark Tomlinson, *Centre for Research on Innovation & Competition (CRIC), University of Manchester*
and Ian Miles, *PREST and CRIC, University of Manchester*

Introduction

The diffusion of knowledge throughout the learning economy is of crucial relevance to economic prosperity and growth. But, as this paper attempts to show, the promotion of flexible labour market policy has to be treated with some caution. Even though it appears that one major way of diffusing knowledge throughout the economy is to promote labour mobility between firms, empirical evidence concerning the actual functioning of this labour flow is hard to come by. In this paper we utilise some recent data and arrive at some unexpected results.

We begin by analysing some of the attributes of knowledge workers (including S&T workers). Then it is demonstrated that external mobility (the mobility of workers between firms) can have some negative consequences. Internal mobility (the mobility of workers within firms) has some significant benefits, which must be considered by policy makers.

In terms of innovation (and hence economic growth) the proportion of scientists and engineers within firms is a significant factor – this result might lend some support to the notion of external mobility. However, we argue that the promotion of networks and collaborations of firms and other research institutions should not be pushed aside. The diffusion of knowledge and learning can be promoted by employees of different firms and organisations working together rather than shifting jobs. Knowledge intensive business services (KIBS) can have a vital role to play in facilitating knowledge transfers as an alternative to external mobility. We analyse firm level data that show the benefits of such collaborations and also refer to earlier work, which revealed the impact of KIBS at macro level.

S&T workers in the context of the learning economy

Following Lundvall's work on knowledge and learning economies, an earlier paper (Tomlinson 1999a) identified 'knowledge workers' (KWs) as comprising Standard Occupational Classification (SOC) groups 1-3¹⁶ (which include S&T workers along with managers and other professionals). The paper showed that, if the movement of these workers was traced over time, there had been a significant shift of knowledge workers **into** services from other sectors, but very little the other way round. Furthermore, very little movement from non-technical occupations to technical occupations was observable during the 1980s. It was postulated that this is because there are significant barriers for workers outside this group to enter into technical occupations. This makes the dynamics of this group of particular importance in the study of labour markets.

16. A detailed description of the SOC is found in the Annex.

The knowledge “embodied in” these workers (to use the standard, if misleading, terminology) is particularly specialised. Its diffusion throughout the economy is therefore of particular importance. It is important to recognise that these workers do not only apply their knowledge through being employees of the firms that are using it to produce and distribute their wares. Increasing numbers of such KWs are active in the specialised service firms; knowledge intensive business services (KIBS). KIBS play an important role in the learning economy, not least in terms of fostering innovative behaviour.¹⁷ And non-manufacturing sectors in general have seen the highest levels of growth in S&T workers in the 1980s (OECD 1998), partly as a result of the growth of these services (though also in part in consequence of the explosion of IT use in financial and other services, and the associated need for software, network, and other professionals within these services). This paper seeks to disentangle the importance of knowledge diffusion through two channels: firstly the mobility of labour (including especially KWs) and secondly through the development of networks of collaborators (including the facilitation of production by KIBS).

Data used

There are two main sources of data used in the analyses of this paper. These are the UK Community Innovation Survey 2 (CIS2) firm level dataset (1998) and the *Employment in Britain* (EIB) dataset of employees (1992).

The CIS2 data is a random sample of around 2 400 firms taken in the United Kingdom in 1998. The data has several items dealing with innovation, collaboration, R&D and other research activities and some information about firm level human resource practices. The dataset has comparable information for both manufacturing and service firms and has been weighted to represent the UK population (by firm size and sector).

The *Employment in Britain* data set was collected in 1992. The data were generated from a random sample of employed and self-employed people aged between 20 and 60. Detailed information was collected from 3 855 respondents, about their current occupation and attitudes to work. One significant aspect of this dataset is that detailed and complete career history data were also collected. This means that, for example, we can trace what a person was doing when they left education and follow them through to 1992. Thus, we can trace the shifts of skilled or knowledge based workers between firms or explore job shifts within an organisation at the employee level. The dataset also features several sections dealing with the nature of work and employment conditions in 1992 and how these were changing. [A detailed sociological analysis of these data can be found in Gallie *et al.* (1998)].

Breaking down some of the variables in the EIB data by occupational groups (Table 1) we find some differences between different types of knowledge workers. For example, more technical workers have used computers and had training than other groups, as we might expect. But, on the other hand, flexible working seems to predominate in managerial and other professional occupations as do skill increases and the increased provision of training. Technical staff appear to be more likely to have had training in the last 3 years and slightly more likely to think they will receive training in the future. But flexible working seems to predominate in managerial and other professional occupations, as do skill increases and an increased provision of training.

Perhaps the most interesting result from our point of view is that very few technical workers (17%) think that it would be very difficult to find another similar job – compared with 37% of managers and 28% of other professionals. This shows the more buoyant nature of S&T labour markets compared with other

17. One evident result of this is the prominence of these services in recent R&D data – in Britain, for example, the “R&D services” branch is responsible for some 10% of all BERD.

KWs, and reflects the high demand for this type of employee. Average tenure times also seem significantly lower for S&T workers than for all other categories (Table 2).

Table 1. Some characteristics of knowledge workers (%)

	Managers	Technical	Other profs.
Use microcomputers	68	78	65
Ever had training	64	85	79
Can work independently (v. true)	55	53	52
Often move between diff. types of work	34	26	27
Expected to be more flexible (v. true)	45	31	42
Keep learning new things (agree strongly)	30	40	48
Use past experience almost all the time	48	52	59
Skill increase last 5 years	73	65	74
Variety of tasks increased last 5 years	70	75	72
Provision of training increased 5 years	46	35	47
Had training last 3 years	55	77	69
Very likely to get training in future	41	42	39
If left job very difficult to get another job	37	17	28

Source: Authors.

Table 2. Average times in current job by occupational group

Group	Average time in current job (months)
Manager	49.9
Tech professional	37.5
Other professional	53.2
Administrative	41.9
Craft/Skilled	72.0
Personal service	55.1
Sales	45.2
Manual	68.5
Unskilled manual	61.5

Source: Authors.

At the firm level

At firm level it is easy to show that the proportion of the workforce that are qualified scientists and engineers, has a significant relationship impact on the introduction of radical new innovations to the market. This is the case whether we look at manufacturing or services (see Table 3). This, of course, does not simply mean that taking on QSEs makes it more likely that the company will innovate. The composition of the workforce is an outcome of strategic choices reflecting the firm's efforts to achieve competitiveness through innovation. Although this result may seem tautological, it must be borne in mind that the coefficient is still significant after controlling for the size and sector of the firm.

Table 3. Logistic regressions predicting new to the market innovations (data is UK CIS2, weighted)

	All firms	Nace 1 - 4	Nace 5 - 7
Log no. employees	0.333***	0.374***	0.284**
Percentage of S&T employees	2.215***	4.726***	1.152*
Import of reducing unit lab cost	-0.081	-0.047	-0.077
Nace Group:			
Mining/food/textiles	0.346	.642*	
Paper/fuels/chemicals/metals etc	0.183	0.383	
Electrical/transport equipt	0.841***	1.007***	
Utilities/construction	-1.962**	Base	
Whole/retail/repair/hotel	-1.005***		-1.250***
Transport/finance	0.482*		0.219
Other business/public	Base		Base
Constant	-3.044***	-3.637***	-2.594***
Chi sqr	194***	76***	117***

Source: Authors.

The diffusion of knowledge embodied in S&T workers

It is widely held that the diffusion of technical expertise as embodied in KWs is taking on a new importance in the era of the knowledge economy. Not only does having a workforce of KWs enhance firm performance, but the mobility of KWs, and particularly of S&T workers, is seen as crucial to enhancing innovation and thus economic growth throughout the rest of the economy. Thus, restrictions on labour mobility are liable to be seen as harmful to economic prosperity in the long term as they restrict the diffusion of useful knowledge. One of the reasons for the advantages of the US is the higher mobility and 'brain gain' in the S&T labour market – or so the story goes. The account is plausible enough, but our data analysis suggests we need to be cautious in assuming its general applicability at least in the United Kingdom.

On the basis of such a positive view of labour mobility, policy relevance to S&T labour markets is a key to enhancing economic gains within the OECD countries. The OECD jobs study thus highlighted the relevance of breaking down barriers between public/private sector job mobility, enhancing relevant training programmes and increasing networks and partnerships where information and knowledge can be exchanged and diffused.

However, if we take a step back, we do not know what the trade-off is between *internal* and *external* labour mobility. What are the relative benefits of the two? Is there a trade-off between tenure time and job shift? How can a firm reconcile fostering life long learning at the same time as accepting a need for some level of labour turnover?

In order to explore such issues, we can use the concepts of 'dynamic' and 'static' knowledge transfer. We will assume that, when a job shift takes place, there are liable to be the most significant advantages to the receiving firm when the knowledge transferred is **dynamic**. Dynamic knowledge transfer is connected with the individual's *learning new skills* and *developing* new competences. Our argument goes that, if a worker does not learn anything new in his/her new position then, although some tacit or embodied knowledge may be applied in the receiving firm, it will do much less to enhance the capabilities of that firm than would a more active fusion of the knowledge brought in with the worker and that generated within the firm. Where the worker has knowledge that can be introduced to the firm's routines and enhance or change them, this

process will usually involve learning on both sides: the individual workers will have to learn new things, and the organisation gains and modifies its own capabilities. Otherwise, the new employee may fit the job description, but some of his/her knowledge goes by unrecognised; and this knowledge is fairly **static**. There are undoubtedly cases where the absorbing firm can benefit a good deal by acquiring people with specialised knowledge to undertake specific missions, and where these people need not learn too much about the firm's own core knowledge. This is often the case with junior software employees – not systems analysts – with people employed for various sectoral marketing tasks, etc. However, we need to find the relative benefits of learning vis-à-vis job shifts as a whole rather than within specialised sectors.

Our data can be used to examine the impact of job shifts within a firm and between firms (i.e. internal and external) on several learning indicators. This will give us an empirical indication of whether these shifts involve static or dynamic knowledge, after we control for other factors such as tenure, occupation and age.

Table 4. Models predicting learning, skill increases and increased variety of tasks at work (logit – after controls for occupation)

Models:	Dependent variable		
	Learning	Upskilled	Increased variety
Independent variables:			
1. No. jobs since 1987	.085**	.139***	0.098***
2. No. jobs since 1987	.125***	.153***	.129***
Log tenure	Ns	Ns	Ns
3. No. jobs since 1987 (same employer)	.141***	.307***	.200***
4. No. jobs since 1987 (same employer)	.157***	.333***	.218***
No. jobs since 1987 (different employer)	Ns	.063*	Ns
5. No. jobs since 1987 (same employer)	.201***	.342***	.246***
No. jobs since 1987 (different employer)	.083*	.078*	.077*
Log tenure	Ns	Ns	Ns
6. Log tenure	Ns	-.094***	Ns

Source: Authors.

Table 5. The effects of age on knowledge indicators rather than tenure (logits - base age is 50-60 years old)

Models	Dependent variable		
	Learning	Upskill	Inc variety
1. No. jobs since 1987	.063*	.095***	Ns
Twenties	.323*	.725***	.745***
Thirties	Ns	.539***	.417***
Forties	Ns	.512***	.373***
2. No. jobs since 1987 (same employer)	.142***	.297***	.179***
No. jobs since 1987 (different employer)	Ns	Ns	Ns
Twenties	.349**	.774***	.778***
Thirties	Ns	.535***	.413***
Forties	Ns	.515***	.374***
3. Twenties	.396**	.833***	.799***
Thirties	Ns	.601***	.446***
Forties	Ns	.540***	.387***

Source: Authors.

Table 6. Effects of inter- and intra-firm-shifts on commitment and other indicators (logits after controlling for occupation)

Dependent variable	Independent variable	
	Job shifts same emplr	Difftr emplr
Work harder	Ns	-.095**
Proud to be in org	Ns	-.140***
Values similar	Ns	Ns
Success depends	Ns	Ns
Take any job	Ns	-.078*
Noticed	Ns	Ns
Had training	.400***	Ns
Increased flexibility	.346***	Ns
Use computers	.358***	Ns
Aiming to get better job	.346***	.376***
I will leave within the next year	.108**	.305***

Source: Authors.

Discussion

From Table 4 we see that the number of job shifts appears to affect our three learning indicators (model 1). However, there appears to be a significantly greater effect from job shifts *within* organisations rather than *between* them (models 3, 4, 5). There also appear to be very weak effects from tenure, suggesting that the amount of time spent in a job has little impact on learning and skills. (There was only a significant effect in one model, which disappears when job shifts are controlled for.) Age has a much more significant impact on learning than tenure (Table 5).

These results indicate that an element of caution must be exercised in promoting job mobility as a way of diffusing knowledge. In terms of dynamic knowledge flows, as represented by our three dependent variables, it appears that the impact of mobility, i.e. within firm shifts is much more beneficial than between firm shifts. Although between firm shifts undoubtedly allow knowledge to diffuse, it appears to be knowledge of a more static kind.

These results therefore suggest that inter-firm job shifts tend not to involve as much learning and upskilling after taking occupation into account. This in turn suggests that people are hired from outside because they *already* have a specific portfolio of required skills rather than being hired into jobs where they can enhance their own stock of competences. This may, of course, be an effective way of importing knowledge into a firm. But if the individual who “embodies” this knowledge is not learning much, him or herself, from the new location, it is likely that this knowledge is remaining compartmentalised and tied to that person: there is little interactive learning. The firm as a whole will not possess much resource, in consequence, if the person moves on. And even while the individual is in place, the firm may not be able to profit from using him/her flexibly, from truly capitalising on that person’s skills.

In terms of an ethos of lifelong learning, there is a potential contradiction emerging between the diffusion of embodied knowledge through the labour market and a commitment to self-improvement. People are more likely to improve their portfolio of skills by moving around within their organisation.

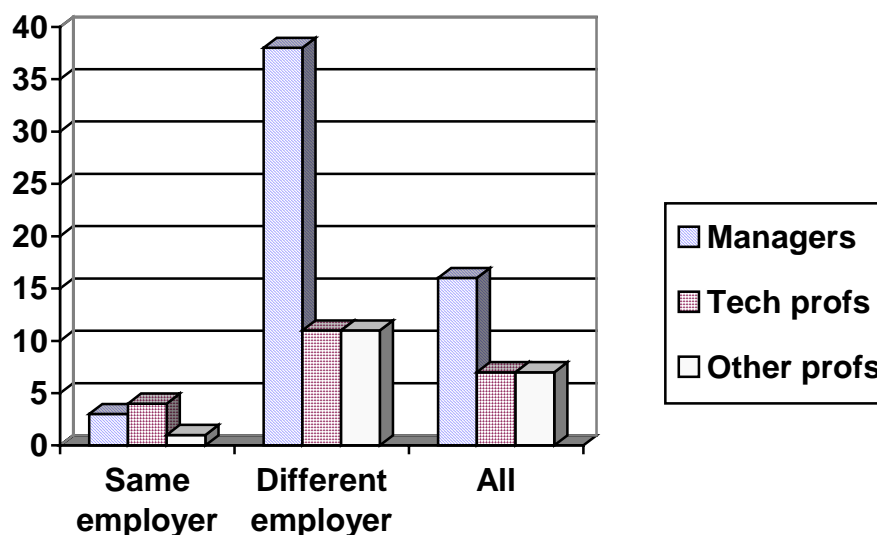
If this is the case, it could be argued that one of the disadvantages of fostering a high degree of external mobility would be a lack of commitment to any particular organisation. While those firms fostering an internal labour market might reap other benefits from their employees in terms of extra effort or dedication to the organisation. Table 6 shows the results of several models predicting organisational commitment

variables. Perhaps surprisingly, it appears that within firm job shifts appear to have no significant impact on organisational commitment after controlling for occupation. However, those workers who have moved between firms the most have significantly negative attitudes to three of the organisational commitment indicators: 'I would work harder in order to make this organisation succeed'; 'I am proud to be working for this organisation'; and 'I would take any job in order to stay with this organisation'. Although there is a potential problem with the interpretation here (workers who have shifted between many firms may do this because they are intrinsically uncommitted) the results again call into question the advocacy of external labour mobility.

Furthermore, Table 6 also reveals evidence that workers who enjoy more internal job mobility appear to have significantly greater access to training, are increasingly flexible and use technology (computers) more often than workers who have external mobility. These indicators were shown to have significant benefits in terms of the learning economy framework in a previous paper (Tomlinson, 1999a). However, both types of job shift appear to influence the employees' commitment to find a better job and to leave their present employer within the year.

A final downside to an uncritical perusal of occupational mobility figures is revealed in Figure 1 which shows the relative chances of downward occupational mobility of KWs depending on whether they switched firms or not between 1987 and 1992. The results show that workers who switched firms were much more likely to have less skilled jobs in 1992 than they had in 1987. (Downward mobility of a KW is here defined as a move out of KW status – i.e. moving out of SOC 1-3).

Downward mobility of KWs (%)



Source: Authors.

In terms of policy, it would appear that caution is required in the promotion of external labour mobility for its own sake. Perhaps other forms of knowledge transfer should be given significant consideration. For example, there is evidence that collaboration between firms is a significant benefit to innovation (Coombs and Tomlinson 1998). Perhaps the best way of transferring knowledge is through innovation and production networks that do not have to entail personnel transfers between the organisations. Firms can

learn from each other without losing their staff. On the other hand there will undoubtedly be situations where this is not possible and some degree of labour market flexibility is therefore desirable. With respect to KIBS this issue is addressed in the next section.

There is also the possibility that these results reflect a UK situation which does not generalise too well. The United Kingdom is well known for not training workers on the grounds that they will migrate. This does not invalidate the policy questions raised, but warns against the automatic assumption that what we find in the United Kingdom will apply elsewhere. We need more work from other countries to validate the “generalisability” of these findings.

KIBS, innovation and economic networks

Knowledge is often described as organised information, and this is a reasonable description of knowledge-representing artefacts. However, it is more helpful to see knowledge itself as an active process involving the **ability to organise information**; not just as the results of applying that ability. It is more of a practice, than a thing. Thus knowledge is a matter of learning. It may be developed in a variety of ways – through learning by doing and by experimentation, communication, formal training etc. Knowledge transfer thus typically requires more interaction between the participants than information transfer.

One of the most important developments in recent economic change has been the dramatic growth of what are variously known as strategic business services, advanced producer services, or, as we shall call them here, Knowledge-intensive Business Services (KIBS). KIBS exemplify, and foster, the knowledge-intensification of industrial economies. Their growth reflects increased demands for knowledge in the economy, and also exemplifies an ongoing division of labour. In this case, the division of labour leads to specialised services emerging and playing prominent roles in knowledge accumulation and transfer. KIBS are important agents in the development of new technologies. This especially applies to the development of applications of these technologies to the specialised requirements of particular businesses or groups of businesses. KIBS assist in the widening of this technical knowledge, as their interaction with clients leads to greater client understanding of the technical choices and solutions they may undertake. This contributes to an amassing of **technological capabilities** in the economy.

Miles *et al.* (1994), listing KIBS and distinguishing them from other services, described KIBS as services that:

- Rely heavily upon professional knowledge. Thus, their employment structures are heavily weighted towards scientists, engineers, and experts of all types. Many are practitioners of technology and technical change. Whatever their technological or professional specialism, they will also tend to be leading users of Information Technology to support their activities.
- Either supply products which are themselves primarily sources of information and knowledge to their users (e.g. measurements, reports, training, consultancy).
- Or use their knowledge to produce services which are intermediate inputs to their clients' own knowledge generating and information processing activities (e.g. communication and computer services). These client activities may be for internal use or supplied to yet other users in turn.
- Have as their main clients other businesses (including public services and the self-employed). Indeed, knowledge-intensive activities will frequently tend to be business-related, since as labour-intensive activities they will be relatively costly. (Educational and medical services demonstrate that delivery to final consumers often has to be mediated through collective service organisation.)

