ASSESSING THE SUPPLY AND DEMAND FOR SCIENTISTS AND TECHNOLOGISTS IN EUROPE

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Assessing the Supply and Demand for Scientists and Technologists in Europe

R Pearson
N Jagger
H Connor and
S Perryman (IES)
with
P Marey
A de Grip and
F Corvers (ROA)

Research Centre for Education and the Labour Market

Report 377

Published by:

THE INSTITUTE FOR EMPLOYMENT STUDIES
Mantell Building
Falmer
Brighton BN1 9RF
UK

Tel. + 44 (0) 1273 686751
Fax + 44 (0) 1273 690430

http://www.employment-studies.co.uk

British Library Cataloguing-in-Publication Data

A catalogue record for this publication is available from the British Library

ISBN 1-85184-306-X

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Acknowledgements

This report is based on a study carried out by IES and ROA for the Research Directorate General of the European Commission. We are grateful for the assistance given by Ugur Muldur, Jacques Zachmann, Ian Perry, Jean Bourles and their colleagues in the European Commission, the many people who gave us information and advice from throughout the European Union, more than 100 in total, and our colleagues in the IES, Emma Hart and Denise Hassany for their assistance in the production of this report. The findings, conclusions and recommendations are, however, the responsibility of the authors alone.

Contents

1. Introduction

1.1 Introduction

It is widely recognised that Europe needs a strong science and technology (S&T) base to ensure its long term economic growth and international competitiveness (European Commission, 1997). Knowledge-intensive industries, both in manufacturing and services, have increased in importance in most European countries, and high technology products and services are a growing part of international trade. Indeed, industries related to information technologies (IT), the Internet, and telecoms, are the fastest growing categories in world trade and production. At the same time, the 'mature' industries such as steel and automobiles also increasingly rely on high technology components, processes and skills. The political and economic importance of a strong and innovative science and technology base is evidenced by the European Union's research and technological development policy and the *Fifth Framework Programme for RTD,* which seeks to boost research and innovation.

However, the position of Europe and individual European countries *vis á vis* the rest of the world, and in particular the USA and Japan, in relation to technological output and economic performance, gives some rise for concern. Europe as a whole has not performed as well in aggregate recently as other regions. Average GDP per capita in Europe is still below Japan and well below USA, and European businesses have failed to be among the front-runners in some of the growing hi-tech sectors (*eg* electronics, software, bio-medicine) though they have done rather better in pharmaceuticals. The strengths, weaknesses and potential of Europe in relation to its global competitors have been extensively documented and analysed in the *Second European Report on S&T Indicators, 1997* (EC, 1997).

Various reasons have been put forward. One is Europe's sluggish research performance (see for example Eaton, Guttierez and Kortum, 1998), another, not unrelated, is its poor showing in adopting innovation and in technological investment (see EU Green paper on Innovation, 1995), and a third, also related, is weaknesses in education levels and human resource development. These issues and policy options have been summarised in '*Society, the Endless Frontier*' (Caracostas, Muldur, 1998).

Skilled and qualified scientists and technologists (S&Ts) play a key role in the innovation process and technological developments. Shortages, or skill gaps, can be a significant constraint on economic development and prosperity, while surpluses may indicate a poor use of scarce resources with the resource potential of a country not being fully optimised.

It was recognised at the outset that labour market imbalances and 'shortages' can be difficult to analyse for a number of reasons. These include a shortage of reliable data, and the complexities and uncertainties in the supply of, and especially in the demand for S&Ts. In addition, any assessments have to take account not only of influences such as technological, economic, demographic, educational and organisational change, but also the attitudes of individuals, and organisational and market adjustments (OECD, 1992b). It was also recognised that the notion of adequacy can be considered from many standpoints, this issue is considered along with other definitional issues below.

The focus of this report is on the human resource base and in particular the adequacy of supply of those skilled and qualified in science and technology (S&Ts) from the universities and higher education in Europe in meeting employers' R&D needs. Given the known inadequacies of the available data the research was also seen as an exploratory study to identify what could be achieved in this area.

This Report is based on research commissioned by the European Commission (DG XII) at the Institute for Employment Studies (IES) in the UK, and the Research Centre for Education and the Labour Market (ROA) in the Netherlands during 1997/99. The research is part of the Science and Technology Indicators (REIST) programme of DGXII. It draws on the available evidence:

- to analyse developments and trends in the supply and demand for S&Ts in the Member States of the European Union (EU)

in order:

- to provide an assessment of the extent to which there are problems in relation to the adequacy of the supply of S&Ts in relation to the needs expressed by employers[1]; and
- to identify those areas where improvements in the information flow would enhance future decision making in this crucial area.

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[1] Employers in this report means employing organisations in all sectors of the economy including the business sector, the public sector, higher education as well as other organisations in the 'not for profit' sector.

1.2 Science and technology and adequacy defined

Before addressing the main objective of the report, assessing the adequacy of S&T supply, a number of definitional issues need to be discussed in order to help clarify the scope of the report.

Firstly, **science and technology** can be defined in a broad way, embracing a full range of disciplines or subject groups such as the sciences, engineering, medicine, the social sciences and the humanities. This is the case in much of continental Europe. A narrower definition excludes the humanities and, in some instances the social sciences. This is often dubbed the Anglo Saxon definition given its widespread use in Ireland, the UK and North America, (OECD, 1992a). In this study the emphasis has been on the narrower definition which included the pure and life sciences, engineering and technology, but which excluded medicine (which is dominated by the health services), the social sciences and the humanities. However, some of the data at an international level are only available for the broader definition and these have had to be used in places. This is explained more fully in Chapter 2 along with detailed definitions.

As well as subject and discipline differences, there are also questions of level. Here the emphasis has been on professional level scientists and technologists who are normally qualified at ISCED level 5 or above[1], where the lead times for education and training are the longest.

Science and technology is not, however, a homogenous grouping; it includes a diverse group of skills and occupations covering a wide range of natural sciences and engineering disciplines. Different disciplines and sub-groups operate in very different economic and labour market contexts. For example, biotechnologists require very different training and operate in a very different labour market to civil engineers, while there is often minimal potential for the transfer of skills even within disciplines, *eg* between nuclear physicists and astrophysicists. Furthermore, traditional definitions of subjects and occupations are breaking down as technological advances embrace new and different disciplines and require cross-disciplinary or multi-disciplinary skills. Examples of this are the recent emergence of bio-informatics, the growth of mathematical modelling in environmental science, the development of new materials involving and combining various branches of physics, chemistry and biological sciences.