These authors distinguished new technology-based KIBS, the key repositories of S&T knowledge and workers, from more traditional professional services. (Software and telematics services versus accountancy and legal services; environmental and engineering services versus staff counselling and public relations services, etc.). However, the traditional professional services are often intensive and advanced users of new IT, and there is some cross-over from traditional professional services to KIBS, reflecting the general process of knowledge-intensification. “Spin-offs” and new firm formation occur where KIBS emerge from traditional professional services. For example, professionals with experience of new technology, in particular IT, establish vertical niche markets promoting the application of technology into their old specialisms (or sometimes to their old clients). They often generate new applications, combinations, etc. of basic technologies. (Examples include: accountancy firms selling financial software to clients; specialised training companies heavily utilising computer-assisted training; firms selling software and database applications to building service companies.) The spin-off from professional services into technology-based KIBS is largely similar to the spin-off from other sectors into KIBS.

Because of their role in interactive learning, KIBS typically require more supplier-user interaction than more standardised “symbol-processing” services (such as packaged software, broadcasting, telephony, standardised financial services). KIBS thus fit the stereotype of services as involving high levels of interaction relatively closely. Their roles may vary: from adding innovative knowledge originating from the KIBS itself (*KIBS as a source of innovation*), originating innovative knowledge from another source to the client firm (*KIBS as carrier of innovation*) or helping out a client in implementing new knowledge mostly developed in house (*KIBS as a facilitator of innovation*). One way of summarising this is to see them as playing *catalytic* roles, or as acting as *interfaces* in innovation systems. Often what is involved is a *co-production* of knowledge with a client or network of collaborators. At one extreme this may be little more than a pooling of the knowledge resources of each party – the service supplier provides generic knowledge, which is combined with the user’s specific problem-related knowledge. In other cases there is more active joint production of new knowledge that involves sharing work on the problems and solutions.

The size structure of KIBS, like many other services, is very skewed. A few international firms typically coexist with a huge tail of small and micro-businesses. This is less so in some of the more hardware-intensive sectors, but software exemplifies the point extremely well. A recent Eurostat report (*Statistics in Focus 1998/99 Business Services Statistics, Software and Computer Services*), presents data on a survey of software and computer services in five EU countries, and reveals, among other things, that firms in the sector are generally small – the vast majority have fewer than ten employees, though such firms contribute a disproportionately small share of the sector’s total turnover.¹⁸ The majority of workers here are young – between 25-39. (But there are relatively few aged below 25 suggesting that most employees are highly qualified, undertaking studies before age 25.) Unlike many other service fields, these IT services are heavily male-dominated in most countries (an exception was Italy). Perhaps surprisingly, work in the sector is overwhelmingly permanent and full-time and the much-touted home-based teleworking is most uncommon at present.

The employment structures of KIBS are heavily weighted towards white-collar, skilled workers. This is apparent from the OECD skills dataset – results for the UK are presented in Table 7 below, and though KIBS are hidden away within a category of “real estate and business services”, the extremely high share of such workers is apparent.

18. A similar picture, though less pronounced, emerges for engineering services in studies by Statistics Canada, (cf. Hamdami 1998).

Table 7. Skill Structures of UK Services, 1991, OECD dataset

Sector:	Shares of total employment				
	White collar	Blue collars	High skill white collar	High skill	Low skill
Real estate & business services	93%	7%	56%	60%	40%
Total services	87%	13%	41%	47%	53%
Total economy by occupation	71%	29%	36%	52%	48%

Source: OECD data set.

The labour market for KIBS workers

Direct social relationships with staff, partners, suppliers and clients are very important in protecting knowledge in KIBS, not least because the sorts of knowledge with which they deal are hard to protect through IPR arrangements like copyright. The sorts of control attempted may involve informal relationships, or be formally governed by employee law, or by contractual arrangements between collaborating or trading firms.

A recent survey¹⁹ of three sorts of KIBS in the UK contrasted technological KIBS (environmental engineers) with professional services (accountants), with architects forming a third and intermediate case. Internal working practices are very widely cited as important means of protection, especially by larger firms. The threat of losing knowledge embodied in key members of staff becomes increasingly important, and is increasingly the focus of management effort, in larger bodies. It is also among the most common methods used by smaller environmental engineering firms.

For firms in all KIBS staff recruitment was one of the main means of acquiring external knowledge, but the emphasis varied: for accountants this was used to acquire routine knowledge, for the environmental engineers specific knowledge. Departure of personnel was thought to be a *major source of threat of losing competitive knowledge* for the latter group, and least so for the architects. Again, this tells us something about the sorts of knowledge that make firms in the three branches of KIBS competitive, and suggests that the S&T workforce's knowledge is particularly valuable. We have examined the correlation between emphasis on internal working methods and the types of knowledge deemed important by the firm, however, and here an interesting result emerges. There is no significant correlation between emphasis on S&T knowledge and on internal working practices, at the firm level; but there are strong relations between the latter and knowledge of policies and regulations, and knowledge of markets and after sales support systems. The results, of course, are bound to be influenced by the specific choice of sectors we have studied here. However, the suggestion is that what is valued in employees is not just their generic technical knowledge (which presumably can be obtained as "paper qualifications") but their having the *ability to contextualise* this in the world of problems which clients confront.

19. See I. Miles, B. Andersen, M. Boden & J. Howells forthcoming, Services Processes and Property, *International Journal of Technology Management*. The sample was of 50 firms in each sector.

Evidence from the CIS2 on KIBS and other institutions as drivers of radical innovation

Finally, using the CIS2 data we can assess the impact of various collaborative factors on radical innovation in the UK economy. It can be shown that collaboration with academia, the use of business consultancy and the use of extramural R&D services (both KIBS) significantly contribute to the development of new to the market innovations. This is after controlling for the size and sector of the enterprise and the number of qualified scientists and engineers within the firm. These results are shown in Table 8.

Table 8. Logistic regressions predicting new to the market innovations (data is UK CIS2, weighted)

	Model 1	Model 2	Model 3
Log no. employees	0.337***	0.321***	0.335***
Percentage of S&T employees	2.824***	2.837***	2.910***
Collaborate with:			
Academia	1.250***		
Business consultants		1.720***	
Use extramural R&D services			1.695***
Nace group:			
Mining/food textiles	0.412	0.505*	0.427
Paper/fuels/chemicals/ metals etc	0.286	0.383*	0.276
Electrical/transport equipt	0.921***	1.034***	0.935***
Utilities/construction	-2.187***	-2.191***	-2.182***
Whole/retail/repair/hotel	-0.960***	-0.973***	-.0963***
Transport/finance	0.491*	0.431	0.514*
Other business/public	Base	Base	Base
Constant	-3.705***	-3.723***	-3.744***
Chi sqr	260***	283***	277***

Source: Authors.

What these results suggest is that as well as the proportion of the workforce that are S&T workers, collaborations with KIBS and other knowledge generating institutions such as universities have significant impacts on the radical innovative performance of UK firms. In other words, assuming a transfer of knowledge takes place or new knowledge is generated during the transactions and collaborations, no personnel transfers need take place for useful knowledge to be transmitted. Other work along these lines also confirms this result and interpretation. For example, Tomlinson 1997, and Tomlinson 1999b and 1999c showed, using macroeconomic data (input-output tables) for the United Kingdom, Japan, Germany and the Netherlands, that KIBS had a significant impact on both output and productivity in the economies as a whole and that the influence of KIBS was generally increasing over time. Coombs and Tomlinson (1998) also showed that collaborative linkages were significantly related to increases in innovative resources using the CBI firm level UK innovation trends survey.

None of the above arguments indicate that flexibility in labour markets is not a good thing, merely that there must be a balanced view that takes into account the other ways in which useful knowledge can be spread throughout economic systems. The balance may shift between sectors and at different times. Also this data may be more applicable to the United Kingdom or Europe and not hold in other countries such as the United States or Japan. More detailed work is required to assess these findings.

Conclusions

- The benefits in terms of ‘dynamic knowledge’ flows in labour markets appear to be fostered more by intra-firm job shifts than inter-firm shifts. Inter-firm shifts are more connected with static knowledge.
- Caution is therefore required when formulating policy to promote labour market flexibility and occupational mobility as a driving force for knowledge diffusion throughout the economy. The benefits of organisational internal mobility must not be ignored.
- S&T workers are particularly prone to job shifts having lower tenure times and relative ease in finding other jobs. But external job shifts appear to have some negative consequences in terms of organisational commitment, for example.
- It might be better to promote diffusion of tacit or embodied knowledge through firm collaborations and networks rather than personnel transfers?
- Certain producer services (especially KIBS) are essential for fostering connections between firms that can promote efficient networks for the diffusion of information and knowledge.
- Collaboration with KIBS and other knowledge institutions are significant factors in determining radical innovation within firms. KIBS inputs can lead to increased productivity at the macroeconomic level.

ANNEX 1. THE STANDARD OCCUPATIONAL CODING SCHEME

This occupational scheme has a 3-digit code at its most detailed level. For the purposes of this paper the first digit is used to define the broad occupational groups as follows (see Goldthorpe and Heath, 1992):

Group	Subgroup	Description
1	10	General managers and administrators in national and local government, large companies and organisations
	11	Production managers in manufacturing, construction, mining and energy industries
	12	Specialist managers
	13	Financial institution and office managers, civil service executive officers
	14	Managers in transport and storage
	15	Protective service officers
	16	Managers in farming, horticulture, forestry and fishing
	17	Managers and proprietors in service industries
	19	Managers and administrators nec
2	20	Natural scientists
	21	Engineers and technologists
	22	Health professionals
	23	Teaching professionals
	24	Legal professionals
	25	Business and financial professionals
	26	Architects, town planners, surveyors
	27	Librarians and related professionals
	29	Professionals nec
	3	30
31		Draughtspersons, quantity and other surveyors
32		Computer analysts and programmers
33		Ship and aircraft officers, air traffic planners and controllers
34		Health associate professionals
35		Legal associate professionals
36		Business and financial associate professionals
37		Social welfare associate professionals
38		Literary, artistic and sports professionals
39		Associate professionals and technical occupations nec
4		40
	41	Numerical clerks and cashiers
	42	Filing and records clerks
	43	Clerks not otherwise specified
	44	Stores and despatch clerks, storekeepers
	45	Secretaries, personal assistants, typists, wp operators
	46	Receptionists, telephonists and related occupations
	49	Clerical and secretarial occupations nec
	5	50
51		Metal, machine fitting and instrument making trades
52		Electrical and electronic trades
53		Metal forming, welding and related trades
54		Vehicle trades
55		Textiles, garments and related trades
56		Printing and related trades
57		Woodworking trades
58		Food preparation trades
59		Other craft and related occupations nec
6	60	NCOs and other ranks, armed forces
	61	Security and protective service occupations
	62	Catering occupations
	63	Travel attendants and related occupations
	64	Health and related occupations

	65	Childcare and related occupations
	66	Hairdressers, beauticians and related occupations
	67	Domestic staff and related occupations
	69	Personal and protective service occupations nec
7	70	Buyers, brokers and related agents
	71	Sales representatives
	72	Sales assistants and check-out operators
	73	Mobile, market, and door-to-door salespersons and agents
	79	Sales occupations nec
8	80	Food, drink and tobacco process operatives
	81	Textile and tannery process operatives
	82	Chemical, paper, plastics and related operatives
	83	Metal making and treating process operatives
	84	Metal working process operatives
	85	Assemblers/lineworkers
	86	Other routine process operatives
	87	Road transport operatives
	88	Other transport and machinery operatives
	89	Plant and machine operatives nec
9	90	Other occupations in agriculture, forestry and fishing
	91	Other occupations in mining and manufacture
	92	Other occupations in construction
	93	Other occupations in transport
	94	Other occupations in communication
	95	Other occupations in sales and services
	99	Other occupations nec

Source: Goldthorpe and Heath, 1992.

ANNEX 2. THE DEFINITION OF TECHNICAL OCCUPATIONS

The following 3 digit SOC codes were used to define technical occupations within the data set.

3 digit SOC code	Description
126	Computer systems and data processing managers
200-209	Natural scientists
210-219	Engineers and technologists
300-309	Scientific technicians
320	Computer analysts/programmers

Source: Authors.

REFERENCES

- COOMBS AND TOMLINSON (1998)
Company innovation styles, *Technology analysis and strategic management*, 10(3).
- GALLIE, WHITE, CHENG, TOMLINSON (1998)
Restructuring the employment relationship. Oxford: OUP.
- LUNDVALL (1992)
National systems of innovation, London: Pinter.
- OECD (1998)
Technology, productivity and job creation-best policy practices. Paris: OECD.
- TOMLINSON (1999a)
“The learning economy and embodied knowledge flows”. CRIC discussion paper 26. University of Manchester.
- TOMLINSON (1999b)
“A new role for services in economic growth”. Paper for the European socio-economic research conference, Brussels.
- TOMLINSON (1999c)
“Information flows from the service sector, a UK-Japan comparison”, forthcoming in Miles and Boden eds. *Services in the knowledge based economy*, London: Pinter.
- TOMLINSON (1997)
“The contribution of services to manufacturing industry”. CRIC discussion paper 5, University of Manchester.

B. HIGHLY SKILLED GLOBETROTTERS: THE INTERNATIONAL MIGRATION OF HUMAN CAPITAL

by

Sami Mahroum, *Institute for Prospective Technological Studies*
Joint Research Center of the European Commission, Seville

Overview

Brain drain, skill shortages, and lack of career opportunities have become issues of major concern for policy makers in government, academia, and industry in the final years of the 20th century. Increasing opportunities for labour mobility across political borders, especially among highly skilled labour, provide a solution for the aforementioned concerns to some actors, but engender problems to others. Drawing on various empirical investigations and on previous studies, this paper attempts to provide a mapping of the various types of human resources mobility across national borders. It argues that various groups of highly skilled persons are driven by different push and pull factors. In addition to immigration legislation, other factors, such as taxation, studying abroad, quality of work, openness in communication, business expansion overseas, labour market supply and demand signals, etc. play an important role in the choice of highly skilled migrants to relocate overseas.

Background

In recent years there has been an increasing concern about the future location of research (Etzkowitz & Leydesdorff, 1997), skills shortages (Metcalf *et al.*, 1995), and the migration of highly skilled personnel (Salt, 1997). This paper deals with the geographic mobility of highly skilled personnel in general and aims at providing a systematic analysis of the various mechanisms that influence the mobility of distinct groups of highly skilled personnel.

This issue has lately become a crucial policy concern at both enterprise, governmental, and inter-governmental levels. For instance, the European Commission for Science, Research and Development (DG-XII) has initiated an inquiry into the possibility of a brain drain in certain technological sectors from Europe, particularly, towards highly attractive labour markets such as the United States. Similarly, the government of Canada, and other concerned bodies in industry and academia there, have expressed their deep concern about the relocation of many Canadian highly-trained workers to the south of the borders. Similar complaints have been echoed in the media from South Korea, The Netherlands, Sweden, Switzerland, and other countries across the globe.

The competition for highly skilled workers seems to be intense and fierce. Traditional flows of talented people between countries that tended to go from the south to the north are now in some cases reversed. More countries in the south, particularly, in South East Asia and in Eastern Europe, are catching up technologically and becoming increasingly knowledge-based economies, and thus highly skilled scientists and engineers might stop flowing out from there. Thus, a motion of brain drain and brain gain might be going in all directions: north-north, north-south, south-north, and south-south. This might threaten countries (like the United States) that depend heavily on foreign talent.

Introduction

The labour market for professional skilled personnel is becoming increasingly global, both in terms of the supply of and the demand for skilled labour. Overseas students, for instance, are forming more and more a greater proportion of university students in most industrialised countries, and international mobility schemes for researchers are available at most universities (Stein et al. 1997). Multinational enterprises too draw increasingly on personnel with qualifications that enable them to be sent on long term missions to their affiliates around the world to enhance and ensure a high quality performance (Straubhaar & Wolter, 1997).

These developments might have numerous implications for the future location of highly skilled personnel, especially on the sending countries. Nations increasingly view technology transfer as primarily a people-oriented phenomenon and fear they might lose their competitive edge in what seems like a global competition for certain skills. Immigration is thus becoming increasingly an inseparable segment of national technology policies. The ability of some countries, regions and cities to attract highly talented personnel from all over the world seems to be enormous and governments are increasingly under pressure to react to these developments. Every year, actors in a few locations around the world recruit many highly talented managers, scientists and engineers. Whereas these trends can have mixed effects on developing countries (Simon, 1987), it is believed that they evoke largely negative effects on knowledge-based advanced economies like those of Europe (Mahroum, 1998). A Canadian-based study has estimated that if all the managers, scientists, and health science professionals who went to the United States between 1989 and 1996 had to be replaced, the costs for the Canadian economy could have totalled CAD 11.8 billion (De Voretz & Laryea, 1998). However, immigration to Canada has helped reduce the costs of recuperating these losses to the United States, although to a certain extent only.

In this paper, I argue that the issue of migration and international mobility of highly-skilled personnel is a complex and diverse one and requires thus very highly tailored and diversified policies. Each group of highly skilled professionals is lured and pushed by different sets of circumstances and provisions. I, therefore, shed light on the various push and pull factors that are involved in the process of relocation and mobility of the distinct groups of highly skilled personnel in the OECD area. In doing that, I firstly discuss the conceptual problems associated with the studying of this phenomenon. Secondly, I introduce briefly the notion of brain drain and brain gain, and thirdly, discuss the main drivers behind mobility for the various groups of highly skilled personnel. Finally, I discuss the main conclusions and policy implications of the paper.

Conceptual problems

There are enormous problems associated with gathering and finding data on the migration and mobility of highly skilled personnel. Firstly, there are conceptual problems. There is no agreed definition across countries and among scholars of what characterises a *highly skilled person*. Is a highly trained executive or technician with no formal qualifications considered a highly skilled person? Or should a highly skilled construction worker be included in data on highly skilled persons? Furthermore, what distinguishes between a *migration* and a traditional skills *exchange*?

However, some efforts have been made, and are continuing, to develop a proxy definition of what constitute a highly skilled person. For instance, the 1993 *OECD Frascati Manual on Proposed Standard Practice for Surveys of Research and Experimental Development* and the 1995 *OECD Canberra Manual on the Measurement of Human Resources Devoted to Science and Technology* have developed a statistical framework to categorise, collect and analyse data on science and technology workers at the international

level. According to the Frascati and Canberra manuals²⁰, there are four ways to classify science and technology workers: *i*) by qualification, *ii*) by activity, *iii*) by sector and *iv*) by occupation. While educational and activity-based classifications have long been in use, these are now joined by efforts to systematically collect and analyse data on where science and technology personnel are employed by occupation or sector. These different categorisations can be used for many different purposes, for example, to assess the supply of PhDs for high-level teaching and research positions, to identify in which industrial sectors S&T personnel are working, or to evaluate whether there are sufficient molecular biologists or computer programmers to meet future market demand. Most meaningful analyses of trends in science and technology labour markets combine one or more classifications, for example, qualification and occupation. This is used to identify the skill levels needed for different types of jobs. Combining data on workers by occupation and industrial sector indicates what types of workers are being employed in different industries, e.g. computer programmers in the chemical industries. However, as yet, such approaches are not totally harmonised across OECD countries and efforts continue to refine the categorisation of science and technology workers.