Knowledge of science and technology is largely cumulative, and as such the majority of scientists and technologists have core

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[1] The International Standard Classification of Education Diplomas (ISECED) has recently been updated by UNESCO as such there an ISCED 98. However, all the data used in this report has been collected in the previous version of ISCED, ISCED 76.

subject knowledge. This is drawn from first degree, and often postgraduate study, there being only limited scope for learning the basic skills and knowledge in the workplace, although there are exceptions such as for some aspects of IT. As such a key element of any assessment of whether there is an adequate supply scientists and technologists therefore has to be an assessment of the supply of such skills. But more importantly the meaning of the term **'adequacy'**, has to be addressed at the outset as it is capable of many different interpretations. For example, it could be defined fairly broadly in terms of:

- meeting **'society's'** needs, *ie* the availability of S&Ts to meet the needs of a well developed 'society' and the aspirations of individuals, or the economy as a whole, regardless of price or how they are actually used; or more explicitly as
- meeting the needs **as expressed by employers,** *ie* employer demand which will be conditioned by economic, business and organisational factors as well as the relative cost of recruiting and employing scientists and technologists; or indeed
- meeting **potential** needs, *eg* to fulfil certain tasks where there may not yet be a defined demand by employers, such as addressing particular environmental problems; *eg* is there an adequate supply of nuclear physicists being trained to meet the likely future needs of decommissioning nuclear power plant or to generate new research and ideas in the future; this overlaps with society's needs as above.

Such alternatives were considered and the following definition was agreed in the early stages of the study:

Adequacy is defined as the extent to which the higher education supply of S&Ts meets the articulated needs of employers in the EU in current labour market circumstances.

Much of the past research on S&T employment has focused on quantitative imbalances, *eg* numerical shortages of graduates in IT or surpluses of PhD scientists, but it is becoming increasingly apparent that the quality of supply is of as much interest and concern. More recent studies have highlighted the criticisms from employers of the quality of science, technology and other graduates in terms of their employment skills or 'employability'. This has been expressed in terms of both technical deficiencies and a lack of more personal and social skills such as team working, communication, business awareness (see, *eg* NCIHE, 1997), and language and cultural acquisitions, where, *eg* former ERASMUS students often felt these skills to be more important than the academic knowledge they gained (Maiworm and Teichler, 1996). This report therefore seeks to embrace both a **quantitative** and a **qualitative** dimension to 'adequacy' as perceived by employers.

1.3 Influences on adequacy

In order to analyse problems of 'adequacy' it is necessary first to understand the way it can be influenced by a wide range of long-term and short-term factors. These affect labour demand, supply and utilisation, and vary between countries and labour markets, which have different historic demographic, economic, cultural and political contexts. Factors affecting adequacy which need to be given attention include:

- On the **demand side:** national economic structures; national and increasingly international economic cycles; European and national priorities and interventions; sectoral differences and trends; levels and patterns of investment in R&D; inward and outward investment; organisational and business strategy and competitiveness; technological change; employers' recruitment, training and employment strategies; and their competitiveness with other parts of the labour market.
- On the **supply side:** demographics; the history, structure and priorities of the universities and higher education in Member states[1], in particular the extent to which it is responsive to the needs of employers; the attitudes and actions of individuals towards education and training and their choices of courses and careers; the relative attractiveness of employment in S&T; the extent of retraining and flexibility by different types of S&Ts. The quality and relevance of the education and skills of the existing labour force may also not be adequate to meet the needs of newly emerging and fast changing and developing technologies and sectors because their skills relate to past rather than present or future needs, creating possibly temporary adjustment problems.
- There can also be poor **utilisation** of the S&T skills and competencies in the work place, *eg* where they carry out low level technician roles in one part of an organisation when their skills might be better used elsewhere; or within a role where poor management, job design or motivation can lead to S&Ts to perform below their full potential.
- Aspects of **market failure** can also affect the balance, *eg* S&Ts may choose to be unemployed or work in other activities because the employers do not offer sufficient pay or rewards, or attractive enough working conditions or training opportunities; or non-S&T employers are prepared to offer higher wages and benefits, *eg* the recruitment of mathematicians or engineers to high paying financial services companies. The available jobs may also be in expensive, unattractive or inaccessible locations, or S&Ts may be unaware of the vacancies that exist.

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[1] In the context of this report this is called the education system.

The extent of adequacy can also be mediated by actions taken by governments, employers, educationalists and individuals, such as:

- **governments and agencies** improving the efficiency and flexibility of labour markets, *eg* making better use of labour market research, information, improving careers advice; supporting (re) training and mobility; and reducing barriers to flexibility, *eg* within legislation
- **employers** responding to recruitment difficulties through raising salaries and benefits, improving management and working conditions; investing in training, retraining and career development; and or substituting other types of staff
- **educationalists** making changes to academic curricula or developing new courses
- **individuals** investing in training and skill development, and being well informed and flexible towards employment opportunities.

There are numerous examples of such national, employer and educational initiatives and these are considered in Chapter 4 and the Conclusions.

The effect of these factors, and ensuing issues of adequacy, vary between S&T disciplines, activities (*eg* research, production, marketing); sectors (*eg* HE, the public sector and the different business sectors); locations and countries; and between individual organisations. They are all susceptible to different pressures and circumstances, often related to historical developments. As such, one would not expect to find a singular European perspective, and there is likely to be considerable variation in patterns in terms of countries, sectors and occupations.

1.4 Indicators of adequacy

The complexities of surrounding the notion of adequacy relating to the supply S&Ts, means that finding appropriate indicators is fraught with difficulty. As the principal focus of the study is to understand the cause and extent of problems it is in practice better to focus on evidence of **inadequacy**, but even here there a number of difficulties when we focus on the paucity of data. Theoretically indicators of inadequacy might include:

- **Rapidly rising relative salaries** — a recognised measure of labour market tightness. However, relevant disaggregated data are rarely available and that which is quoted is often selective and or out of date. There are also difficulties of comparing 'like with like', *eg* comparison should be made as to overall reward packages which are contingent to their national, economic, social and organisational contexts.

- **Vacancies reported to public employment services** — these data are often used to illustrate shortages, but is less useful for high-level skill shortages as often these vacancies are not reported to the public employment service. There are also considerable difficulties comparing the classifications used by the public employment services.
- **High turnover** at an enterprise level and **high mobility** between organisations or countries ('brain drain', 'brain gain'); again a generally discussed indicator but where data is often inadequate to make generalisations between organisations, *eg* most is based on small samples or not disaggregated sufficiently at S&T occupational or discipline level.
- Employers reporting **long standing or 'hard-to-fill' vacancies** — an often used indicator but one that may not be related to a genuine skill shortage, for example where recruitment problems arise because employers offer uncompetitive wages or working conditions, or when employers use poorly developed recruitment strategies.
- Rapid increases in **job advertisements** or reported vacancies. These increases may simply be related to high or low turnover rather than underlying shortages or surpluses. Therefore, they can often seriously understate or overstate changes in demand. Also, firms are more likely use advertising if they think a vacancy is hard to fill and less likely to use this medium when unemployment is higher. Finally, little comprehensive monitoring of detailed occupational advertisements and of specialist posts takes place.
- **Employers utilising lower level or inadequately skilled staff** in S&T posts — this can be related as much to internal working practices as supply-side problems. Data on this aspect can only be collected by detailed, structured research.
- **Very low levels of unemployment rates** among new graduates. This is an indicator simply of the ability to find jobs relatively easily. It does not say anything about the relevance of the job to their education level/discipline, *eg* PhDs historically have had very low unemployment levels in some countries but concerns remain about the quality and relevance of the jobs entered (Connor and Jagger, 1993*)*.
- **Employers', and trade or professional bodies', perceptions of shortages** — used frequently as indicative of recruitment problems but can be of little value if based on very small samples, or have 'leading' questions. There are also problems of data aggregation if, *eg* all firms are expecting to increase their share of the market.

1.5 Data availability

As can be seen in the above, there are little data available for these potentially useful indicators and where there is there are problems in their interpretation. The position is further complicated by the fact that national governments have different priorities and interests to data collection on, say, education and the employment of S&Ts in different sectors of the economy, and the amount and quality of research they undertake on S&T labour market (Annex 1). Some of the data that are often used and quoted by commentators about S&Ts can also provide a misleading picture, being based on poorly conducted surveys, or over-simplistic econometric extrapolation and modelling, or very partial data. In some cases their purpose is more for 'lobbying' governments or others on behalf of partisan interests, *eg* to boost spending or encourage public intervention initiatives to make recruitment and training 'easier' for employers, to boost investment or wages in the public sector or higher education, or to meet the agenda of other interest groups.

A detailed assessment of sources for this research showed that there are few regular, reliable, harmonised data sources which can be used to obtain a European wide perspective; *eg* reliable comparative data on salaries of S&Ts in European countries are non-existent (Annex 1). Where harmonised EU sources do exist, such as the Labour Force Survey, the data rarely allows for sufficient disaggregation to enable detailed patterns of S&T supply and demand to be analysed. There has also been little previous research on this aspect of the S&T labour market at European level, with an earlier European-wide review of labour market information on scientists and technologists undertaken in 1994 commenting on the severe limitations on the available data (Court, 1995e).

These factors and deficiencies add to the complexity of understanding adequacy problems and assessing likely future problems. It has meant that more reliance has had to be put in this study on piecing together evidence from a variety of disparate sources, which are often more of a qualitative than a quantitative kind. In themselves they may provide fairly meagre insights, but when joined with other indicators, such a triangulation can provide more reliable evidence on which to base future policy development. Further consideration of data issues are presented in each Chapter, in the Conclusions in Chapter 6 and in Annex 1.

1.6 The research approach

It was recognised at the outset of the study that there was a paucity of existing, relevant data form which to draw conclusions, and to this end two special components were developed. The first was the *IES Survey of R&D Establishments.* The second involved the development of a pilot econometric model to try to assess the quantitative adequacy of higher education in the Member States for the period to 1997-2002 in relation to the demand for Research Scientists and Engineers (RSEs). In this way the conclusions could draw off a number of different approaches and sets of evidence providing a form of triangulation.

The **methodology** was thus developed in the light of the above circumstances and the resources available for the study. It involved five main stages plus reporting as follows:

- a detailed review of the literature: over 450 reference documents have been included in the bibliography, many more were of indirect relevance
- a detailed review of national and international sources, covering national governments, training and employer bodies in the EU countries, and the key international organisations (Eurostat, OECD, UNESCO, ILO)
- contact with over 100 international and national experts in all the EU countries
- a survey on S&T employment and recruitment, covering a specially selected sample of 1,000 R&D establishments across Europe to obtain more detailed data relating to the employment and the adequacy of the supply of R&D personnel, and to provide the necessary data for the modelling below. The survey was also extended through a small number of follow up employer interviews.
- a pilot econometric modelling exercise designed to assess the feasibility of modelling, in the light of the available data, the quantitative adequacy of supply from education in relation to demand up to year 2002
- regular dialogue with DGX11 and Eurostat
- preparation of reports, including two interim reports and this final report.

The work was undertaken over the period 1997-98. It aimed to focus on recent and current developments and trends, during the mid to late 1990s.[1]

Further details of the methodology are given in the Annexes.

1.7 The report

This report comprises five further chapters which present the evidence used to assess adequacy and the main conclusions that can be drawn.

- Chapter 2 discusses further definitions and employment trends and issues affecting demand. It looks first at the available European data on S&Ts. It discusses various factors influencing employer demand and trends in different sectors,

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[1] Time lags in the collation and publication of international datasets, and the release of national government data and sponsored research outside of their own countries, mean some of the available information used related more to the early/mid rather than the late 1990s.

disciplines and countries. It then discusses the main subset of the S&T stock of interest to this study in more detail — R&D workers, and research scientists and engineers (RSEs) in particular. Here there are considerably more data available than for the S&T population as a whole.