In dealing with this issue, the literature on the migration and mobility of the highly skilled is generally grouped into several categories. Firstly, there are studies that look into the international movements of highly skilled personnel in general and detect their inwards and outwards flows for the various countries (Salt, 1997; Carrington & Detragiache, 1998). Another group of studies focuses on individual professions within highly skilled categories, such as medical practitioners (Miller *et al.* 1998), bankers (Beaverstock, 1994), scientists and academics (North, 1995; Gaillard & Gaillard, 1998; Johnson & Regets, 1998; Mahroum, 1999) or individual nationalities (Findlay & Garrick, 1989; Song, 1997). In this group of studies, some stress the impact of scientists emigration on the sending countries (e.g. Bhagwati & Partington, 1976; Mountford, 1995), and others are concerned with the impact of these on the receiving countries (Gover & Huray, 1998; North, 1995).

Mobility and brain gain/drain

The OECD paper (1998) "Science and Technology Labour Markets: Mobility and Flexibility" indicates that there are two main types of mobility: *external* and *internal* mobility. The first can be divided into geographic mobility (regional, national and international) and into mobility from labour turnover (i.e. changes in individuals among jobs, regardless of whether the jobs are new or existing). Internal mobility refers to occupational changes (i.e. moving across occupational categories) and/or movement within the firm (e.g. between divisions, establishments). In the case of the labour market for science and technology personnel, the most relevant types of internal and external mobility concern: *i*) movement from the educational system to the labour market; *ii*) mobility *within* the public research sector (e.g. universities, laboratories, public research institutes) and between public research and industry; *iii*) mobility of S&T personnel within industry and; *iv*) international mobility which sheds light on the temporary and permanent migration of science and technology personnel (i.e. "brain gain" and "brain drain" issues). This paper deals exclusively with the latter, namely, international mobility of S&T personnel.

The main drivers of international mobility

Various sorts of geographical mobility exist, short-term overseas visits, long-term stays, and permanent stays. When highly skilled persons are involved in one of these various forms of mobility, various outcomes might result from it. Gaillard & Gaillard (1998), and later Johnson & Regets (1998), talked of a

20. The information in this section is derived from the OECD paper entitled "Science and Technology Labour Markets: Analytical Framework".

notion of “*brain circulation*”, or of what others have described as a “*professional transients*” movement (Appleyard, 1991). It is believed that this form of mobility, which refers to long term subsequent expatriation of skilled personnel in and out of various locations, is on the increase due to diminishing economic disparities between countries (Salt, 1997). This form of mobility is often perceived as a positive mobility that provides a channel for knowledge transfer. An OECD report (1997) on the movement of the highly skilled identifies, and distinguishes between, two main outcomes for their mobility: “*Brain exchange*” and “*brain waste*”. A “*brain exchange*” implies a two-way flow of expertise between a sending country and a receiving country. Yet, where the net flow is heavily in one direction, the terms “*brain gain*” or “*brain drain*” is used. A “*brain waste*”, however, describes the waste of skills that occurs when highly skilled workers migrate into forms of employment not requiring the application of the skills and experience applied in the former job (OECD, 1997).

There are many various types of professionals within the highly skilled category of migrants and the push and pull factors for their migration are various. The push and pull factors for the migration and mobility of scientists might vary, for instance, across disciplines. The motives for a scientist to relocate somewhere else other than his/her own country might be personal aspirations and scientific curiosity, whereas for a manager, it might be a mere reflection of the employer’s priorities. Governmental policies or industrial lobbies’ policies might also play a role in influencing the incentives to stay or move abroad, such as by instigating incentives for foreign skills to flow in or remain in the country in certain fields (e.g. US policies). Governments’ policies can make certain locations attractive for individuals by for instance providing tax incentives, superior research infrastructures, and preferred wages.

Additionally, the nature and structure of *National Innovation Systems* (NIS) play an important role in shaping the inflows and outflows of highly skilled persons. For instance, countries whose NIS revolves around universities will attract primarily academics from abroad, as universities will be the place where cutting edge national activities in science and technology are happening. The same is true regarding NIS whose core S&T bases lie in industrial research or large public research organisations. Such imperfections across NIS shape to a large extent individual choices for mobility and determine in the long run the patterns of flows between countries. In the United States where the NIS revolves around a number of centres of excellence some of these have become so powerful that their attractiveness goes beyond their regional and national borders into a global scale. The University of Stanford in California and MIT in Massachusetts are two examples of such centres of excellence. Each of these two institutions attracts large numbers of overseas scientists and research students to their realms. Over 50% of all post-doctorates in science and engineering specialisation in these two institutions come from overseas (NSF/SRS, 1998), and already in the Silicon Valley 30% of computer professionals are foreign-born. Likewise, a study conducted in the early 1990s on American scientists in France (Martin-Rovet *et al.*, 1991) found that the majority of these (60%) were hosted by the CNRS, which in turn has over 1 500 laboratories and reflects the centralisation of R&D activities that characterises the French NIS.

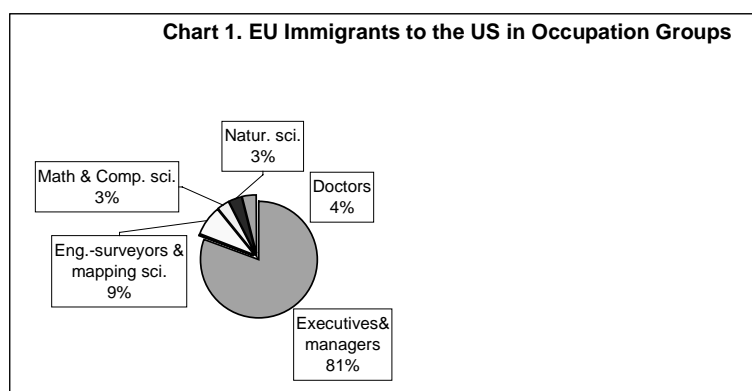
Thus, the flows of professionals tend to go through leagues of cutting-edge *activity-intensive* locations. The reputation as a cutting-edge workplace is a strong attraction for scientists and engineers. This is already evident in industry, academia, and in the service sector. In industry, the IT sector in the US, for example, performs as a magnet for IT specialists from all over the world (Hsiao, 1997). In academia, Cambridge and Oxford universities attract most of Europe’s foreign talents in biosciences and clinical medicine (Mahroum, 1999). In the service sector, particularly, in the banking sector, London, Tokyo, and New York are global magnets of top bankers (Beaverstock, 1994).

The next sections will identify the main push and pull factors and the main channels of migration for the distinct groups of professionals and highly skilled. These are: *i) Managers & Executives, ii) Engineers & Technicians, iii) Academics & Scientists, iv) Entrepreneurs, and v) Students*. This paper uses the definitions and classifications of the *International Standard Classification of Occupations (ISCO)* as a

guideline. Accordingly, the first four groups all fall in the ISCO groups 1, 2, and 3 categories (see OECD, 1995). Students, however, are considered as main supply channels to these groups. These five groups are by far the largest groups of migrant professionals and the most frequent movers.

Managers and executives ⇒ accidental tourists

These are mostly affected by corporate policies, especially regarding expanding activities overseas and internationalisation. A study from Australia has shed some light on the extent of the phenomenon of mobility among managers (Lewis & Stromback, 1998). The study found that in Australia, and during the 1990s, some 10 000 managers (and 25 000 professionals) are arriving and departing each year. The majority of these arrived from and/or left to the United Kingdom, Ireland, and neighbouring Southeast Asian countries. Similarly, in 1996 executives and managers made up 81% of the 7 638 highly skilled permanent immigrants to the United States from the EU (see chart 1 below). Chart 1 shows that the largest group of professional EU immigrants to the US is made up of those who have executive and managerial occupations (4 324 persons).



Source: INS 1998; Data: Author's own calculations.

These are referred to as *accidental* tourists because the decision for their mobility comes often unplanned and surprisingly based upon a new merger or expansion activity of the employing firm. These often originate from temporary intra-corporate transfers that later turn into long term and permanent moves. Salt & Clarke (1998) found that the majority of 13 266 foreign professionals (from non-EEA countries) that have sought residency in the United Kingdom in 1995 were mainly executives and managers resulting from intra-corporate transfers and came from other advanced economies such as Japan and the United States.

Various types of foreign investments necessitate different type of intra-corporate personnel expatriation. For instance, senior engineering staff might be sent abroad to supervise and operate a project in a less advanced developing country which possesses little of such human resources, whereas, senior managerial staff will often be transferred between firms in advanced countries after a merger or a take-over. In the latter, foreign investment necessitates some expatriation of local talents in order to incorporate new businesses abroad into the mainstream corporate environment prevalent at home, and also to reach equal efficiency and quality standards.

In this context, Straubhaar and Wolter (1997) have provided a dynamic picture of the process. In their opinion, the early stage of internationalisation of a firm requires intensified expatriation of some of its managers to run its activities abroad and to provide certain firm-specific expertise. During its later stages

of internationalisation, the consolidation phase, the firm's activities overseas become deeply and fully integrated in their local environments so that expatriation becomes less important. But this differs across national practices. Japanese management, for example, tends to depend on Japanese staff in both the early and late stages and most of the time (Findlay *et al.* 1995). It is not surprising, thus, to find the United States, Europe, and Japan, due to their foreign investments, to be the main sources of highly skilled temporary migrants in South East Asia (Lewis & Stromback, 1998). The United Kingdom sends annually a significant amount of professionals to countries in Australasia (e.g. Hong Kong, China and Singapore), particularly in the banking sector (Beaverstock, 1994). In 1996-97, around 2 340 highly skilled immigrants from the United Kingdom arrived to settle in Australia (Source: DIMA, 1998).

The international mobility of executives and managers comes more as a result of business expansion than a personal decision. The cost of such mobility usually entails significant financial (as well as social) costs for both the employing firm and the person concerned. As outlined above, it is believed that expatriate managers enhance the control system of the parent company over its subsidiaries abroad. The various benefits and remuneration enjoyed by this group of professionals (e.g. stock options in employing firms) make their mobility often internal to the organisations they work for. However, in a study based on Hong Kong, China, Findlay *et al.* (1996) found that while abroad expatriate managers become part of an international pool of skills that is vulnerable to all sort of offers from other employers, especially from local companies in the host country. Findlay *et al.* add that the probability of changing employer increases with the amount of time spent abroad (*ibid.*, pp 53).

Engineers and technicians ⇒ economy-class passengers

These are largely affected by immigration policies, industrial and labour policies of governments. They are like *Economy-Class Passengers* because they are “pulled” and “pushed” primarily by economic factors, i.e. best offers. Governments, firms, and individuals make their decisions on the labour market in accordance with *supply* and *demand* mechanisms of the labour market. But individuals in particular make their choices according to what they perceive as most rewarding for them. Thus they would go to where the demand for their skills is most needed and most rewarded. Research from the United Kingdom has shown that this group seems to be more responsive to the state of the national economy than other groups (Salt & Clarke, 1998). For instance, greater numbers of highly skilled labour were hired in the United Kingdom in response to a growing foreign investment (including technological investment) in the British manufacturing industry (*ibid.*, pp. 380). Apart from EU countries, the majority of these came from other highly industrialised countries such as the United States and Japan.

In the United States, according to the 1990 census, there were around 234 178 foreign-born engineers representing 12.3% of total engineers (Bouvier & Martin, 1995); of these, there were 104 101 engineers from Asia. Asian immigrant-engineers had the highest pay rate among all engineers in the United States (including native-born engineers), Japanese engineers had the highest pay amongst them all. This observation goes perhaps against the assumption that immigrant professionals push local wages down (as discussed below). Around 20% to 28% of all employed S&E workers with a doctorate in the United States are foreign-born. The United States is expected to attract more engineers from abroad, since employment in science and engineering occupations are expected to increase at more than three times the rate for all occupations (science and engineering Indicators, 1998) in the 1996-2006 period. In 1993, around 5 000 EU technicians and technologists were granted "green cards" in the United States (INS 1998), this number has been almost static over the years.

However, concerns are raised on the effect of this group of immigrants on the local labour market for engineers. Gover & Huray (1998) indicate that with the immigration of engineers to the United States free market mechanisms are sabotaged as supply and demand signals are distorted by the supplies coming from

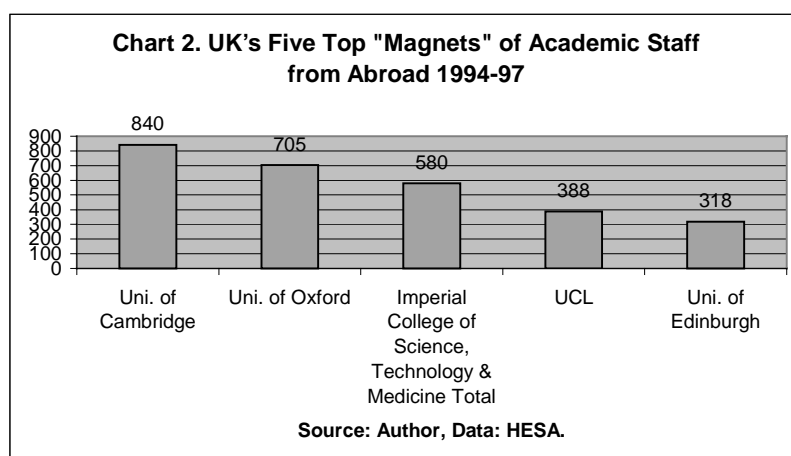
abroad rather than from the local market. The effect of that, the authors say, is an artificial lowering of engineers wages' at home (Ibid., pp. 11). Whereas this argument might be true when considering one single group, the immigration of engineers, and broadly speaking other highly skilled groups too, is widely acknowledged to yield more benefits to the overall society than losses, especially in the longer term (Simon, 1987; Freeman, 1997; Cobb-Clark & Connolly, 1997; Johnson & Regets, 1998; Miller *et al.* 1998). Regets (1997) adds to the debate by indicating that engineers (and scientists) immigrants do not necessarily substitute for local talents but complement them due to existing differences in aptitude and methods of study between countries.

Academics and scientists ⇒ pilgrims

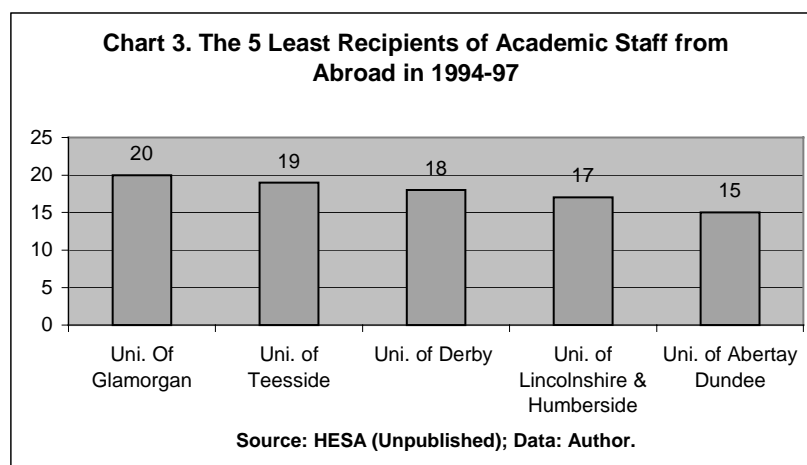
International contacts between scientists from different countries are a normal part of scientific life and an old norm among scientists. The movements of scientists are most affected by bottom-up developments in academia and science, as these are instrumental in the diffusion of scientific ideas. However, scientists do not work only for academic organisations but also for industry and enterprise.

In general, scientists seem to be attracted to the nature of the work they are required to do and the conditions under which they have to conduct their work. For instance, Deeds & McMillan (1998) argue that a "reputation" for scientific openness (i.e. encouraging staff to publish their results) is an important quality for firms wishing to recruit best scientific talents. To test this argument, they conducted a survey of over 400 PhD students to determine if a firm's support for publication matters in their job search; thus they asked students for their opinion regarding a list of twelve US pharmaceutical companies. The results showed that publication support does matter for choosing an employer, although not as much as the quality of research staff in the organisation, working conditions, and salary. However, a ranking of the top three organisations most cited as prospective employers mirrored a ranking that reflects publication records. In other words, organisations that ranked high in the number of scientific publications produced, ranked equally high as desired employers. This suggests that publication records may indeed be a signalling device providing a higher degree of visibility for prospective employees.

In academia, empirical research from the United Kingdom has shown that between 1994 and 1997 around 11 000 foreign academics were employed in the UK higher education system (Mahroum, 1999), the biggest single group of these came from the EU (45%). The distribution of the inflows is random, certain field areas and certain universities have attracted most of these inflows. Chart 2 below provides more details.

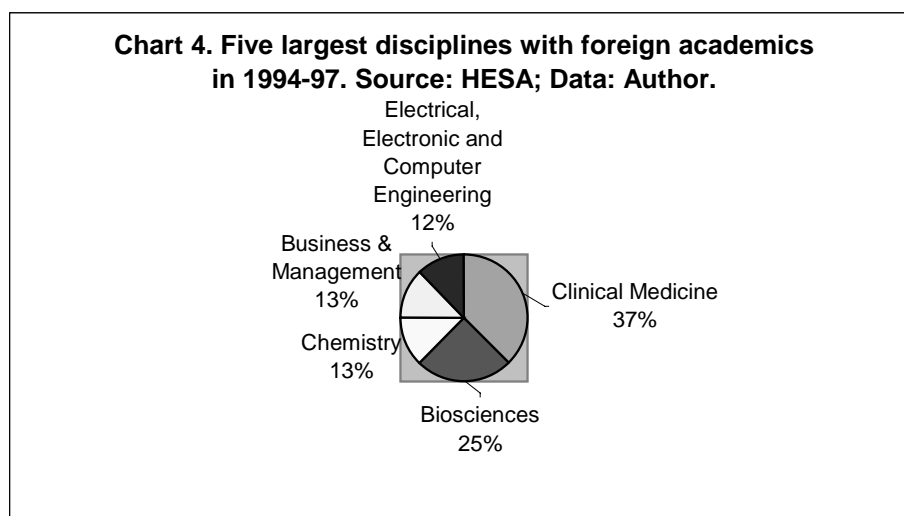


The biggest recipient (University of Cambridge) received 840 foreign scholars, 210 times more than the lowest recipient (Thames Valley University), which recruited a mere four foreign scholars in the whole period. Chart 3 below provides more information on the five least substantial recruiters of foreign academic staff among British universities²¹.



All universities in Chart 3 are former polytechnics who neither enjoy a strong international reputation for excelling in some disciplines nor a long time cumulated prestige. The variation across fields and institutions implies that different sets of factors stand behind the various types of inflows. One might argue that there are two main dynamics for scientific attraction: *i*) the attraction of a country in a particular discipline, *ii*) the prestige of an institution. A country might be known to be strong in a particular discipline and thus gains collectively as a nation a reputation for being good in that particular discipline becomes attractive to scientists working in that discipline worldwide. For instance, the strength of the United Kingdom in clinical medicine and biosciences might explain the international attractiveness of the United Kingdom in this field, as reflected in the proportion of foreign academics in these two disciplines in that country. Chart 4 provides more detail.

21. Universities that had less than 15 recruits from abroad in the 3-year period were left out.



Source: HESA; Data: Author.