- Chapter 3 then discusses the supply side. It first emphasises the diversity of European higher education (HE) in terms of structures of national HE sectors, entry routes and participation rates, and the differing roles and relationships of HE sectors with national governments and industry. It then goes on to identify common themes across countries and a variety of issues which affect the supply of S&Ts. This is followed by a section presenting available data on the key trends in S&T output.
- In Chapter 4 the adequacy of supply in meeting employer demand is considered along with the issues that affect adequacy. This is discussed from both a qualitative and quantitative perspective and covers both undersupply and oversupply problems. It also addresses how employers and HE institutions are responding to such problems.
- Chapter 5 then moves on from discussing the available data and literature on adequacy to present the findings of the econometric modelling work. This sought to assess the feasibility of modelling, given the data available, the quantitative adequacy of the EU countries' higher education in relation to the future demand for RSEs. It includes a discussion on how the model was constructed, the available data, and its effectiveness. It then forecasts the demand under four scenarios relating to economic growth and human capital policy. Because of the nature of the modelling exercise the results are presented together in this chapter rather than being integrated with the text of the earlier chapters.
- The conclusions from all the different elements of the methodology are then drawn together in Chapter 6. This summarises the main findings of the study and draws out the conclusions and makes recommendations.

The bibliography follows and Annexes contain more details of the different components of the study and their outcomes:

- Annex 1: Data sources, their adequacy and selected supplementary methodological details and statistics.
- Annex 2: The methodology and results from the forecasting model undertaken by ROA.

2. The Employment of Scientists and Technologists

2.1 Introduction

This chapter examines the available data on the stock, and the pattern of demand for graduates, professionals, and research scientists and engineers (RSEs). As discussed in Section 2.2 below there are numerous categories and definitions of populations that relate to aspects of science and technology employment but none which focus on scientists and technologists alone. Overall there are 28.5 million employed people with degrees at ISCED level 5 and above; by some definitions this is the number of scientists and technologists employed. A narrower focus on those working in professional occupations reduces the figure to 18.5 million, while a considerably smaller number, 0.8 million, work as research scientists and engineers (RSEs). The following sections discuss the definitions, data availability and the data itself in more detail. In particular:

- The second section examines the range of definitions, and their suitability, that can be used to examine the stocks and supply and demand of scientists and technologists across Europe.
- Using these definitions section three considers the broader population, or stock, of graduates and professionals across the EU.
- Section four moves on to examine what can be determined about employer demand for the more specific sub category of scientists and technologists (S&Ts).
- The next section then examines the employment an even more specific category, namely that of Research Scientists and Engineers (RSEs). This draws partly on the *IES survey of R&D establishments* which is also used to examine in more detail the pattern of recruitment and leaving of RSEs.
- Finally, the chapter also examines how global economic, social and technical dynamics are leading to employers' changing requirements for S&T skills.

2.1.1 Objectives

As noted in Chapter 1, the group comprising scientists and technologists is both diverse and capable of many different definitions. There are also serious data deficiencies relating to information about the stock, its characteristics, and the distribution of scientists and technologists at both national and European level.

The stock or 'population' of scientists and technologists can be defined in terms of those with relevant qualifications, *eg* those possessing a university degree or equivalent qualification in, say, chemistry, or those in certain occupations, *eg* working as chemists, or both, *ie* qualified chemists working as chemists.

This report is about the adequacy of the **supply** from higher education in meeting employer **demand** for scientists and technologists; as such the interest is in both those qualifying, which is normally defined in terms of their **qualifications**, and employer demand, which is normally defined in terms of **occupations** and may include both qualified and unqualified scientists and technologists. However, there is not necessarily a close match between the two, which complicates the analysis. For example, many of those qualified in science and technology disciplines may not be working as scientists and technologists. Some may have chosen to work in other occupations after qualifying, while others may have left their original science and technology occupation and developed their careers in other areas such as management or marketing which may or may not be related to their former science and technology employment. Yet others who qualified may not have been able to find suitable employment and are unemployed or otherwise inactive in the labour market, or have taken up lower level jobs when they would have liked to make use of their skills more. The extent of the latter can represent a level of 'under-employment', or under-utilisation of their science and technology education, this is discussed later in Chapter 4.

There are, thus, many different ways in which the population of scientists and technologists can be classified and analysed, as is discussed in the *Canberra Manual* (OECD, 1995b). These factors should not be underestimated in contributing to difficulties in analysing the available data or in discussions with employers about their requirements. Equally, sometimes confusing terms are used to describe the different categories of personnel involved. This makes it important to start the process by defining various categories of interest.

Whatever approach is taken to deal with these definitional issues, it has also to be recognised that there is not a singular labour market for scientists and technologists: far from the homogeity noted in the *Canberra Manual* (OECD, 1995b). For example, there is little relationship between the population and skills of biotechnologists and those of civil engineers. Even within disciplines there are wide divergences with, for example, the population and roles of school physics teachers being very different from those of physicists working in an electronics R&D centre. In our increasingly knowledge-based and complex society, there is also the issue of overlapping roles and disciplines. This can be seen in a range of science and technology areas. For example, in the environmental sciences, waste management projects now require a wide range of skills and knowledge from a range of disciplines. These are then applied to solving complex problems by combining elements of, *eg* soil science, mathematical modelling, economics, microbiology and IT, in multi-disciplinary teams. This example illustrates how the term environmental science can embrace a very wide range of sub labour markets, each with some common elements but also with different characteristics.

Before presenting the available evidence, the different definitions are considered.

2.2 Definitions of populations relating to science and technology

There are many possible definitions that can be used, the most common and those used in this report are defined as following.

The widest definition of scientists and technologists includes all those in employment who have completed tertiary education (ISCED level 5 and above[1]) in the wide range of science and technology disciplines. These include the natural sciences, engineering and technology, medicine, the social sciences and the humanities. As this embraces all disciplines we now refer to this group as **graduates**. The 1997 Labour Force Survey indicated that 19.3 per cent of the EU's employed population aged 25-59 **(or 28.5 million people) were in this category.**

Professionals are defined in terms of occupations defined using the International Standard Classification of Occupations (ISCO Major Group 2). This includes the following Sub-Major Groups: 21 Physical, mathematical and engineering science professionals; 22 Life science and health professionals; 23 teaching professionals, and; 24 Other professionals. Given the occupation-based definition, this category can only apply to those who are in employment. The 1997 Labour Force Survey indicated that 12.5 per cent of the EU's employed population **(or 18.5 million people) were in this category.**

R&D personnel is the group defined as 'all those employed directly on R&D' as in the OECD's Frascati Manual as (OECD, 1994a). Eurostat estimates that in 1997 there were approximately **1.6 million people in this category in the EU.**

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[1] This is based on ISCED 76 as is all the ISCED data used in this report.