However, an institution with a strong prestigious background can capitalise on its prestige²² to attract the best scientists available around the world. Shapin (1998), in his analysis of the role of *trust* in science, indicates that scientists today are attracted towards *expertise* and the institutions that produce and vouch for expertise. He argues that modern science is no less trust-dependent than science in the past, and that scientists put their trust in organisations that are highly reputed for excellence, quality, and originality. Therefore, “attraction” is dependent on the possession of certain qualities that are not available in all organisations, and which are often difficult to assess from the outside. Thus a lot of judgement from outside depends on the prestige and reputation an institution enjoys. In many cases, the reputation and prestige of an organisation are enhanced by the existence of “star” scientists (e.g. Nobel laureates) among the faculty. Kretschmer (1997), for instance, suggests that there is a sort of “homophile” among scientists, that is “persons [scientists] are guided more or less by a deliberate search for persons with similarity in characteristics” (Kretschmer, 1997, pp. 581). Accordingly, scientists’ networks follow the same structure; a top scientist from Harvard will go only to another top organisation abroad that is operating in the same field.

As the demand for skilled scientific labour is expressed increasingly outside traditional fields of academic activity, a reputation for scientific openness, excellent quality, and prestige for excelling in research are important qualities for all organisations engaged in science-based activities and seeking to lure scientists of high calibre.

Entrepreneurs ⇒ explorers

These are business-oriented persons who arrive with capital and ideas aiming at setting up certain business activities. They are stimulated by a variety of policies, most prominently, governmental (visa, taxation, protection, etc.) policies and credit facilities. Some countries like Australia, Canada, and the United Kingdom have certain legislation that allow entrepreneurs to immigrate and settle providing that they invest or bring with them certain “minimums” of capital to the country. A study by David Keeble (1989)

22. Brewer, Gates, & Goldman, (1998) define “Prestige” as the notoriety for being among the best at some activity that is difficult to define or demonstrate concretely.

showed that around 70% of Cambridge area hi-tech entrepreneurs (at the time of the study) were immigrants.

In Australia, for instance, the number of entrepreneur immigrants has risen from 1 900 (ca. 2.5%) in 1993 to 2 700 (ca. 3%) in 1996. The total of these in the whole 1993-96 period was 7 000 business people (DIMA, 1998). The benefits of entrepreneur immigrants are perceived not only in the capital they bring with them, but also in their knowledge of overseas markets and their business networks. A very much sought after group is entrepreneurial scientists and technologists. This group is usually attracted to locations where tax incentives and venture capital for new start-up hi-tech firms are available, or where public funds to support hi-tech entrepreneurs exist. Silicon Valley in the United States is a traditional destination for such migrants and remains for many a model to pursue. In a very recent study carried out by an American research consultancy²³ on behalf of the *Institute for Prospective Technological Studies* entitled "The European Entrepreneurial Presence in the USA" the following was found. About 350 hi-tech companies in the San Francisco Bay Area were created by Europeans from the EU member countries and that, according to the French Consulate General, results in about 500 new French citizens arriving every year in the Bay Area, either to work in local hi-tech companies or to create their own company. On the other hand, the representative of the Netherlands thinks that the flow of Dutch entrepreneurs arriving is now receding. Of 32 founders of hi-tech firms from the EU in the Silicon Valley, the majority has indicated that they would not come back to Europe under any circumstances (60%). The main reasons that were given are:

- Family.
- Too much "red tape" and bureaucracy.
- Unfavourable entrepreneurial climate.
- No flexibility for human resources management (hiring, firing, work hours, ...).
- Lack of venture capital.

The study also noticed that migrating does not necessarily mean "burning the vessels" and breaking the relationship with the home country. On the contrary, most of the entrepreneurs that were interviewed maintain close relations with their home countries. They consider it essential to stay connected with what happens there, especially in the event that they have to return. Yet those who would consider coming back to Europe, would do so:

- To create a business presence for their company in Europe.
- To turn around/start a business in their country of origin.
- For tax incentives.

Emigré EU entrepreneurs have also indicated that more flexibility to manage human resources in the EU, and a better stock option system, would attract them back. These factors are both pull and push factors and can have serious effect on the making of personal decisions for relocation and mobility.

Students ⇒ passengers

These are the main sources of workforce supply to the labour market and to local and global knowledge pools. They are mostly affected by governmental, intergovernmental, and inter-institutional policies. A 1998 survey of European graduates, conducted by the Swedish human resources consultancy Universum,

23. ACTEAM International Corporation.

found that 82% of European students state that they are interested in an international career and 88% are interested in working and living abroad for at least one year. Students today show an increasing recognition of the global workplace. Given a choice of where to locate a career abroad, the United States or Canada are most attractive (63%), followed by the United Kingdom (35%) (Source: Universum, 1998). Smaller countries, such as Sweden, Holland, and Ireland, in particular, seek to produce more internationalised graduates able to work abroad in order to cope with their growing international businesses activities. Participation in international education and training, including the various international exchange schemes and fellowships, has stimulated interest of young scientists to work abroad and has helped internationalise domestic graduates (Stein *et al.* 1996). Students are perceived here as *passengers* who are heading abroad to certain destinations, but the motives or the ultimate destiny of the various passengers at their destinations is unknown to most of us. Table 1 provides information on the increase of foreign students in a number of major host countries from the 1950s to the 1990s.

Table 1. Third-level foreign student numbers and total higher education enrolments: six major host countries: 1950-1990

	1950	1960	1970	1980	1990
Foreign student enrolments ('000)					
Australia	0.3	5.0	7.5	8.8	29.0
Canada	3.2	7.3	22.3	28.4	35.2
France	13.5	27.1	34.5	110.8	136.0
Germany*	2.1	21.7	27.8	61.8	107.0
United Kingdom	8.2	12.4	24.6	53.0	80.2
United States	29.8	53.1	144.7	311.9	407.5
Total	57.1	126.6	261.4	574.7	794.9
All higher education enrolments ('000)					
Australia	36	81	180	324	485
Canada	82	142	642	1 173	1 917
France	134	215	801	1 077	1 699
Germany	151	265	504	1 223	1 799
United Kingdom	134	169	601	827	1 258
United States	2 297	3 583	8 498	12 097	13 710
Total	2 833	4 454	11 226	16 725	20 868
Foreign students as proportion of all students (%)					
	2.0	2.8	2.3	3.4	3.8

* FRG only.

Source: UNESCO.

The number of foreign student enrolments has increased in all countries as the number of total enrolments is growing. Nevertheless, Table 1 shows that the proportion of foreign students has increased from 2.0% in the 1950s to 2.3% in the 1970s to reach 3.8% in the 1990s. Not only did the absolute numbers of foreign students increase but also their proportion in total enrolments. These numbers are expected to grow in the next 10 to 25 years to reach around 4.9 million students seeking to study abroad, of which 2.9 million will come from Asia. Table 2 provides the figures.

Table 2. Forecast of number of students seeking higher education abroad

Year	Number of students
1992	1.4 million students studying abroad
2010	2.8
2025	4.9

Source: IDP Education Australia (1995).

Host countries are often the main beneficiaries of these inflows as stay rates are often quite high. For instance, about 50% of all Europeans who finish their PhD training in the United States stay there for longer. Many stay there permanently (Finn, 1997). This however fluctuates and varies across regions and countries of origin. European doctorate graduates have a much higher stay rate in the United States than their Korean and Japanese counterparts. The difference between Japan and Europe in the propensity to stay is very big, only 8% of Japanese PhD graduates stay. Graduates from England have the highest European stay-rate in the United States. Whereas most German graduates return (ca.75%), only ca. 30% of English graduates do. Variations appear across fields of graduation, if we take England as an example, 73% of engineering graduates stay compared to 65% of Life sciences, and 60% in Physical sciences. According to a recent study, 30% of the foreign students in the Universities of Northern California (primarily UC Berkeley, Stanford, San Francisco SU, and San Jose SU) stay and work in Silicon Valley (ACTEAM, 1999).

Richard Lambert, in his study of foreign students flows, indicates that, in the United States, “it is in the elite research universities that the share of foreign enrollees among graduate students is most dramatic” (Lambert, 1992). In a study on brain drain from France to the United States (Terouanne, 1997), it was found that the states that host some of the United States' finest higher education institutions, such as California, Massachusetts, and New York have attracted most French post-docs to the United States. In 1997, almost 50% of all post-docs at Stanford University, and over 55% of those at Harvard and MIT, were from overseas (NSF/SRS, 1998). There is growing evidence that post-graduate students are most influenced by the quality of the organisations they choose to enrol with (Lambert, 1992; Mahroum, 1999), and equally important, by the after training opportunities that exist in the host country.

But the host country is not always the main, or the sole, beneficiary of the movement of students. The concept of “brains circulation” (Gaillard & Gaillard, 1998; Johnson & Regets, 1998), which refers to the cycle of moving abroad to study, then taking a job there, and later returning home to take advantage of a good opportunity, increases knowledge transfer to the home country. This sort of circular migration has been observed amongst Malaysians who had studied in Australia (Kritz & Caces, 1992), and it is the sort of mobility that governments often have in mind when supporting their students in going abroad. Yet when the outflows of students are permanent and are not replaced by equal inflows from other countries, then a case of brain drain occurs and the source country is largely perceived to be on the losing side. This remains largely true unless the host country is benefiting from its émigrés by maintaining contacts with them and setting up relations with them, as is the case with students from Japan, Korea, Chinese Taipei, and China. For some developing countries it may even pay off to keep these students abroad so that they continue to send important remittances back home.

Conclusions and policy options

This paper has identified five major channels for international mobility of highly skilled personnel. It has shown that different *push* and *pull* factors influence the volume, the frequency, the length, and the direction of mobility in the various channels. Today, countries, regions, cities, universities, research centres and firms all around the world are competing to maintain their attraction for highly skilled personnel in the various professional areas. The United States, Canada, and Australia have all raised the ceiling of skilled immigrant quotas, and the expression of brain drain fear is no longer confined to developing countries. In management professions, the expansion of business and industrial activities overseas is an important factor in driving some of the best local talents abroad. For entrepreneurs, tax allowances and the availability of supporting funds and venture capital represent a major attraction for them to relocate. More important though is the availability of legislation that allows them to immigrate to the country of concern. In academia and science, “colleges” and “scientific norms” operate a self-organised motion between and

among research colleges that are embodied in various institutions. Finally, following education and training programmes abroad is another major source of long term, or even permanent, expatriation in almost all professional areas.

Table 3 below provides a systematic mapping of the various groups of mobile professionals, the relevant push and pull factors, and the corresponding policies.

Table 3. A classification of highly skilled mobility, types of influencing factors and policies

Group	Type of push & pull factors	Type of policies
Managers & Executives	Benefits and remuneration	Business-oriented
Engineers & Technicians	Economic factors (supply and demand mechanisms)	Immigration legislation Income tax
Academics & Scientists	The state of the national economy Bottom-up developments in science Nature & conditions of work Institutional prestige	Inter-institutional and intergovernmental policies
Entrepreneurs	Governmental (visa, taxation, protection, etc.) policies Financial facilities Bureaucratic Efficiency	Governmental and regional policies Immigration legislation
Students	Recognition of a global workplace Accessibility problems at home Inter-cultural experience	Intergovernmental, and inter-institutional policies Immigration legislation

Source: Author.

As the mapping of Table 3 reveals, different policies should be tailored out to suit the very different organisational and cognitive structures of the various sectors and professions. As has been shown in this paper, various groups of professions are driven by different push and pull factors. Therefore, supplementary and complementary immigration and non-immigration legislation, such as income-tax allowances, investment capital tax relief, and copyright legislation should be introduced to encourage the inward flows of skills and expertise.

Nonetheless, immigration legislation remains the first and utmost important legislation area where human mobility is concerned. Countries that have designated special legislation to allow highly skilled immigrants to take jobs in their local job markets stand better chances of benefiting from a growing international pool of high calibre human resources. For example, the United States government has agreed to raise the ceiling of skilled immigrants intake from 54 000 to 140 000 annually (Gover & Hurray, 1998). Australia, another major immigration country, is set to lower the ceiling of the *Points System* it operates for immigration intakes and through which it discriminates in favour of young and productive skilled persons.²⁴ The number of immigration entries to Australia was estimated to have increased by around 11 000 to total 98 000 entries in 1995-96 up from 87 000 in 1994-95. Singapore, too, according to *Nature* (August 5 1998), has set up an active policy to attract foreign talents from abroad. Singapore today has 4 000 scientists of whom 40% are foreigners. Likewise, Chinese Taipei is about to introduce a science and technology law, which will make it easier to recruit overseas nationals, and wants to simplify regulations for intellectual property rights. Schemes for short- and long-term visits (e.g. postdoctorals) for scientists from overseas have been increased. Finally, China is planning and working to recruit scientists from overseas. However, China realises that, in contrast with Chinese Taipei and Singapore, most of these will have to come from the Chinese Diaspora in the West. The *Chinese Academy of Science* is targeting the

24. Department of Immigration & Multicultural Affairs, 1998.

so-called “Mobile Researchers”, such as graduate students, postdocs, and visiting professors. It hopes to more than double the number of *mobile* researchers to around 10 000 in the next three years, and to further boost the number to 30 000 in the year 2010.

Higher education is the major backdoor for international mobility; however, internationalising higher education and training should not only mean preparing local students to work overseas, but also foreign students to work in local labour markets. For instance, anecdotal evidence points to the *after-training* opportunities that exist in the United States for foreign students as a major pull factor for those seeking education abroad. In 1996, around 1 000 United States-trained European PhD graduates started their own businesses in the United States (Mahroum, 1998). The availability of venture capital and a business friendly climate in the United States has lured many foreign students to stay on. Other facilities such as the right for a spouse of a student to join his wife and take employment in the host country; or to spend a couple of years working in the host country after the completion of education are two examples of important tools in stimulating foreign students and enriching the human resources potential of the host country. Consequently, further important preparatory efforts should be made such as language and culture classes for foreign students to make it possible to draw on foreign students, upon completion of their training, in professions with skills deficits. Last but not least, accreditation and recognition of foreign qualifications and experiences are essential for nurturing a skill attractive area in order to ease the inflows and outflows of skills. Without full recognition of training and qualifications gained abroad, the potential mobile researcher or student will be reluctant to take opportunities that exist outside his/her national borders.

Mobility programmes should expand to provide mobility opportunities for students and young researchers to go where they think it is best for them to go. This secures a “bottom-up” driven mobility that is driven by inter-institutions collaborations and inter-personal contacts. In other words mobility programmes should be qualitative oriented rather than geographically oriented. Shifting quantities from one direction to another might not be the right thing to do. The important thing is to maintain a two-way flow of talent. For instance, European Commission mobility programmes could be designed to include two stages of mobility, where the first destination could be anywhere in the world, but the second and final destination has to be in an EU member country.

Last but certainly not least, the migration of young high-tech entrepreneurs, particularly to the United States, might eventually become a problem for the source countries in quantitative terms, but even more so in qualitative terms. For instance, it is the most creative people who leave Europe for the United States. This might delay the establishment of new growth areas in Europe and heavily affect the future development of, for instance, a *European Information Society* or a strong European biotechnology sector. In order to make Europe attractive to these young entrepreneurs, easier availability of venture capital would be important, as well as the removal of cumbersome bureaucratic rules for setting up firms and the ease of access to financial services.

REFERENCES

- ACTEAM INTERNATIONAL CORPORATION (1999)
“The European Entrepreneurial Presence in the USA” a study carried out for the IPTS, unpublished.
- APPLEYARD, R. (1991)
International Migration: Challenge of the Nineties (IOM, Geneva).
- BHAGWATI, J. & M. PARTINGTON (1976)
“Taxing the Brain Drain: A Proposal” (Amsterdam, North Holland).
- BEAVERSTOCK, J. (1994)
“Re-thinking Skilled International Labour Migration: World Cities and banking Organizations”,
Geoforum, Vol. 25, N0 30, pp. 323-338.
- BOUVIER, L. F. & John L. MARTIN (1995)
Foreign-born Scientists, Engineers and mathematicians in the US. Center for Immigration Studies
Washington, DC.
- BREWER, Dominic J., Susan M. GATES, & Charles A. GOLDMAN (1998)
In Pursuit of Prestige: Strategy and Competition in US Higher Education. RAND, Santa Monica.
- CARRINGTON, W. and Enrican DETRAGIACHE (1998)
“How big Is the Brain Drain?”. IMF Working Paper. IMF Research Department.
- COBB-CLARKE, D.A., & M. CONNOLLY (1997)
“The Worldwide Market for Skilled Migrants: Can Australia Compete?” in *International Migration
Review* Vol. 31, No. 3. Center for Migration Studies New York.
- DEEDS & MCMILLAN (1998)
“The role of reputation in the recruitment of scientists” in *R&D Management*, Vol. 28, issue 4,
Blackwell Publishers.
- De VORETZ, D. & Samuel A. LARYEA (1998)
“Canadian Human Capital Transfers: The US and beyond”, in *C.D. Howe Institute Commentary*,
ISBN 0-88806-440-3. Renouf Publishing Co. Ltd. Ottawa.
- Deutsche Forschungsgemeinschaft Statistics* (1995)
German Research Society, Bonn.
- DIMA- Department of Immigration & Multicultural Affairs (1998)
<http://www.immi.gov.au/facts/03recent.htm>
- ETZKOWITZ, H.& L. LEYDESDORFF (Eds.) (1997)
A Triple Helix of University-Industry-Government Relations. The future location of research, Book

of Abstracts, Science Policy Institute, State University of New York, European S&T Indicators Report, 1997. European Commission DGXII, publication no. EUR 17639.

- FINN, Michael G. (1997)
 “Stay Rates of Foreign Doctorate Recipients from US Universities, 1995”. Oak Ridge Institute for Science and Education.
- FINDLAY, A. and L. GARRICK (1989)
 “Scottish emigration in 1980s: a migration channels approach to the study of skilled international migration”, *Transactions of the Institute of British Geographers* 15: 177-192 (1990).
- FINDLAY, A. M., F. L. N. LI, A. J. JOWETT, & R. SKELDON (1996)
 “Skilled international migration and the global city: a study of expatriates in Hong Kong” in *Transactions of Institute of British Geographers* NS 21 49-61. Royal Geographical Society.
- FREEMAN, R. (1997)
 “Migration of Foreign Scientists & Engineers to the US” Sloan Foundation Workshop 21 May, <http://econ.bu.edu/ied/saesum.html>
- GOVER & HURRAY (1998)
 “The US Engineers Shortage-How Real?” in *Research Technology, Management*, November-December 1998.
- GAILLARD, J., A.M. GAILLARD (1998)
 “The International Circulation of Scientists and Technologists: A Win-lose or Win-Win situation?” *Science Communication*, Vol. 20 No. 1, September 1998 106-115.
- HESA: Higher Education Statistical Agency, unpublished data.
- HSIAO, R. (1997)
 “Global Competition and Knowledge Migration”, Report no, D97-2048, SRI Consulting, Surrey, UK.
- IDP Education Australia (1995)
 Source quoted in *Virtual Mobility: New Technologies and the Internationalisation of Higher Education (1998)*. Nuffic Papers 10, The Hague.
- JOHNSON, J. M. & M. REGETS (1998)
 “International Mobility of Scientists and Engineers To the US - Brain Drain or Brain Circulation?” NSF Issue Brief 98-316, June 22, 1998.
- KEEBLE, D. (1989)
 “High-Technology Industry and Regional Development in Britain: The case of the Cambridge Phenomenon,” in *Government and Policy*, 7: 153-72.
- KRETSCHMER, H. (1997)
 “Patterns of Behaviour in Coauthorship Networks of Invisible Colleges” in *Scientometrics*, Vol. 40. No. 3. Nov-Dec. 1997.
- KRITZ, M. and F. CACES (1992)
 “Science and Technology Transfers and Migration Flows”, in Kritz, LIm, & Zlotnik, *International Migration Systems: A Global Approach*, Clarendon, Oxford, pp. 221-44.

- LAMBERT, R. D. (1992)
“Foreign Student Flows And the Internationalisation of Higher Education” American Council on Education/Series on Higher Education.
- LEWIS, P. & T. STROMBACK (1998)
Recent Trends in Skilled Labour Movement, a report for DIMA- Department of Immigration & Multicultural Affairs, 1998, <http://www.immi.gov.au/research1/recent.htm>
- MAHROUM, S. (1998)
“Europe and the Challenge of Brain Drain” IPTS Report, November No. 29.
- MAHROUM, S. (1999)
“Patterns of Academic Inflows to UK Higher Education System” *Higher Education in Europe*, The Entrepreneurial University: How to Survive and Prosper in an Era of Global Competition Vol. XXIV, No. 1. 1999.
- MAHROUM, S. (1999)
UK Global Magnets of Excellence.
- MARTIN-ROVET, D., T. CARLSON, J. RICHARDSON, K. BRENNAN (1991)
“American Scientists in France”. *Laboratoire d’Evaluation et de Prospective Internationales*, Paris.
- METCALF, H. (1995)
Future Skill Demand and Supply: Trends, Shortages, and Gluts, edited by H. Metcalf. Published by Policy Studies Institute (PSI).
- MILLER, E.A., Miriam LAUGESEN, S., D. LEE, S. MICK (1998)
“Emigration of New Zealand and Australian Physicians to the US and the international flow of medical personnel” in *Health Policy* 43.
- MOUNTFORD, A. (1994)
“Can a Brain Drain be good for Growth?”, Center for Economic Research, Tilburg University, P.O. Box 9053, 5000 LE Tilburg, The Netherlands.
- NATIONAL SCIENCE FOUNDATION/SCIENCE RESOURCES STUDIES (1998)
Science and Engineering Indicators-1998. Arlington, VA.
- NATURE (1998)
“Singapore attracts foreign talent”, *Employment Review*, August 6 1988.
- NORTH, D. (1995)
“Soothing the Establishment: The Impact of Foreign-Born Scientists & Engineers on America” University Press of America, Inc.
- OECD (1995)
Manual on the measurement of Human Resources Devoted to S&T-Canberra Manual, OCDE/GD(95)77, Paris.
- OECD (1997)
Occasional Papers No 3, by John Salt “International Movements of the Highly Skilled”.

- OECD (1998)
Science and Technology Labour Markets: Analytical Framework,
- OECD (1998)
Science and Technology Labour Markets: Mobility and Flexibility.
- REGETS, M.(1997)
“Migration of Foreign Scientists & Engineers to the US”, Sloan Foundation Workshop 21 May, 1997. <http://econ.bu.edu/ied/saesum.html>
- SALT, J. and J. CLARKE (1998)
“Flows and stocks of foreign labour in the UK”, *Labour Market Trends*, July, 1998.
- Science And Engineering Indicators, 1998, NSF.
- SHAPIN, S. (1998)
“Placing the view from nowhere: historical and sociological problems in the location of science” in *Transactions of the Institute of British Geographers*, NS. 23 5-12.
- SIMON, J. (1987)
The Economic Consequences of Immigration into the US,
<http://www.inform.umd.edu/EdRes/Colleges/BMGT/.Faculty/JSimon/Immigration>.
- SONG, H. (1997)
“From Brain Drain to Reverse Brain Drain: Three Decades of Korean Experience” *Science, Technology, and Society* 2:2.
- STEIN, J. A. *et al.* (1996)
“International Education and Training of Scientists & Engineers and their Employment in European Industry” PREST Report, published by the European Commission.
- STRAUBHAAR, T. and A. WOLTER (1997)
“Globalisation, Internal Labour Markets and the Migration of the Highly skilled” *INTERECONOMICS*, July/August 1997.
- TEROUANNE, D. (1997)
Présence Française en Science et Ingénierie aux Etats-Unis : Cerveau en Voyage? Bureau du CNRS à Washington 1997.
- UNIVERSUM, (1998)
The European Graduate Survey. <http://home.universum.se/>

C. FOREIGN SCIENCE & TECHNOLOGY PERSONNEL IN THE UNITED STATES: AN OVERVIEW OF AVAILABLE DATA AND BASIC CHARACTERISTICS*

by

Dr. Mark C. Regets *National Science Foundation, Washington DC*

**The text and charts in this paper reflect my presentation and discussion of questions at the May 17, 1999 OECD Thematic Workshop on Science and Technology Labour Markets. It does not necessarily represent the position of the National Science Foundation.*

“There is no national science just as there is no national multiplication table”. - Anton Chekhov

Although there may well be different national styles in the organisation of science, science itself is a very international activity — in part because laws of nature do not change at national borders — but also because of large international movement of scientists and engineers. This includes the movement of students seeking degrees; short-term migration of S&E workers to multinational research projects conducted by businesses, academia, and government, and longer term migration that may include change in citizenship.

In the general international migration literature²⁵, there is much discussion of problems of skill transferability: the inability of migrants (particularly those moving from less to more developed economies) to fully use their home country human capital in their destination country. Regardless of funding sources, hierarchical structures, attitudes towards risk taking, and other factors that are identified as possible differences in national styles, it is clear scientific skills cross borders very well. The commonalties of tools, subject matter, and perhaps the role of English as a *lingua franca* all contribute to this.

Data sources

Major US data sources on foreign-born or non-citizen scientists and engineers include the following:

- **Immigration and Naturalisation Service Admissions:** This includes data only on those granted permanent resident visas (“green cards”) in the United States. The data is publicly available and includes information on an immigrant’s occupation and class of admission under US law. Unfortunately, even in the confidential version of this data set, there is no information on field of degree or level of education, and “occupation” in most cases represents a recording of information given on occupation in an immigrant’s country of origin, and not US occupation.
- **NSF Survey of Earned Doctorates:** This data comes from a short interview form filled out by all recipients of US School PhDs at time of degree. It includes information on place of birth, previous degrees, and immediate post-PhD plans.

25. A review of skill transferability issues is contained in “Immigrants and Human Capital Investment”, Harriet Duleep and Mark Regets, *American Economic Review*, May 1999.

- **NSF Survey of Graduate Students and Postdocs:** This is a survey of graduate departments of science and engineering in the United States. Data collected includes counts by field of graduate students and postdocs on temporary visas.
- **NSF SESTAT Workforce Data:** This is a collection of 3 complementary sample surveys, primarily of holders of science and engineering degrees at the bachelor's, master's and doctorate level. Three biennial longitudinal surveys are combined to form a portrait of the labour force with science and engineering degrees in the United States.²⁶

The National Survey of College Graduates (NSCG) is a sample of individuals with at least a bachelor's degree as of April 1990. In 1993, the NSCG included individuals with all fields of degree (include non-science and engineering), as well as all degree levels. In subsequent NSCG surveys in 1995, 1997, and 1999, individuals were dropped from the NSCG sample who did not have either an S&E degree or an S&E job in 1993, and those who had a S&E PhD from a US school. It is important to note that the NSCG does include information on degrees earned outside of the United States (including PhDs) and identifies the country of degree.

The Survey of Doctorate Recipients (SDR) is a biennial longitudinal survey of a sample of individuals residing in the United States who had received a science and engineering PhD from a U.S. institution at any prior time. The SDR was first collected in 1973.

The National Survey of Recent College Graduates (NSRCG) is a sample of individuals receiving BS and MS S&E degrees from US institutions after April 1990.

Together these three surveys create a profile of most of the science and engineering trained workers in the United States that NSF calls the SESTAT data system. An important gap for the discussion in this paper, it does not include any individual whose science and engineering credential is a degree from a foreign educational institution, unless that individual was resident in the United States in 1990.

At the PhD level, the SESTAT file showed 135 000 foreign-born Ph.D.s in science and engineering resided in the United States in 1993 — more than one quarter of the total (Table 1). PhD scientists and engineers came from all parts of the world, with slightly over half from Asia, and slightly over one-quarter from Europe.

Foreign-born individuals are an important proportion of those with science and engineering degrees even at the bachelor's and master's degree level. Ten per cent of those with S&E bachelor's and 18% of those with S&E master's degrees in 1993 were foreign-born (Table 2). At the BS level, the percentage of foreign born ranged by field of degree from 5% in the geosciences to 17% in civil engineering and chemical engineering.

At the master's and PhD level, even more so than at the bachelor's, the proportion of foreign-born is greatest in fields with high quantitative content, reaching around 40% for PhDs in engineering fields and in computer science.

26. Public use versions of SESTAT data, as well as publications using this data, are available from <http://srsstats.sbe.nsf.gov>

Table 1. Employed Foreign Born Science and Engineering PhDs in the United States

<i>All Foreign Born</i>	135 000
<i>% Foreign Born of Total S&E Ph.D.s Employed</i>	25.6
Place of Birth:	Total Employed:
Africa	7 000
Asia	76 000
China	21 000
India	21 000
Japan	3 000
Korea	4 000
Chinese Taipei	9 000
Central/ South America	10 000
Argentina	2 000
Brazil	1 000
Chile	1 000
Cuba	2 000
Mexico	1 000
Europe	38 000
France	1 000
Germany	6 000
Greece	2 000
Italy	2 000
Netherlands	1,000
United Kingdom	10 000
North America and Other	8,000

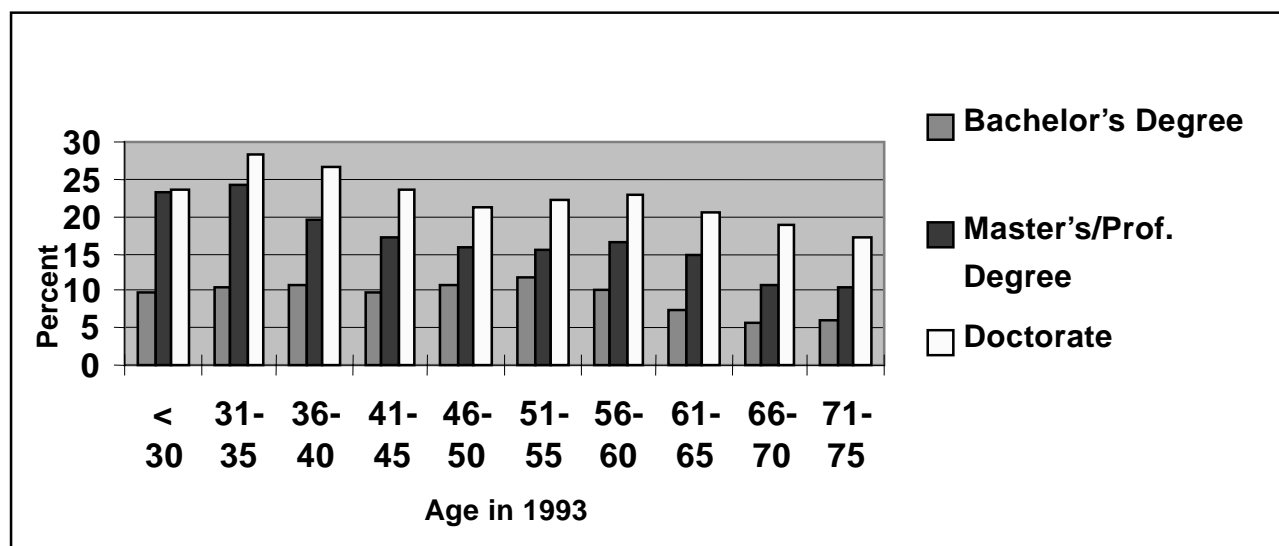
Source: NSF/SRS 1993 SESTAT data file.

Note: Numbers rounded to the nearest 1 000.

The importance of foreign-born scientists in the United States is not a new phenomenon or limited to younger scientists. Indeed, at the bachelor's degree level, the highest proportion is found for those aged 51 to 55 (Figure 1), but varies around 10% for all age groups up to age 60. At the master's degree and PhD level, the percentage of foreign born is also fairly constant over most age groups in the middle of the age distribution, but somewhat greater for younger scientists and engineers and less for scientists and engineers over age 65. Even these differences may represent in part temporary presence in the United States for graduate and postdoctoral training, and the emigration from the United States of some workers after retirement.

Many of the foreign-born scientists and engineers in the United States received their training outside of the United States. Roughly one third of foreign-born PhDs and half of them at the bachelor's degree level have their highest degree from a foreign educational institution (Table 3). While it is certainly true that students seeking US higher education is a major way that many scientific migrants first come to the United States, it is not our only source of S&E immigrants. In fact, scientists enter the United States labour force at all ages and stages in their careers.

Figure 1. Percentage of Science and Engineering Trained that are Foreign-Born by Age and Education



Source: NSF.

Table 2. Percentage Foreign Born Science and Engineering Trained Individuals (by high degree)

	Bachelors	Masters/Prof. Degree	Doctorates
Engineering	13.9	28.4	40.3
Chemical	17.0	32.5	38.6
Civil	17.3	36.4	50.6
Electrical/Electronic	14.8	28.6	39.1
Mechanical	12.8	30.3	38.1
Life Sciences	8.0	15.0	21.3
Agricultural	5.6	16.0	20.7
Biological	9.4	15.5	21.5
Math/Comp. Sciences	11.3	17.1	25.9
Computer	13.6	29.0	39.4
Mathematical	9.2	13.2	31.1
Physical Sciences	11.3	17.1	25.9
Chemistry	14.8	23.6	25.7
Geosciences	5.2	9.7	16.8
Physics/Astronomy	11.2	20.0	30.6
Social Sciences	6.7	10.1	13.1
Economics	11.1	25.5	23.6
Political Science	6.9	12.4	14.9
Psychology	5.9	6.1	9.0
Sociology/Anthropology	4.4	13.1	14.4
All Science and Engineering	9.8	18.0	23.0
Non Science and Engineering	6.8	7.7	12.4

Source: 1993 National Survey of College Graduates

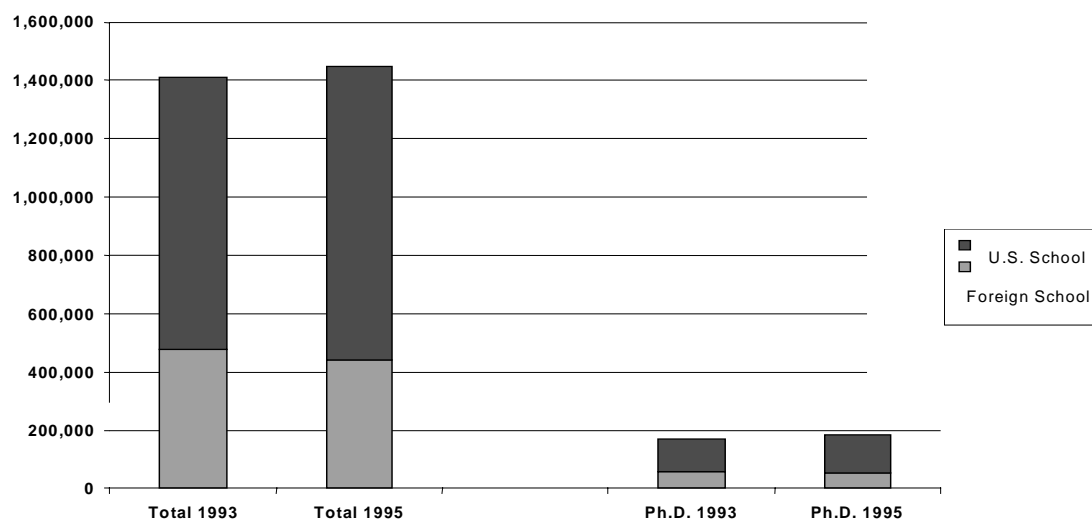
Table 3. Percentage foreign-born and foreign-educated in the United States by degree level

	Percent Foreign Born	Percent Foreign School for High Degree	Percent Foreign School
Bachelor’s Degree	7.8	4.0	5.7
Master’s Degree	9.6	2.6	7.6
Professional Degree	11.0	7.7	8.7
PhD	22.7	7.4	17.8
All Degree Levels	8.8	4.0	6.8

Source: 1993 National Survey of College.

The number of foreign-born scientists and engineers in the United States continues to grow (**Figure 2**), even as we lose our ability to keep an accurate count within the SESTAT data system. While the total estimated number of foreign-born scientists and engineers continues to increase, the number with foreign degrees within our data system decreases — something that is highly unlikely to be true. Since 1992, changes in US immigration law have allowed increases both in the total number of immigrants, and in the number entering with employment-based visas. However these recent migrants will be reflected in NSF statistics only to the extent they have US science and engineering degrees. There have been some recent decreases in fulltime non-citizen enrolment in US science and engineering (Figure 3). The exception is in computer science, where non-citizen enrolments have been increasing rapidly since 1995.

Figure 2. 1993 and 1995 SESTAT Counts of Foreign Born S&E By Place of High Degree



Source: SESTAT.

Figure 3. Number of Fulltime Non-Citizen Graduate Students in US S&E Departments

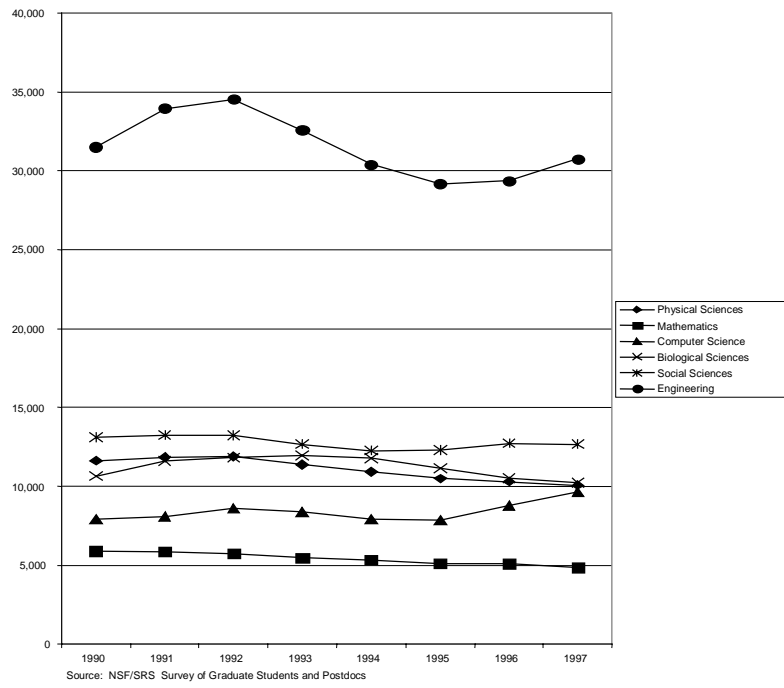
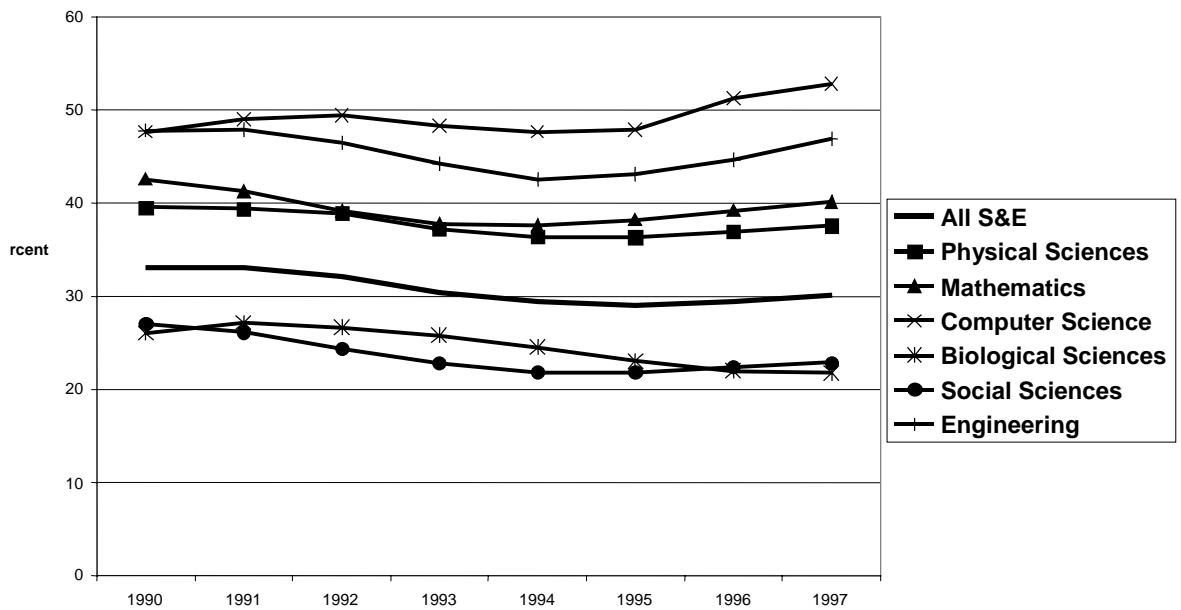


Figure 4. Percentage of Full Time Non-Citizen Graduate Students in US Science and Engineering Departments



Source: NSF/SRS Survey of Graduate Students and Postdocs.