The focus of this report is on the narrower grouping of those who are qualified in, or work as natural scientists or engineers and technologists, and are called **scientists and technologists (S&Ts)**. This is often called the Anglo-Saxon definition, which excludes medicine, the social sciences and the humanities. There are, however, no harmonised data sets covering the working population by discipline of their highest qualification **no reliable figures can be generated for this category.**

Research scientists and engineers (RSEs) are a sub group of R&D personnel who are defined by the Frascati Manual as professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, and in the management of the projects concerned.(OECD, 1994a). It is estimated on the basis of Eurostat and OECD data that there are approximately **0.8 million people in this category** within the EU.

In practice, data availability dictates the types of analyses that can be presented. The statistical focus of this chapter is on the 0.8 million RSEs as this is the group for whom the best-published data are available. Table 2.1 summarises the key populations in each member state, each category is then considered in turn.

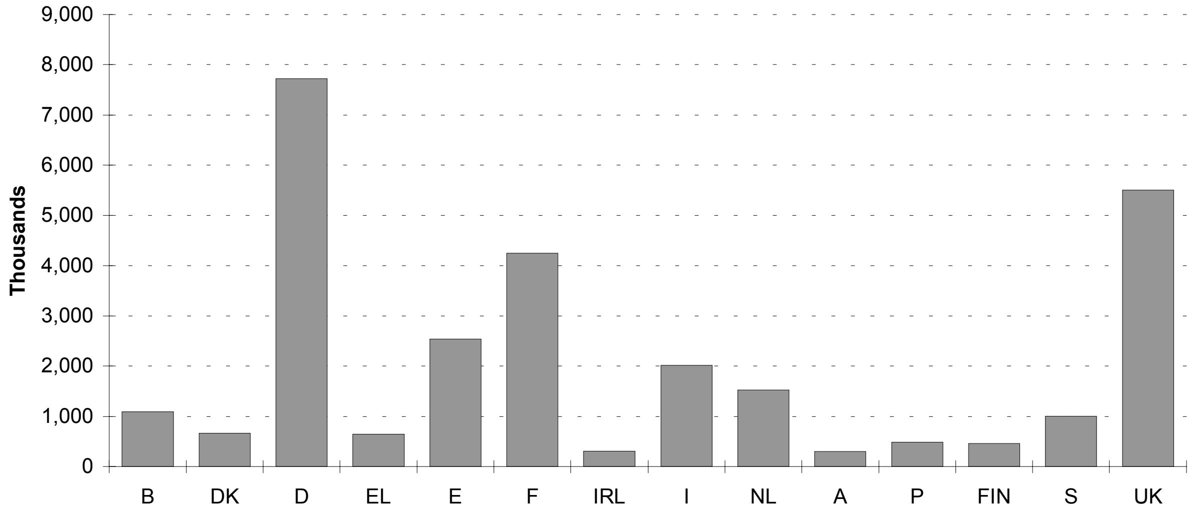
Table 2.1: Employed professionals and employed graduates, 1997*

	Graduates Employed with third level education, 1997 (1,000's)	**Graduates as per cent of employees %**	**Employed Professionals (1,000's)**	**Professionals as per cent of employees %**	**Research Scientists and Engineers (RSEs) (1,000's)**	**Graduate (ISCED 5-7) qualifications awarded 1994/95 (1,000's)**	**Employees (1,000's)**
Belgium	1,091	28.6	728	19.1	23	na	3,819
Denmark	670	25.3	321	12.1	16	30.2	2,649
Germany	7,723	22.1	4,358	12.5	231	338.3	34,947
Greece	643	17.3	439	11.8	8	31.2	3,725
Spain	2,535	20.1	1,434	11.4	47	177.7	12,609
France	4,248	19.3	2,298	10.4	151	na	22,048
Ireland	306	22.8	231	17.2	9	33.7	1,341
Italy	2,013	10.2	1,946	9.9	76	183.1	19,731
Netherlands	1,526	21.4	1,193	16.7	34	80.7	7,126
Austria	302	8.4	351	9.8	13	18.8	3,574
Portugal	487	11.4	291	6.8	12	36.4	4,254
Finland	464	22.1	374	17.8	17	28.0	2,103
Sweden	1,002	26.0	584	15.1	34	34.8	3,860
United Kingdom	5,506	21.0	3,972	15.2	148	470.0	26,181
EU	**28,516**	**19.3**	**18,520**	**12.5**	**818**	**na**	**147,967**

Note: Graduate output for each country is shown in Figure 3.5

Source: Eurostat (1999) Labour Force Survey Results 1997 and RSE data Eurostat (1999) Research and Development Statistics 1998 and OECD (1999) Main Science and Technology Indicators, Eurostat (1999) Education Across the European Union Statistics and Indicators (Note: RSE data for 1995 apart from DK 1996 GR and PT 1993)*

Figure 2.1: Graduates* in employment by country, 1997



Source: IES/Eurostat (1998) Labour Force Survey 1997 results
EU Total 37 million
** Graduates defined as those with a ISCED 76 level 5, 6 or 7 qualification*

2.3 The employment of graduates and professionals

In 1997, it was estimated that there were 37 million graduates[1] across the 15 EU countries with a qualification at ISCED level 5 or above. Of these 28.5 million were employed and in the age range 25 to 59 this being the core age range for the working population. This is as used by Eurostat, and is not to ignore the contribution to the workforce of those outside this age range. Rather, it has been chosen to represent the core of adult participation in the work force, with many of those under 25 still being in education and many of those aged over 60 being retired. Graduates account for about 19 per cent of the EU employed population aged 25 to 59. In many EU countries, until the 1992 Labour Force Survey there was no annual or internationally consistent collection of data on the educational attainment of the populations. Often the only available data was from national population censuses (Eurostat, 1992) and these were normally only undertaken every 10 years. These national censuses also use national classifications of educational qualifications that map poorly onto ISCED 76. This means that it is impossible to create a longer time-series.

The number of graduates aged 25 to 59 in each country ranges from 9.3 million in Germany, 6.5 million in UK and 5.2 million in France, to under half a million in each of Ireland, Austria, Portugal and Finland (Figure 2.1).