This decline in non-citizen enrolments can also be seen as a decline in the share of total full-time enrolment in science and engineering (Figure 4). This is a less dramatic decline than that seen for the number of non-citizen students, since native US attendance in science and engineering graduate programmes also declined over this period. Computer science and engineering had notable increases in the late 1990s in the number of non-citizen graduate students, with over half of fulltime graduate students in computer sciences being non-citizen.

One important question for both host countries and sending countries is what proportion of these foreign students will ultimately stay in the United States. Recent work by Michael Finn at the Oak Ridge Institute for Science and Education uses US Social Security tax records to examine this for those earning science and engineering PhDs in the United States while holding temporary visas. This stay rate differs by both field of degree and country of origin.

Looking at 1990-1991 S&E doctoral recipients, 47% were still in the United States in 1995 (Table 4). By country of origin, the percentage still in the United States in 1995 ranged from 11% and 13% for Korea and Japan, to 88% for PhD recipients from China²⁷ and 79% for India. Little research has been done into reasons for differences in the stay rates, but a common speculation is that they are related at least in part to the quality of the employment opportunities in a student's home country.

Stay rates for 1990-1991 temporary visa S&E PhDs by field (Table 5) ranged 28% in the social sciences to 53% in the mathematical and physical sciences, and in engineering. Nearly identical stay rates are found for the 1970-1972 cohort of temporary visa PhD recipients in 1995 as for the more recent cohort. Other tables not reproduced here suggest stable stay rates over time even when following the same graduation cohort. However there is much anecdotal evidence, supported in part by NSF SESTAT longitudinal data, that it is common for foreign-born PhDs to leave the US at various stages in their careers, and not just right after graduation. One unconfirmed possibility is that the stay-rate stability found by Finn results from a mix of PhDs leaving and returning to the United States. This hints at a more complex international flow of scientists and engineers and corresponding flow of ideas than would a simple "brain drain" model.

Table 4. 1990-91 Foreign doctoral recipients from US universities working in the United States, by country of origin: 1995

Country	Foreign Doctoral	% working in US in 1995
China	2 779	88
India	1 235	79
Japan	227	13
Korea	1 912	11
Chinese Taipei	1 824	42
United Kingdom	142	59
Germany	177	35
Greece	240	41
Canada	417	46
Mexico	194	30
Total S&E fields	13 878	47

Source: M.G. Finn, Stay Rates of Foreign Doctorate Recipients from US Universities, 1995 (Oak Ridge Institute for Science and Education).

27. Stay rates for Chinese students may have been particularly high for this cohort due to the 1991 Chinese Student Protection Act, which made it easier for Chinese citizens in the United States at the time of the Tiananmen Square conflict to receive permanent visas.

Table 5. Foreign recipients of US PhD. degrees residing in the United States in 1995 (Percentages)

	1990-91 PhDs Temporary and Permanent Visas	1970-72 PhDs Temporary and Permanent Visas
All S&E	47	47
Life sciences	45	36
Physical sciences and mathematics	53	57
Social sciences	28	30
Engineering	53	58

Source: M.G. Finn, Stay Rates of Foreign Doctorate Recipients from U.S. Universities, 1995 (Oak Ridge, TN: Oak Ridge Institute for Science and Education, 1997).

That international flow does to some degree include US scientists and engineers working outside of the United States. A lower bound estimate of US PhDs abroad is possible using administrative records generated when collecting the 1995 Survey of Doctorate Recipients (Table 6). Counting only those positively identified by survey collectors as residing outside of the United States, 3% of native born S&E PhDs, 7% of the foreign-born who had US citizenship at the time of their degree, and 14% of those with permanent residence visas at their degrees (many of these in fact had citizenship at the time of the 1995 survey). This suggests that an important source of US ties to foreign science is family and educational ties to another country by foreign-born PhD graduates of US universities.

Not included in this table are those who had a temporary visa at the time of their PhD, but who may have later acquired US permanent resident status or citizenship, as do a majority of long term immigrants to the United States. However, it may be reasonable to assume that they are at least as likely as PhDs with citizenship at the time of their degree to be working outside of the United States.

Table 6. Lower bound estimates of US citizens and permanent resident PhD graduates residing outside the US: 1995

	Native Born		Foreign-born with citizenship at time of PhD		Permanent resident at time of PhD		Total citizen or permanent resident at time of PhD	
	Number Abroad	Percent of Total Abroad	Number Abroad	Percent of Total Abroad	Number Abroad	Percent of Total Abroad	Number Abroad	Percent of Total Abroad
All S&E	13 900	3.3	1 400	7.4	4 300	13.6	19 600	4.1
Life Sciences	3 400	2.7	200	5.0	900	12.0	4 500	3.3
Math and Computer Sciences	1 000	4.2	100	4.2	200	10.2	1 200	4.6
Physical Sciences	2 200	2.5	300	8.7	800	12.6	3 200	3.3
Social Sciences	5 900	4.2	300	7.5	1 200	18.0	7 400	4.9
Engineering	1 500	3.0	500	9.1	1 300	13.1	3 300	5.0

Source: National Science Foundation, Science Resources Studies, Doctorate Record File and administrative records associated with collection of the 1995 Survey of Doctorate Recipients.

Another sign that international collaboration is aided by the international enrolment in US graduate programmes is the close relationship between collaborations in publishing between authors at US research institutions and research institutions in another country, and the number of US PhDs received by natives of that country. Specifically, the correlation between the log (number of 1986-1990 US S&E PhDs) and the percentage of a country's multinational authored papers that had a US author, was a positive .61.

This is not a perfect measure²⁸, but it does show a plausible association. Although it is not possible to quantify from this data source, these collaborations can take many forms -- between a foreign born scientist working in the US and a scientist from his country of origin, between a native US scientist working in the US and a former graduate student, or any of the other possible exchanges that can originate with individuals seeking science degrees outside of their home countries.

For all of the discussion of brain drain, versus brain gain or brain circulation, there remains a great deal of policy discussion of the effect of foreign scientists upon the United States. In general, foreign scientists do very well in the United States compared to natives with similar age, education and field of degree -- earning more, being more likely to engage in research and development, and for PhDs report publishing more articles. Differences in R&D as a primary or secondary work activity are shown in Figure 6 for science and engineering doctorates by field, nativity, and country of degree. In general, the highest involvement in R&D is found for foreign-born scientists with US degrees.

There are no good comprehensive studies of the impact of immigrant scientists on the opportunities available to native scientists or would-be native scientists. To the extent that spending on education, research, development, and other science intensive activities is considered fixed, foreign scientists could only damage the salary and employment prospects of native scientists²⁹. To the extent that R&D and other spending by industry and government is responsive to opportunities for new products and new knowledge, foreign scientists could actually increase the opportunities available to native scientists. As a thought experiment, what would happen to the size of the science and engineering enterprise in the United States if the foreign born quarter of PhD scientists had never migrated? Would it be almost the same size as more natives entered to take over opportunities? Would it be one-quarter smaller? Would the size of the US science and engineering enterprise fall by much more than a quarter as the US became a less desirable place to conduct research and the rate of new knowledge creation slowed?³⁰ Policy discussion on the migration of scientists and engineers to the United States often appears to be based implicitly or explicitly on one of these three scenarios.

Some data that do exist just provides the relationship between the number of foreign-born scientists and other measures of labour market conditions. Figures 7 and 8 relate the proportion of foreign-born among recent science and engineering PhDs who are resident in the United States, to measures of labour market conditions in each S&E field. The involuntarily out-of-field (IOF) rate is one reasonable³¹ measure of labour market distress for PhD holders. Across major science and engineering fields, there was a negative correlation (-.36) between the percentage of foreign born and the IOF rate for recent PhDs (Figure 7). Similarly, there is a positive correlation (+.75) between the percentage of foreign born and median salaries for recent PhDs. In general, the highest proportion of foreign-born PhD scientists and engineers are found in fields with good labour market conditions. This association does not prove any particular path of causation -- healthy fields of study may draw more immigrants or more immigrants may make for a healthier field.

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- 28 . Aside from unresolved issues of what causes what, a conceptually better measure would use the percent of a country's S&E PhDs that are US educated, but this data is not available for most countries.
- 29 . Although a substitute for native scientists in a scenario where spending on R&D is fixed, foreign scientists would still presumably be a compliment to the labour of other natives and raise their wages.
- 30 . It is possible that scientists will be just as productive regardless of where they are located. But comparative opportunities to do research and to form particular collaborations are also a reason that a scientist might want to migrate across borders in the first place. Policies that restrict such migration might reduce world output of new knowledge and not just the amount produced within a national border.
- 31 . This measure appears to work particularly well for PhDs, who have made a significant investment in a particular field of knowledge, but whose high general skill level may make unemployment rates a poor measure of actual labour market distress.

**IMPROVING THE CONTRIBUTION OF S&T PERSONNEL TO SCIENTIFIC DISCOVERY,
INNOVATION AND GROWTH**

**A. THE PUBLIC-PRIVATE PARTNERSHIP TO MEET THE DEMAND FOR IT SKILLS:
PROGRAMME FOR INCREASING EDUCATION IN THE FIELDS
OF INFORMATION INDUSTRY IN FINLAND**

by

Jari Jonkinen, *Project Manager, Ministry of Education, Department for Education and Science,
Helsinki, Finland*

Abstract

This paper briefly describes the activities carried out in Finland to ensure the availability of the qualified workforce in one rapidly growing field i.e. information industry. The paper also shortly illustrates the development of some key figures of the information industry in the 1990s in Finland and the changes in Finnish polytechnics, universities and in vocational training concerning this field.

Background

Information Industry in Finland - Some key figures

Finnish industry has traditionally had two strong branches, the pulp and paper industry and the heavy metal industry. However, in recent years the third strongest sector, the information sector, has arisen to challenge the two older sectors. In the 1990s, the information sector has mainly been responsible for increasing exports, the number of employees and production in Finland.

In 1997, enterprises in the information sector accounted for 11% of the turnover of all enterprises and 10% of their personnel in Finland. Industrial information technology products were valued at FIM 39 000 million in 1996, representing an average annual rise of some 37% over the period 1991-96. The figure for other industrial products at the same time increased by about 11% a year. Information technology exports amounted to FIM 46 000 million in 1998, more than 20% of the total value of Finnish exports.

A total of 112 000 persons were employed in the information sector in 1997, 31% in the production of goods, 37% in the production of services and 32% in content production. The information sector accounted for almost 13% of the total expansion in the employed labour force in 1996/97. Half of the new industrial jobs involved the production of goods in the information sector, which thus occupied a particularly prominent role in overall employment. The labour force in the information sector is relatively young compared with employed persons as a whole, 44% being under 35 years of age as opposed to the 32% in the active labour force in general. This effect was most prominent in the production of goods, where as many as 58% were aged under 35 years.

The information sector has also attained a remarkable role in research in Finland. Research expenditure in Finland in 1997 amounted to FIM 17 000 million, of which FIM 11 000 million took place in enterprises. Information sector enterprises accounted for some 61% of all research expenditure in enterprises.

Anticipation of training and recruitment needs - a project based approach

The Ministry of Education has financed several projects anticipating the training needs in the fields of information industry, both in electronics and the electrical industry and in the new media industry.

According to the survey carried out by the Federation of Electronics and Electrical Industry the proportion of personnel in electrical and electronic industry in production will decrease from 54% to 45%. At the same time the share of personnel in R&D functions will increase from 30% to 38%. Taking into account the age distribution of the current personnel, the study indicates that the increase of personnel in the Finnish electronic and electrical industry will be approximately 31 000. The need for new employees in R&D function would be more than 16 000 and in production about 8 000 persons between the years 1997-2002.

In February 1998, the Federation of Finnish Industries published a survey concerning recruitment needs in the Finnish industry in 1999-2001. According to the survey the required number of new employees in enterprises in the field of the electronics industry would be approximately 7 000 and in the electrical industry approximately 500 during 1999-2001. In Finland, the software industry turnover in 1998 was approximately FIM 10 billion, giving employment to around 20 000 people. In February 1999, TEKES, the National Technology Agency, published a report according to which the sales of the Finnish software industry were expected to increase to FIM 70 billion. The number of new jobs being created in the software industry has been estimated at more than 2 000 in 1999, 3 000 in 2003 and over 5 000 in 2006.

According to the report "Job Profiles and Knowledge Requirements in the Finnish New Media Industry 1999", the Finnish new media companies will recruit approximately 1 000 new employees between 1999-2001. The report estimates the total impact on employment brought about by new media applications and solutions to be a great deal larger.

Education provision in the information industry fields

Education provision in the information industry fields increased substantially in recent years. From 1993 to 1998, university education almost doubled and polytechnic education tripled. In addition, the information industry has been a special target area in the provision of continuing professional training partly or totally financed from public funds. According to studies undertaken by the Ministry of Education and results of the anticipation projects, four of which were described above, the growth in the field is, however, so rapid that the graduation rates still did not adequately meet the recruitment needs of enterprises. University graduates are expected to be in particularly short supply. The situation is complicated by the fact that the increases already effected in enrolments take time to show in the number of graduates -- the delay in university degrees is at least six years, and four years in polytechnic degrees.

Education, training and research in the information society - a national strategy for 2000-04

In December 1998, the Ministry of Education set up a working group to prepare a proposal for a National Strategy for Education, Training and Research in the Information Society for 2000-04. This strategy is a sequel to the Strategy for 1995-99 described earlier. The National Strategy for Education, Training and Research in the Information Society for the first years of the new millennium can be crystallised in the following vision: By the year 2004, Finland will be one of the leading knowledge and information societies. Success will be based on citizens' equal opportunities to study and develop their own knowledge and extensively utilise information resources and educational services. A high-quality, ethically and economically sustainable mode of operation in network-based teaching and research will have been

established. The overall theme of the strategy, the systematic development of learning environments based on research can be divided into six sub-themes:

- Information society skills for all.
- The information society skills of educational staff.
- The knowledge of professionals in the information and content industries.
- The consolidation of virtual learning environments.
- Electronic publication, classification, and distribution of research information and teaching material.
- Strengthening structures of the information society.

The Ministry of Education has established an action programme to implement the aims of the strategy. The Department of Education and Science Policy of the Ministry of Education is in charge of co-ordinating the Strategy. The programme for increasing education in the information industry fields is a significant part of the implementation of the strategy.

Programme for increasing education in the information industry fields 1998-2002

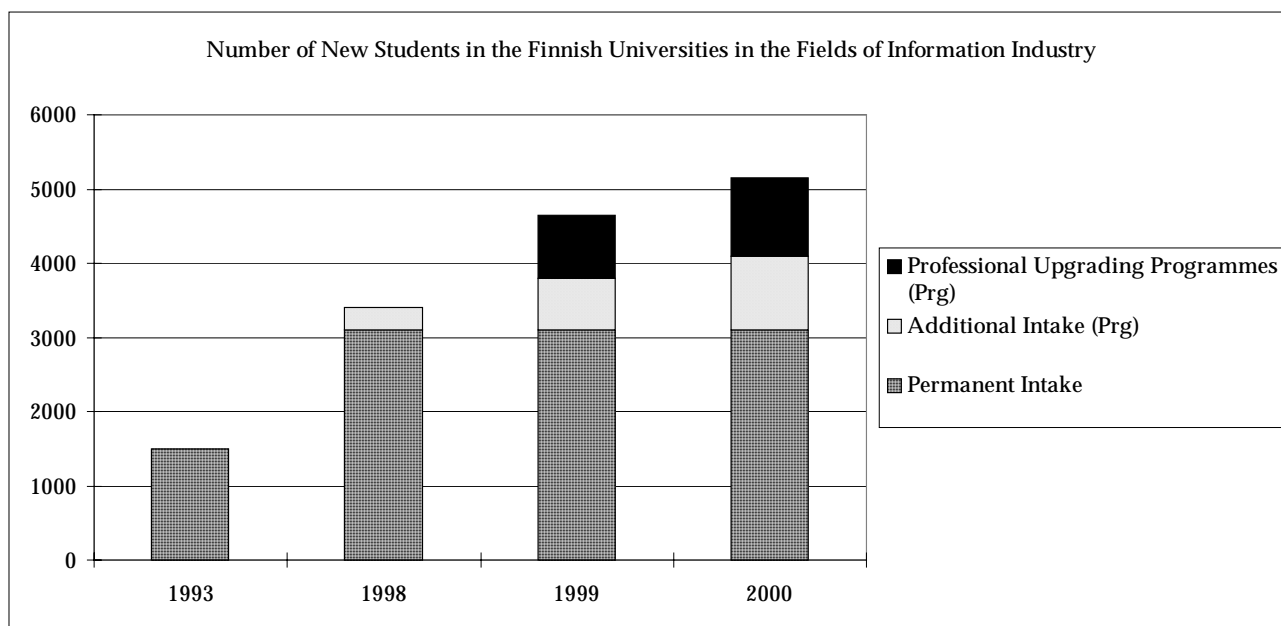
In March 1998, the Government adopted a programme which will increase education relating to the information industries between 1998 and 2002. The programme includes both *ad hoc* measures for promoting know-how and increasing the number of graduates in the near future and permanent increases in the provision of university and non-university professional education.

The programme will concern over 20 000 students between 1998 and 2002.

Universities

- Enrolments in universities will be increased from the projected 1998 level by 1 000 new students by the year 2000.
- Between 1998-2002, universities will admit a total of 5 150 new students to professional upgrading programmes.
- In researcher training, 60 new posts for postgraduate students will be established by 1999. The number of postgraduate student posts in the fields of information industry totals 248 in 1999.

Table 1. Number of new students in the Finnish universities in the fields of information industry (1999 and 2000 prognoses, Prg. refers to the Programme)

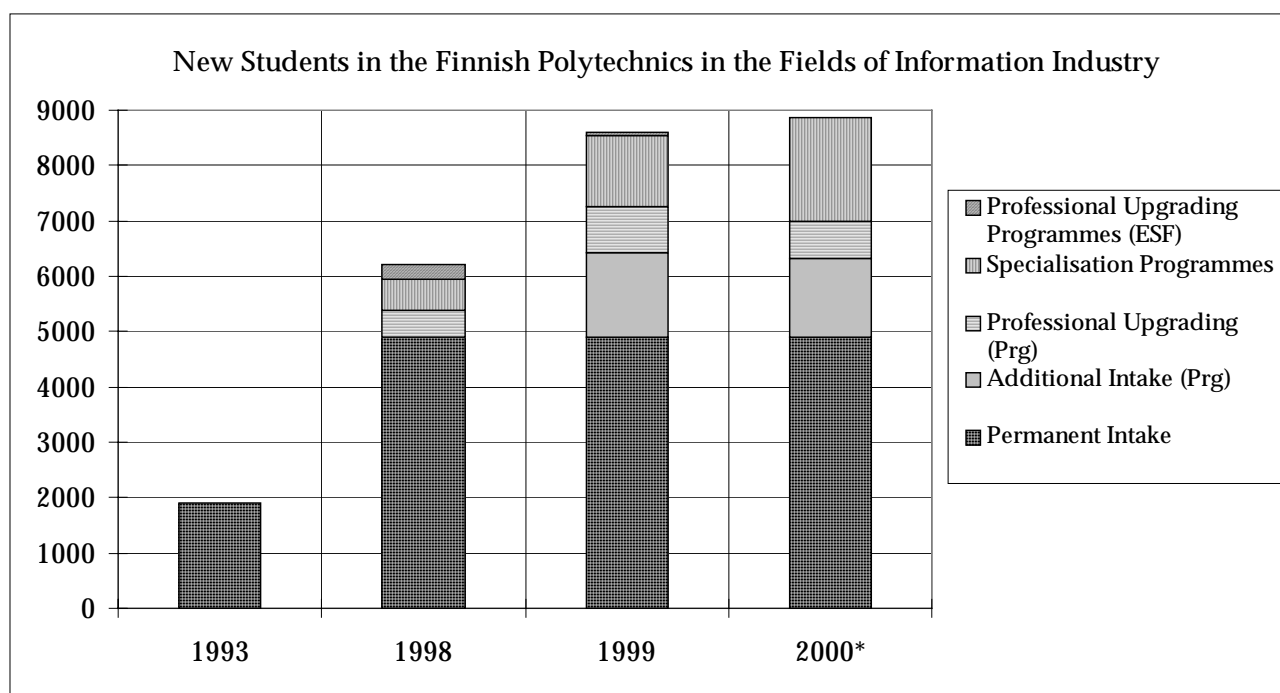


Source: Author.

Polytechnics

- In the year 2000, there will be 1 400 more enrolments in polytechnics than the permanent provision in 1998.
- Between 1998-2002 polytechnics will admit a total of 2 400 new students to professional upgrading programmes.
- Polytechnics will admit 2 400 new students into specialisation programmes between 1998-2002.
- 1 000 new students from related fields to take up subjects relating to the information industry.

Table 2. Number of new students in Finnish polytechnics in the fields of information industry (1999 and 2000 prognoses, Prg refers to the Programme, ESF refers to projects funded by the European Social Fund)



Source: Author.

Vocational institutes

- Between 1998/99 vocational institutes will admit a total of 400 new students to professional upgrading programmes.

The professional upgrading programmes aim at rapidly increasing the number of graduates in the sector. The target group of the upgrading programmes are those who want to upgrade their degree either from a lower level (e.g. Polytechnic) to a higher level (e.g. University) or from another sector to the information sector. The professional upgrading programmes typically take two to four years to complete. The specialisation programmes in the Polytechnics are education programmes for those with a degree from a polytechnic who wish to upgrade their skills and know-how in the field concerned. In addition, the provision of continuing education and apprenticeship training will be expanded in the information industry fields.

The cost of the programme

The *ad hoc* measures included in the programme will require a total of FIM 780 million (US\$143 million) in public funding between 1999 and 2002. The expenditure on the permanent increases in educational provision will amount to FIM 440 million (US\$81 million) per year by 2006.

Industry contributes to the programme

Industry will also contribute to the implementation of the programme. Enterprises will provide internships, avoid recruiting students before graduating and enable and encourage undergraduate students to graduate. Moreover, industry will encourage and promote their experts to participate in training and education in polytechnics and universities and support universities and polytechnics by donating the necessary equipment for educational and research purposes.

The contribution from industry has been secured in several ways. For example, during 1998 more than 500 experts from industry have contributed to education in polytechnics and universities. In March 1999, 26 companies donated about FIM 50 million (USD 10 million) worth of equipment and computer programmes to three major universities in the programme and further donations and collaboration programmes will follow.

Monitoring and evaluation

The Ministry of Education has established a monitoring group to support and monitor the implementation of the programme. In order to ensure the quality of the training programmes, the Ministry of Education launched an evaluation of the education programmes in fields of information industry. The evaluation will be carried out by the Higher Education Evaluation Council and will include an independent international evaluation. The first part of evaluation should be completed by the end of 1999.

REFERENCES

FEDERATION OF FINNISH ELECTRONICS AND ELECTRICAL INDUSTRY

ELEKTRONIIKKA-JA SAHKOALAN ENNAKOINTI (1999)

Anticipation of the training needs in the Electronics and Electrical Industry. Helsinki, 1999.

FEDERATION OF FINNISH INDUSTRIES

Teollisuuden osaamistarveluotain 2/98. Helsinki, 1999.

MINISTRY OF EDUCATION

Heikki MAENPAA, Kirsi KANGASPUNTA, Tarja OLENIUS, Ari SAARINEN (1997)

Tietoteollisuuden koulutustarveryhmä (Working Group on Training Needs in the Field of Information Industry). Tietoteollisuuden koulutuksen lisätoimenpideohjelma 1998-2002 -

Programme for Increasing education in the Fields of Information Industry 1998-2002, Helsinki.

ISSN 0359-761X. ISBN 952-442-000-7.

MINISTRY OF EDUCATION

Education, Training and Research in the Information Society A National Strategy for 2000-2004.

Nykypaino, Helsinki, 1999. ISBN 952-442-228-X.

PELKONEN, TOMMI (1999)

Job Profiles and Knowledge Requirements in the Finnish New Media Industry 1999. Oy Edita Ab, Helsinki. ISBN 951-735-344-8.

STATISTICS FINLAND. (1999)

On the Road to the Finnish Information Society II. University Press, Helsinki. ISBN 951-727-639-7.

B. SCIENCE AND TECHNOLOGY LABOUR MARKETS: RELEVANT ASPECTS OF SUPPLY AND DEMAND

by

Dr. Carlo Corsi, Director Roma Ricerche, *Rome*

Abstract

The strategic importance of a deep and solid culture in science and technology is generally accepted for sustaining the growth of future socio-economic systems. Consequently, great efforts have been made by the most advanced countries to develop education and training in S&T and a high-tech culture as strategic tools for future wealthy economy.

This general approach appeared very successful up until the end of the 1980s, but recently evidence of differences in labour market outcomes in various OECD countries have emerged. Differences in the match between the supply and demand for science and technology skills in the labour market are evident among very high-tech and strong economies such as the United States and other advanced countries but also in weaker advanced economies such as Italy.

In fact, although recent statistics are lacking, it appears the unfavourable economic situation that originated from the crisis in the large high-tech companies in Italy is having a negative effect on the labour market and is resulting in a considerable reduction in the hiring of highly skilled employees. This is happening especially in large industries operating in markets showing various, although different, signals of structural crisis (military production, hardware electronics, etc.), but it is also limiting the potential of newer high-tech sectors such as biotechnology.

Surely, a compensating trend has been the movement of personnel with high-tech skills towards advanced “tertiary” sectors such as multimedia services, office automation, etc as well as the higher education sector. In conclusion, although the high-tech sector is among the most promising for the future, it has not generated that many new jobs, especially for workers with science and technology skills. In addition, the development of personnel with high-tech skills appears to be geared towards improving the quality of labour in sectors dominated by more mature technologies.

Background

Given the strategic importance of science and technology to future socio-economic systems, the most advanced countries are investing a great deal in sustaining the growth of S&T especially technological innovation. There are many complex phenomena involved in this process and it is not only difficult to clearly define the objectives, but also to establish and quantify the results of investments in S&T.

This is particularly true with regard to the impact on the labour market for human resources in science and technology. First, some general considerations are needed in order to carry out an analysis based on the scientific approach.

BACKGROUND SCENARIO

- The strategic importance of science and technology is evident and generally accepted for sustaining the growth of future socio-economic systems.
- Government interventions have resulted in large amounts of money being invested at national and international level (e.g. European Union Framework Programme).
- During the 1970s, most of these efforts were dedicated and oriented towards R&D. In subsequent years, the focus has shifted towards innovation development and technology transfer.
- Governments have identified various measures and compared them across countries quite satisfactorily. However, the quantification of results remains a difficult task.

Globalisation is influencing and sometimes imposing new rules in socio-economic spheres worldwide, especially in advanced countries. This means that the objectives and rules guiding developments in science and technology, especially innovation-based technologies, are strongly conditioned by globalisation. This process highlights the importance of national competitiveness in science and technology for success in global markets. At the same time, there is a strong influence on the labour market in those strategic activities that depend on the application of R&D results. Thus at the international level, the scope for acting and *working* in science and innovation is more and more conditioned by the possibility of applying the R&D results to product development and commercialisation in the global market.

Objectives of government policy and results

The main objectives of government policies for sustaining research and innovation have been the improvement of technical, industrial and economical aspects, including employment. This was generally true at the time when economies were operating in well-defined territories, mainly within national borders, and when international co-operation in technology was strongly conditioned by the prominence of manufacturing in the country importing knowledge. This is generally no longer the case mainly because of globalisation. Increasingly products are manufactured where the ratio between cost and performance is at a minimum and where there is also a strong knowledge-based infrastructure.

This is particularly true in high technology, especially in scientific fields, where the gap for “followers”, not only third countries, but even “second countries”, is increasingly widening. Moreover, insofar as science and technology are first level activities (i.e. fields where either “one is first or nothing”), it is clear that the relevance of what, how and where science and technology is carried out is conditioning the labour market in high technology. The complex and often unfavourable situation of the labour market in OECD countries has raised greater attention to the outcomes of the relations between technology innovation and the creation of new business and jobs.

For reasons mentioned above, a tentative analysis of the present situation and even more of future trends is not easy and surely depends on complex phenomena such as globalisation, technological culture and attitudes, and industrial strengths and economical cycles (conjunctural versus structural).

GOVERNMENT POLICY OBJECTIVES AND RESULTS

The main objectives of government policies for sustaining research and innovation have been concentrated on improving technical, industrial and economical aspects while less attention was specifically paid to improving jobs and employment creation.

The weak labour market situation in OECD countries has resulted in a major focus on the outcomes of the relationships between technology innovation and the creation of new business and jobs.

A tentative analysis of the present situation is complex and is conditioned by phenomena such as the impact of globalisation, technological cultures and industrial capabilities and economic trends.

At the same time, some observations as to the future trends in the labour market for science and technology personnel can be made. First, globalisation has a strong impact on innovation technology development and transfer thus exerting consequences for the labour market. This means that investments in science and technology are obliged to follow rules and evaluation criteria that are strongly based not only on the scientific and technological achievements, but also on the applications aimed at the creation of new products and/or processes. In this way, most of the criteria for successful results are governed by the rules of competition and therefore the "winning" technologies (and quite often the winning societies and countries) will impose themselves in science and technology. The weaker countries however, will pay for their dependence with a reduction of their R&D activities and with negative constraints on the labour market.

Moreover, this phenomenon is spreading to most high-tech activities, i.e. to the major part of high value or high return products. This worsens the labour market in general and provokes a negative spiral between the lowering of high-technologies activities, diminishing the quantity and quality of high-tech employers. The rapid pace of innovation is generating more and more power (cultural and economical) in the first, advanced countries. However, it is causing problems, even of a reduction in jobs in the countries which cannot meet the challenge and, in some way, are suffering due to the innovation technology developments in the most advanced countries. These laggard countries are obliged to pay for the know-how to be active, in some way, in the global market.

This problem is particularly notable in some other advanced countries (e.g. Italy) which were among the first countries to produce highly specialised, high-tech products (e.g. refined mechanics, etc.). As globalisation imposed the rule of being the first or otherwise becoming a secondary actor, these countries, for various reasons (economic situation, limited culture of risk taking and contained size of the industrial structures), were suffering the constraints of the new situation.

Moreover, another aspect of the globalisation process was that the integration and merger of industries has directed strategic activities towards the greatest industries and towards centres of excellence on the global scale. This gave more and more power and consistency to the leading countries, especially the United States, but also to certain centres of excellence in niche markets in other countries. Most of Italy's centres of excellence were quite active and efficient, although few attained the level of success achieved in other European countries (e.g. the Mobile Telephones in Finland, advanced Microsystems Technology in Sweden and Norway, high-tech Sw and Hd microelectronics in Ireland etc.).

GENERAL CONSIDERATIONS

Globalisation phenomena are impacting over human life aspects and are strongly influencing innovation technology development and transfer.

Innovation technology (and even “innovation *per se*”) is a key factor for socio-economic growth and therefore greatly influences employment creation and maintenance.

Innovation technology is strongly affecting the economy but needs high investments in human and capital resources.

High-tech countries are becoming richer, acquiring capital investments for sustaining high-tech developments in a positive spiral.

Excellence in science and technology is only possible at the highest global level.

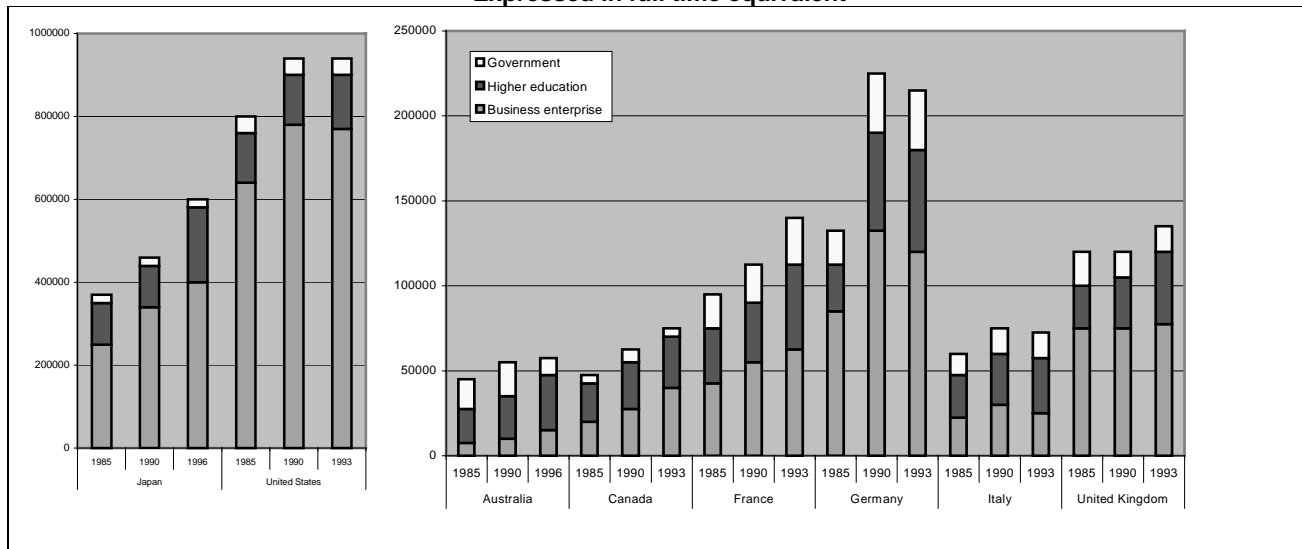
Secondary roles for economies cannot be sustained in the long run. In the future, economies will be obliged to unite as powerful entities.

The Italian situation

Due to reasons mentioned above, mainly weak investments in R&D in recent years (R&D investments in Italy are lower than in most advanced countries), but also due to stricter fiscal policies in light of EU engagements, the Italian situation is characterised by weak job creation in the higher technology sector where Italy, despite its size, had assumed a leading international role.

This is evident in some key strategic sectors such as microelectronics and biotechnology, sectors where the presence of large high-tech industry is needed for sustaining a high level of investment. In recent years a restructuring process has been carried out. Among other developments in recent years, the movement of a growing share of young researchers to the advanced professional training sector has become clear. This movement has been directed mainly towards the high-level research activities sponsored by grants for Research Doctorates and which have partially compensated the reductions in the large company R&D Centres. On the other hand this phenomenon is clearly emerging in all high-technology countries that have recently shown, due to reasons cited above, a large shift of their intellectual resources from the R&D sector towards higher education. The most evident examples are Germany, the United Kingdom and most recently, Japan (Figure 1).

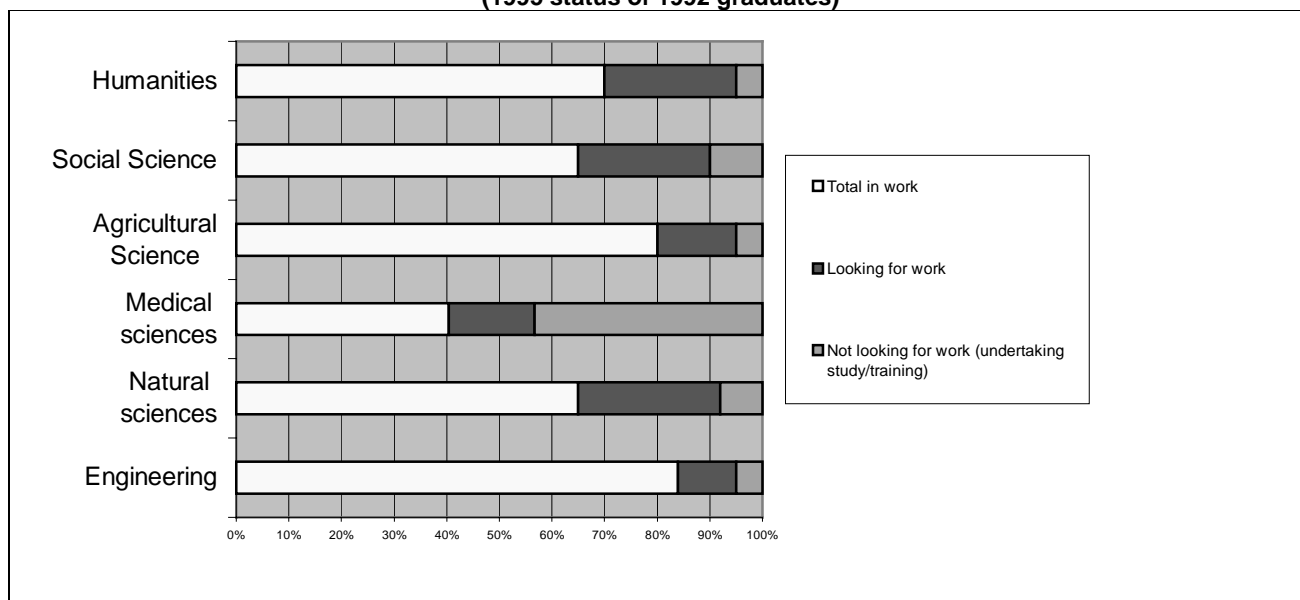
Figure 1.
Number of researchers by sector of employment, 1985, 1990, 1996
Expressed in full time equivalent



Source: OECD.

This trend has been aggravated by the absence of a positive attitude of flexibility and mobility for employment in highly specialised activities. This greatly influences the chances of getting experience and access to highly specialised training which is needed for high technology. So the employment possibilities for young researchers worsen at a time when the market already shows signs of "industrial" crisis, even in the high-tech sectors (Figure 2).