The highest density of graduates, in relation to their employed populations, is found in Belgium with 27 per cent so qualified and

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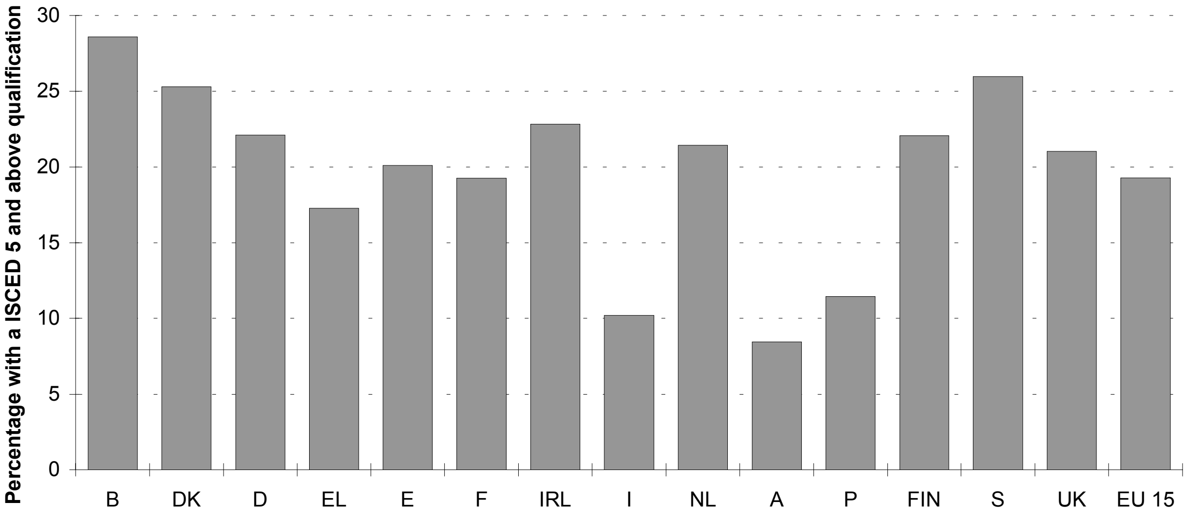
[1] That is those with ISCED 76 level 5, 6 or 7 qualifications.

Figure 2.2: Graduates** as a percentage * of employed population aged 25 to 59, 1997

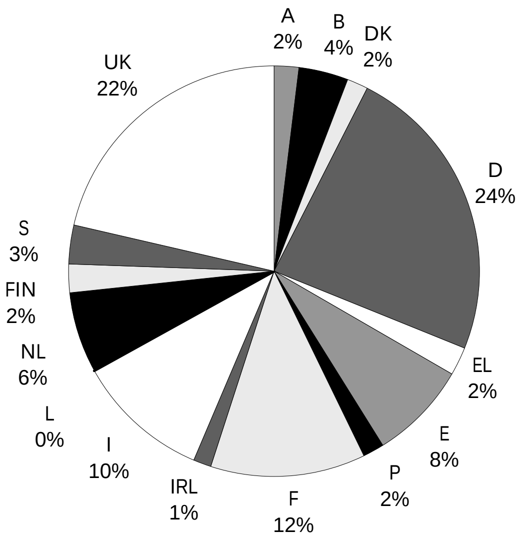


Source: IES/ Eurostat (1998) Labour Force Survey 1997 results.
*Notes: * As a percentage of the population aged 25 to 59, ** ISCED levels 5 and above.*

the lowest in Austria with 8 per cent. The overall figure for the EU was 19.4 per cent (Figure 2.2).

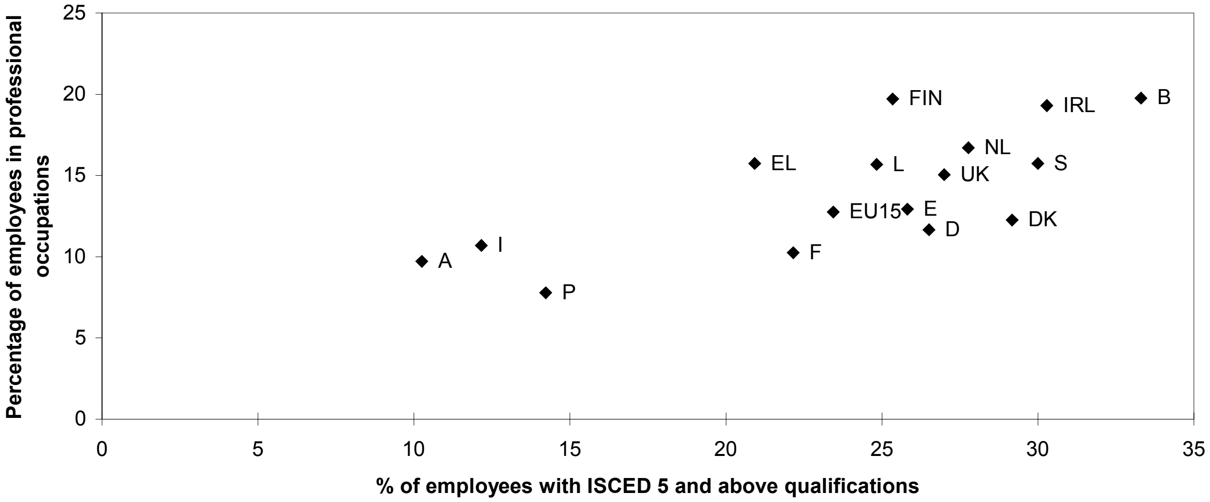
Unfortunately, there are no EU wide data that allow us to focus on employment by S&T fields of study, detailed occupations, or sub-labour markets. See Annex 1 for discussion of data sources. However, a focus on those in **professional occupations** as defined above (*ie* ISCO Major Group 2.) shows that there are 18.5 million professionals in the EU, with Germany again the largest. Germany accounts for 24 per cent of the total professionals, followed by the UK with 22 per cent, while France has only 12 per cent and Spain 8 per cent (Figure 2.3).

Figure 2.3: The population of professionals* (ISCO 2 professional occupations) by country, 1997



Source: Eurostat (1999) LFS results 1997
**EU total is 18.5 million*

Figure 2.4: Densities of professionals (ISCO 2) and graduates in employment, 1997



Source: IES/Eurostat (1999) Labour Force Survey 1997 results

Finally, the countries with the highest densities of professionals within the working population are Belgium (19 per cent), Ireland (18 per cent) and the lowest are Portugal (7 per cent), Austria (9 per cent) and Italy (10 per cent).

It can also be seen that while there are broad similarities between the densities of graduates and of professionals in the employed populations in most countries, this is not always the case. It is also difficult to generalise about the relationship between the two (Figure 2.4). The diversity is illustrated by the fact that while France and Greece have similar proportions of their working population with a high level qualification (22 and 21 per cent respectively), they have widely different proportions of their working populations in professional occupations (10 and 16 per cent respectively). However, as a general rule the percentage in professional occupations rise in line with the percentage with high level qualifications. In part, this is to be expected as a statistical artefact as professional occupations are defined as requiring ISCED level 6 and 7 qualifications.

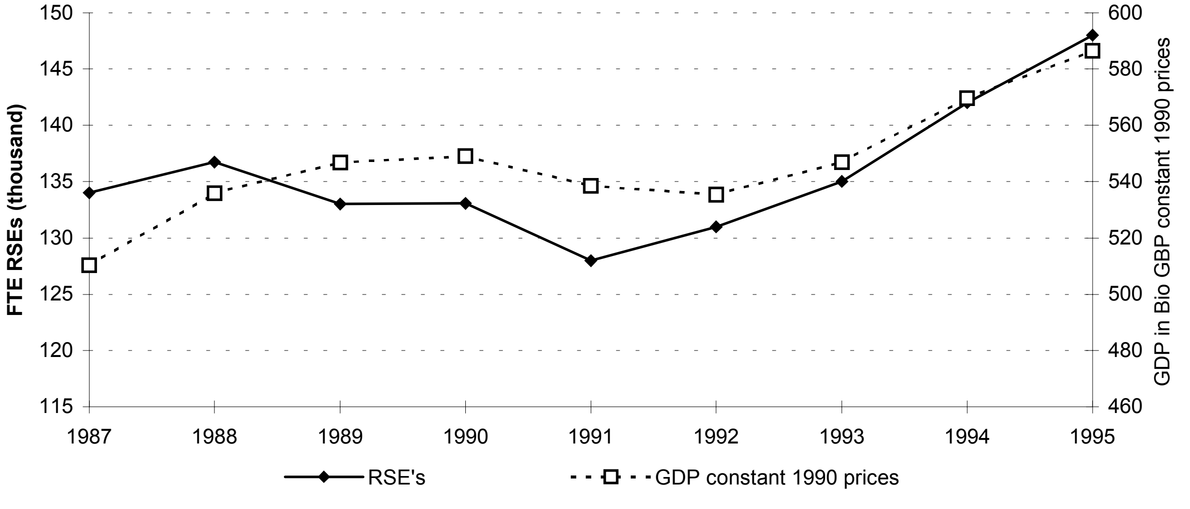
2.4 Key influences on employers' demand for science and technology skills

There are numerous explanations for these different patterns and the diversity between countries in their employment of different types of graduates and scientists and technologists reflecting trends in both the supply and the demand for skills. Employer demand is a function of a number of varied, complex and often inter-related factors. Some are relatively short term and very specific to certain occupations or sectors. For example, the 'millennium bug' and the introduction of the Euro currency, both had a major impact on the growth of demand for information technology (IT) workers, both in the IT sector and among IT users in industry and services sectors (such as banking and retailing). Others are longer term and generic, and although trends vary between countries, it is possible to identify several clusters of factors influencing employer demand and the employment of S&Ts across Europe.

The first, and most frequently written about, are **economic** factors. Much of the research that has been undertaken on employment trends in different countries (*eg* ROA (1995a); Collins (1988); and Wilson (1994)) focus on economic factors as the main influences on the demand for S&Ts. This is particularly the case in research, as have the various econometric models, which extrapolate from past economic and industry trends, have been developed for use in forecasting future demand. However, as pointed out in the introduction to the modelling work in this study (Chapter 5), trends in S&Ts and RSEs do not necessarily always mirror economic trends. Nevertheless, it is generally the case that periods of employment expansion tend to coincide with periods of economic growth and prosperity. This is not always the case, since R&D investment can be higher in times of economic recession, as companies try to recapture lost markets, or because governments act to try to stimulate R&D related activities through public research programmes. Also, there is sometimes a time lag when businesses increase their R&D spending only after they feel sufficient funds have become available (see Annex 2). Nevertheless the relatively close linkage between the number of RSEs (expressed as FTEs) and GDP in constant 1990 prices for the UK is shown in Figure 2.5.

The **industrial policies of national governments and the EC** have also been influential in the development of Europe's science and