Figure 2.
Labour market status of first degree (Laurea S&T graduates in Italy
(1995 status of 1992 graduates)



Source: OECD calculations based on data from ISTAT – Italy (G. Sirilli).

The increase in specialisation is narrowing the field of technological application. The high rate of innovation is increasing the “use of the right specialisation at the right time” and decreasing the value of flexibility.

The narrowing of technical specialisation results in a more rigid and selective form of job creation. Although higher salaries usually compensate this, such a narrowing of specialisation reduces the “cultural flexibility” of the highly specialised personnel.

Recent policy actions

At the national level, the strong acknowledgement of the importance of R&D in high technology for socio-economic development has resulted in important legislative action to sustain social and cultural growth in the high technology sector. Several new laws (Laws No 196. and No 449, in addition to the law on financing and sustaining applied research – mainly Law No 46 and No 488) illustrate the government’s commitment to this important sector, even if the current economic situation, and the ongoing changes in the world economy, will influence the future outcome of these efforts.

Statistical data on R&D investments show a small decrease, but recent policy actions aim to address this, such as:

Law 196: Contribution of Euros 15 000 per year (2 years maximum) for supporting the employment of professionals with a Laurea degree in R&D activities by SMEs.

Law 449: The same objective as Law 196 but with a tax credit of Euros 7 500 per each new researcher hired up to a total of Euros 30 000 for each SME. This law also encourages the mobility of researchers between universities, public research institutes and SMEs.

The industrial crisis in some large high-tech companies (e.g. those operating in military, pharmaceutical and even telecommunications sectors) has had a negative impact on high-tech job creation, or has at least lowered expectations.

Many of these actions are the result of evaluations by economic policy based on scientific information and knowledge. The gap between science and technology (even if these two themes have, of course, very close cultural roots) often causes confusion and it is important to stress the fact that job creation is more strongly related to innovation technology than it is to science. Therefore, strategic policies focusing on innovation to create a number of relevant jobs for young people should be strictly related to new product innovations. Besides drawing on macro-economic analysis and scientific forecasting by universities and research centres, the development of these policies should consider the innovation culture in the high-tech companies where these innovative products are developed.

The “continuous selling” of “new methods of managing innovation” is creating new jobs, but the “continuous change in technical culture” and moreover in “working methodology” is pushing a lot of high-tech personnel aside, often outside the line of productive work.

These positive and negative aspects are almost balanced on a global scale, but there is a clear trend of positive balancing in the most advanced countries that are creating and managing innovative technologies. However, there is a negative balance in those countries that are not leaders in the high-tech sectors.

In conclusion, these trends have led to a greater commitment by the more advanced countries' governments (of which Italy is one) to the issue of job creation in the high-tech and R&D intensive sectors. At the same time, since this sector is operating at a global level, its rapid development is vital for its success. Yet, competition is so intense and global that it not only minimises the potential of “third” catch-up countries, but also the role of “second” following countries. This is illustrated by the recent results that show employment opportunities in the high tech and R&D intensive sectors to be below the expectations, or, aspirations of young people.

C. COMPETENCE DEMANDS FOR TODAY AND TOMORROW: QUALITY PROGRESS THROUGH INTERACTION WITH INDUSTRY

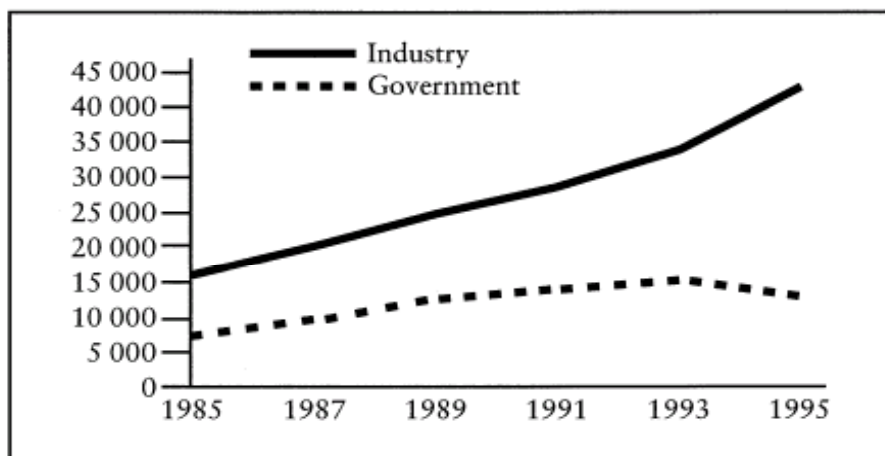
by

Camilla Modéer, Federation of Swedish Industries, Stockholm

The perspective from Industry

Industry today is characterised by rapid change, the emergence of new structures and production of high-tech value-added products. Global competition sets the framework within which companies must act. The rapid diffusion of knowledge, especially information technology, has resulted in increasingly knowledge intensive products, shorter and customer oriented product cycles, more efficient production and increased specialisation. Companies focus on satisfying customer needs by delivering systems and goods with extensive software and service elements integrated. Global competition is fierce for all companies and countries but only the best are successful. The importance of knowledge in the economy is illustrated by the increase in R&D performed in industry (Figure 1). It can also be seen by the change of "competence

Figure 1 R&D in Sweden, MSEK

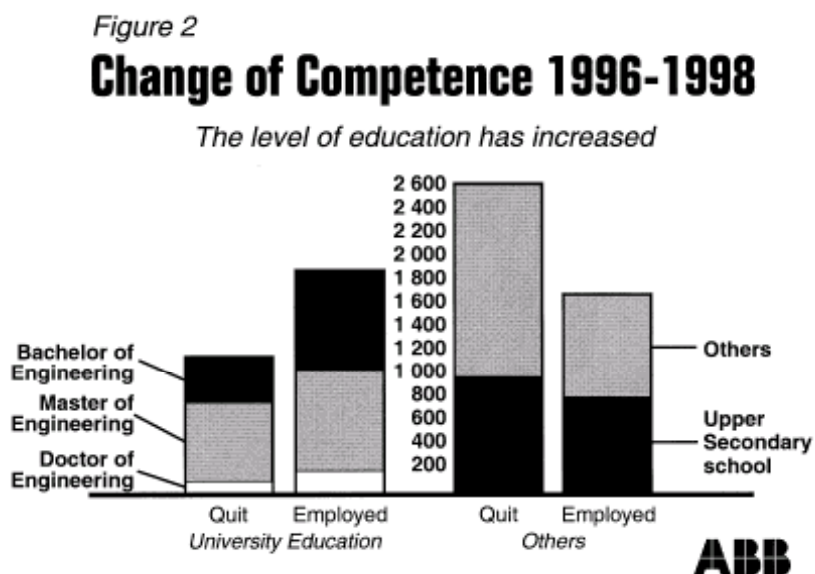


Source: MSEK.

profile" or the skills profile of the labour force in companies (Figure 2). There is a clear relation between the investment in R&D of enterprises and their growth and number of employees that can be shown by OECD data (Figure 3). Industry needs an increasing supply of well-educated and competent professional staff at all levels: skilled workers, engineers, academics and researchers, generalists as well as specialists.

To meet these challenges, companies are radically changing their structures and organising their activities differently. Companies are concentrating on core businesses, outsourcing more peripheral activities forming networks and integrating services with hardware production. Employees are being given a wider range of tasks and responsibilities, managers are becoming "coaches". Traditional hierarchical structures

are being compressed and decentralisation in favour of autonomous teams. As this is occurring on an economy-wide level, the classification of businesses into manufacturing and services is becoming obsolete. As society is moving into a new era, not just from an industrial to an information society but into a different industrial world, the transformations in the economy should instead be discussed in terms of larger industrial systems. Such systems encompass large and small enterprises, manufacturers, R&D-companies, software companies, marketing specialists, suppliers, maintenance etc.



Source: ABB.

Examples of such larger industrial systems are pharmaceuticals and instruments, energy supply and transmission, food supply and packaging, etc. These should be looked upon as integrated entities. Interactive industrial services like transport, financing, engineering consultants, software specialists, and others are an important part of these systems. When analysing employment in such industrial systems, it appears that at least 25% are employed in pure service companies. If all employees within industry involved in such service activities are included, the figure rises to more than 60% of employees in industrial systems. The number of employees in this area is rapidly increasing while the number employed in pure manufacturing remains unchanged or has decreased. The characteristics of successful companies are the same for all kinds of enterprises, large or small, domestic or international, manufacturers or service companies. These can be summarised as follows, whereby to be successful, companies must:

- Change quickly.
- Rapidly integrate new science and technology.
- Adapt new forms of work organisation.
- Develop new leadership.
- Focus on continuous development of competencies.
- Conduct active collaboration with schools and universities.

Figure 3 Employment and R&D
Average growth difference relative to total manufacturing industry in 14 OECD-countries 1973-1994

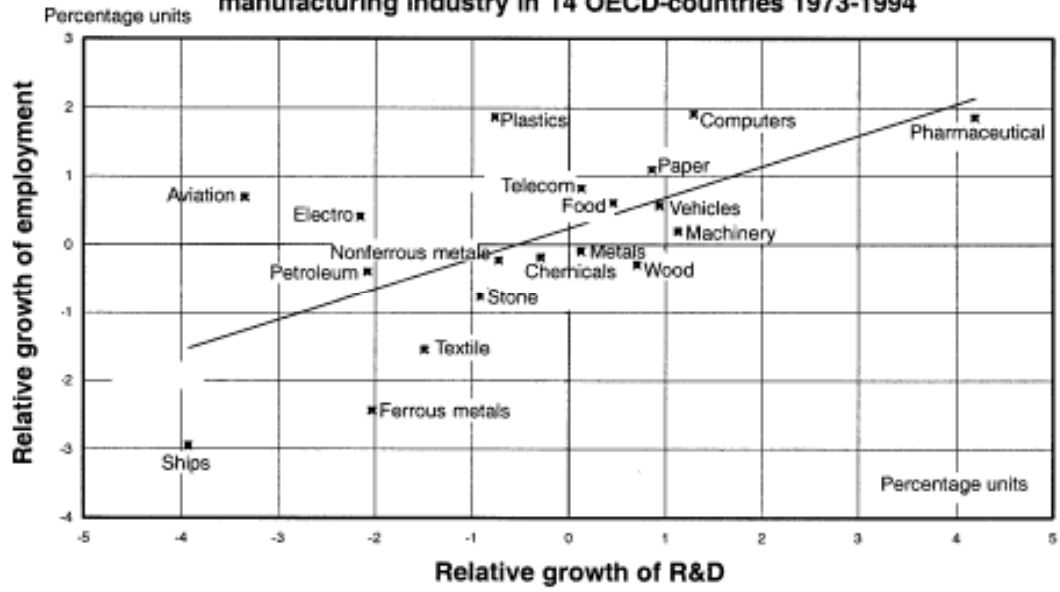
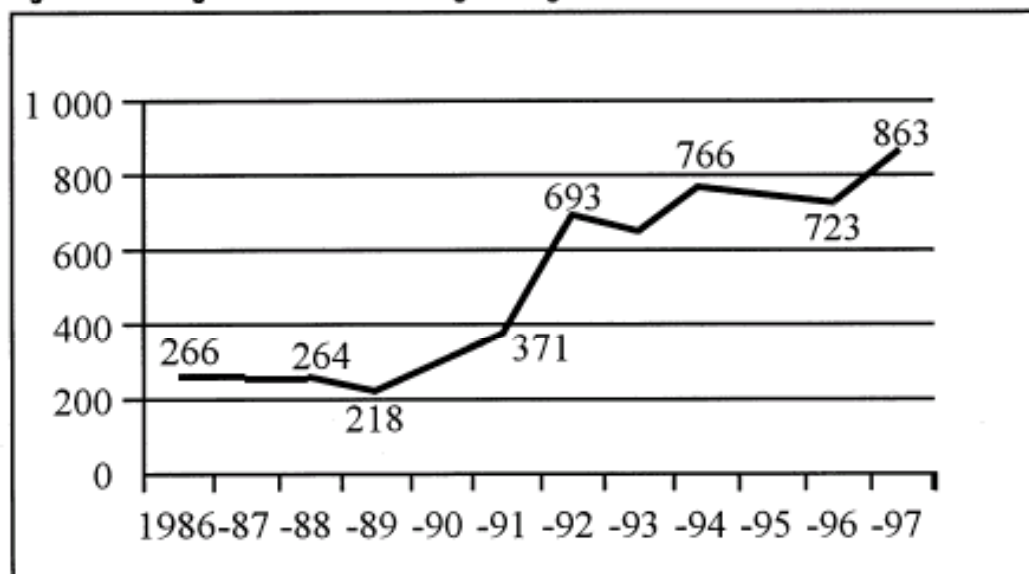


Figure 5 Emigration of Master of Engineering

Source: Author.

To accomplish all of these objectives, highly skilled personnel are needed – especially personnel in science and engineering, including at the PhD level. Because nearly all successful companies must compete on a global market, an important part of their competitiveness is their stock of skilled personnel and the ability of this staff to act internationally. In Sweden, the propensity of skilled workers such as engineers to migrate abroad has increased rapidly during the last decade. This can be illustrated by Figure 5. It would be interesting to know if other OECD countries have experienced a similar trend and what are the underlying push and pull factors.

While industry needs an increasing number of well-educated scientists and engineers, numbers are not the only aspect. The core issue is real competencies. Quantity without quality is meaningless. And quality includes several aspects. On the one hand, advanced knowledge in S&T is absolutely necessary, but it is insufficient. There is also a need of social competence and other abilities. The ability to co-operate with specialists and customers, creativity, responsibility, marketing are all demands that are crucial for today's businesses. Continuous personal development is also necessary for today's professionals. The will and aptitude to learn and utilise new knowledge and providing the means and tools for this is a joint responsibility that must be assumed by the individuals and companies. There are three main qualitative demands by industry for employees, that can be stated as follows:

- * Knowledge
 - Of relevant disciplines.
 - Expert and general.

- * Abilities
 - Comprehensive view.
 - Creativity, entrepreneurial.
 - Initiative, responsible, implement.
 - Forcible.
 - Personal development.

- * Social competencies
 - Co-operation.
 - Customer skill.
 - Communication skills.
 - Language and cultural proficiency.

Higher education must adapt to the new demand of enterprises. The most important fields in demand are in science and technology. It is imperative that the higher education system evolve accordingly and at a faster rate. But the programmes should be developed continuously in close collaboration with industry. This means changing educational programmes and research profiles, opening up new fields, establishing new courses etc. To achieve this in a continuously changing world, the producers of supply, the universities must -- just like firms -- listen to and interact with their customers. Their customers, however, are not just universities, the scientific community and politicians and the public sector. Their customers are to a larger extent industry and the business sector in general. In the future, the demands on education in science and technology will require enhancing the focus on i) advanced science and technology; and ii) the integration of training, abilities and social competencies (i.e. not divided and separate).

Ultimately, progress in quality is driven by interaction with the outside world. Thus universities, colleges and schools must open themselves up to civil society. Governing boards, education and research committees, those bodies that decide on content and structure must include professionals from the outside, including the public health sector, services and industry. Interactive networks must be formed and their role strengthened. There are many forms and structures possible, but the essential issue is to build close co-operation. Quality also means satisfying demands. To be competitive, universities and politics should have the same characteristics as successfully competitive companies.

LIST OF EXPERTS
Thematic Workshop on Science and Technology Labour Markets
17 May 1999

Chair: Mr. Lennart ELG (NUTEK, Sweden)

Dr. Carlo CORSI

Tel: 39 6 723 4616

Fax: 39 6 723 4305

E-mail: corsi@roma.ccr.it

General Director

Roma Ricerche

Universita Tor Vergat

Via Orazio Raimondo 8

00173 Rome,Italy

Dr. Paloma SANCHEZ

Tel: 34 1 388 2180

Fax: 34 1 759 9612

Professor of Applied Economics

Autonomous University of Madrid

Julian Hernandez 8

28043 Madrid, Spain

Dr. Carolina CA •IBANO

E-mail: canibano.sanchez@mad.servicom.es

Email: carolinac@wanadoo.es

Assistant Professor

Alfonso X University

Avenida de la Universidad 1,

Villanueva de la Canada

Madrid, Spain

Mr. Lennart ELG

Tel: 46 8 681 9266

Fax: 46 8 1968 26

E-mail: lennart.elg@nutek.se

Senior Programme Officer, Technology Policy

and Foresight, Swedish Industrial and

National Board for Technical

Development (NUTEK)

S 11786 Stockholm

Mr. Friedhelm PFEIFFER

Tel: 49 621 1235 150 or 131

Fax: 49 621 1235 225

E-mail: pfeiffer@zew.de

Projektleiter im Forschungsbereich

Arbeitsmärkte,

Personalmanagement und Soziale Sicherung

Z.E.W. GmbH

L7,1

D-68161 Mannheim

Mr. Jacques ZACHMANN

Email: jacques.zachmann@cec.eu.int

DG XII

200 rue de la Loi,

B 1049 Bruxelles

Dr. Charlotte KUH

Tel: 202 334 2700

Fax: 202 334 2725

E-mail: ckuh@nas.edu

Executive Director,

Office of Scientific and Engineering Personnel

National Research Council

2101 Constitution Ave. NW

Washington DC 20418

United States

Mr. Ian MILES

Tel: 44 161 275 5922
Fax: 44 161 273 1123
E-Mail: ian.miles@man.ac.uk

Director, PREST
University of Manchester
Oxford Road
Manchester M139PL
United Kingdom

Dr. Mark REGETS

Tel: 707-306-1776 ext.6923
Fax: 707-306-0510
E-mail: mregets@nsf.gov

Science and Engineering Indicators
National Science Foundation
4201 Wilson Boulevard
Arlington VA 22230
United States

Dr. Mark TOMLINSON

E-mail: msrpsm+@fsl.ec.man.ac.uk

ESCR, Centre of research on Innovation and
Competition
University of Manchester
United Kingdom

Dr. Richard PEARSON

Tel/Fax: (0) 1273 678184
E-Mail; richard.pearson@employment-studies.co.uk

Institute for Employment Studies (IES),
Mantell Building
Falmer
Brighton BN1 9RF
United Kingdom

Mr. Sami MAHROUM

E-mail: sami.mahroum@jrc.es

Research Fellow, European Commission, Institute
for Prospective Technological Studies
Seville
Spain

Mr. Daniel MARTINELLI

E-mail: martinelli@cereg.fr

Centre d'Etudes et de Recherche sur les
Qualifications
Marseille
France

Mr. Shin-ichi KOBAYASHI

E-mail: skob@is.uec.ac.jp

Associate Professor
Graduate School of Information System
University of Electro-Communication
Tokyo
Japan

Mr. Yuichi MAEZAWA

Email: maezawa@nistep.go.jp

Director, First Policy Oriented Research Group
National Institute of Science and
Technology Policy
Science, Technology Agency
2-2-1 Kasumigaseki, Chiyoda-Ku
Tokyo 100
Japan

Mr. Foppe de HAAN

E-mail: f.h.dehaan@minez.nl

Head of the Knowledge Infrastructure Department,
Ministry of Economics
The Netherlands

Ms. Camilla MODEER

Tel: 46 8 783 8094

Fax: 46 8 665 9019

E-mail: camilla.modeer@industriforbundet.se

Federation of Swedish Industries

Storgatan 19, P.O Box 5501

S 114 85 Stockholm

Mr. Jari JOKINEN

Tel: 358 9 1341 7029

Fax: 358 9 1341 7025

E-mail: jari.jokinen@minedu.fi

Project Manager

Ministry of Education

Department for Education and Science Policy

PB 293

FIN-00171 Helsinki