Figure 2.5: The Relationship between RSE*s and GDP — UK

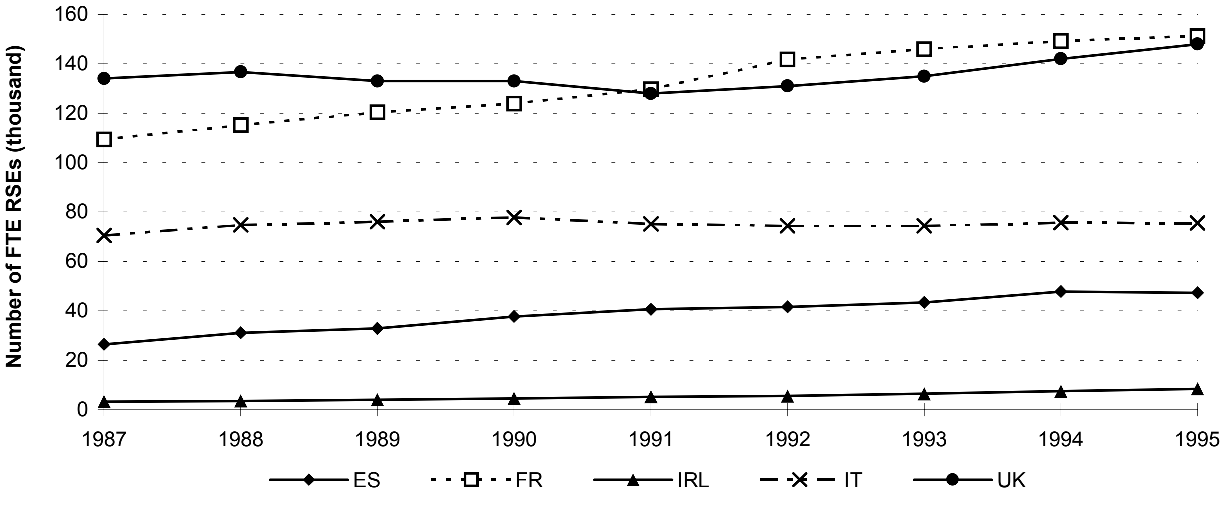


Source: IES/Eurostat (1999) Research and Development Statistics 1998 and *OECD (1999) Main Science and Technology Indicators * RSEs expressed as FTEs* technology base. This has occurred, both through direct funding and subsidy as a purchaser, and as a direct employer of R&D workers in state institutions and universities. It is illustrated, for example, in a study on the demand for French PhD scientists (Beltramo *et al., 1992)* which differentiated clearly between employment in the state, private and higher education sectors, and the influences the changing demand from these sectors has had on the nature of research training. Individual countries have responded to the development of a global economy, to varying degrees, by adopting industrial strategies which link together industrial competitiveness, innovation and skill levels of the workforce (Bianchi, 1994). Other examples include Airbus Industries and the Eurofighter project, along with national examples in France (Balter, 1998); Ireland (Department of Enterprise and Employment, 1997) and Spain (Ballart and Subirats, 1997). Many other examples of ways in which the creation of a highly skilled, technologically advanced workforce is expected to bring about added-value through increased international competitiveness, can be seen in the *Second European Report on S&T Indicators,* 1997 (EU, 1997), which examined many of the factors influencing the competitiveness of the EU.

These national differences and related patterns of innovation have meant that RSE growth has varied by country. Figure 2.6 presents time series data for those countries where consistent data have been regularly available. This shows that RSE numbers have increased most in Spain (up 80 per cent between 1987 and 1995) although from a relatively low base, and France (up 38 per cent). On the other hand the numbers in Italy have grown only slowly over this period (up by 7 per cent).

Other changes relate to the balance between **private and public ownership** and the management of the public sector by central

Figure 2.6: Trends in the numbers of RSEs selected countries, 1987 to 1995 (FTEs)



Source: IES/Eurostat (1999) Research and Development Statistics 1998 and *OECD (1999) Main Science and Technology Indicators* government. The privatisation of national research establishments has led to some reductions in S&T employment, *eg* in the UK. It has also lead to a shift in the type of research being undertaken, away from long term theoretical 'blue sky' to more commercially focused research. This has had implications for recruitment of scientists, *eg* physicists to public sector institutions, with more emphasis being put on recruiting young graduates with a broader range of skills and more commercial awareness (see Section 2.6).

Structural changes in the economy, driven by economic change and or national policies also influence the demand for S&Ts across and between sectors. In general terms service sector employment has been rising and manufacturing falling across Europe, and more widely in the developed world, with growth being concentrated in financial and business services, health care, education and personal services (DGV, 1999). There are great contrasts between mature, traditional industries, and the newer ones. For example, the European steel industry has been affected by a decline over a long period in its share of world markets, which has lead to a reduction in demand for traditional metallurgy skills. In contrast, the growth of the European electronics consumer market and the development of new products, have been key factors behind the long term growth in demand for electronics and software engineers. Many of these are now also being employed directly, or via suppliers or subcontractors to the mature industries. However, gains and losses in different sectors are not spread evenly across occupations and even in some mature industries, such as automobiles, while overall employment has been declining rapidly, there has been growth in key S&T occupations.

Another change has been the growth of small firms, in particular the increasing role that **small and medium sized enterprises (SMEs)** play in the European economy as a whole, and in technological developments. While in some countries, such as Italy and Spain, SMEs have always had a much larger employment share than large enterprises, this has not been generally the case across Europe. In most countries the proportion of employment in the SME sector has grown (EC, 1994). Small firms and start-up businesses are being targeted by governments and agencies as the growth 'sector'. A number of developments such as special grants and advisory services have been established to help them, while the growth of science parks and incubator units are seen to be particularly helpful in encouraging and facilitating innovation and R&D. Unfortunately, data sources are poor in differentiating employment in companies of different sizes. According to the *1994 European Report on S&T Indicators* (EC, 1994) SMEs form a significant portion of R&D in the EU, though this varies by country. For example, in Belgium, Denmark and Spain, over 30 per cent of R&D employment in enterprises was in SMEs. In contrast, in France and Germany it was around 20 per cent and only 6 per cent in the UK (European Commission 1994b).

While most of the influences on the demand for S&T skills are nationally focused, **international** trends are also of importance. There has been a growth in cross-border collaboration, some governmental and some privately backed, *eg* CERN, European Space Agency, Airbus, and the Human Genome project. Re-groupings, mergers and cross border take-overs of national companies (*eg* in pharmaceuticals and telecoms) are also bringing together and rationalising R&D facilities and international expertise into single, integrated organisational structures.

The availability of high quality staff is also an important factor in **inward investment** decisions by foreign owned companies, especially in electronics, IT and pharmaceuticals. Many multi-national enterprises (MNEs) are now locating R&D facilities outside of their home base, and in many cases to the benefit of Europe, as a way of encouraging the growth of global business networks, to control costs, and to better access the EU single market (Papanastassiou and Pearce, 1994). The impact of inward investment varies between countries, in both increasing job opportunities and creating greater competition for available labour. Its effect has been particularly noticeable for the S&T labour market in Ireland. Here the government aimed to transform and expand the country's industrial base by attracting inward investment through the development of its infrastructure and more importantly its education and training system. This has now become more orientated towards producing qualified S&Ts for electronics and high-tech manufacturing industries (an example of S&T demand being 'supply' driven). The availability of high quality labour and a high quality education and training system has also been influential in the development of the semi-conductor industry in Scotland, and the software industry in the South of France. While such inward investment in R&D is seen as a boost to national and local economies, especially in less developed regions, there is some concern that such investment can be a disguised form of 'brain loss'.The scientific skills are 'exported' to be used by companies to support manufacturing, sales, employment and profits in the parent company's home country (Pearson, 1999b).

There are thus a multitude of factors that shape the employment structures of countries and, in particular the balance between the business sectors, higher education and government activities and occupations.

As noted above, there are no internationally harmonised data which focus on the employment of S&Ts by occupational group or sector, within the diverse heading of S&T. Some very limited, and generalised, international evidence are, however, available from the review of the literature coupled with the interviews for this study. This enables some general trends to be highlighted. These are:

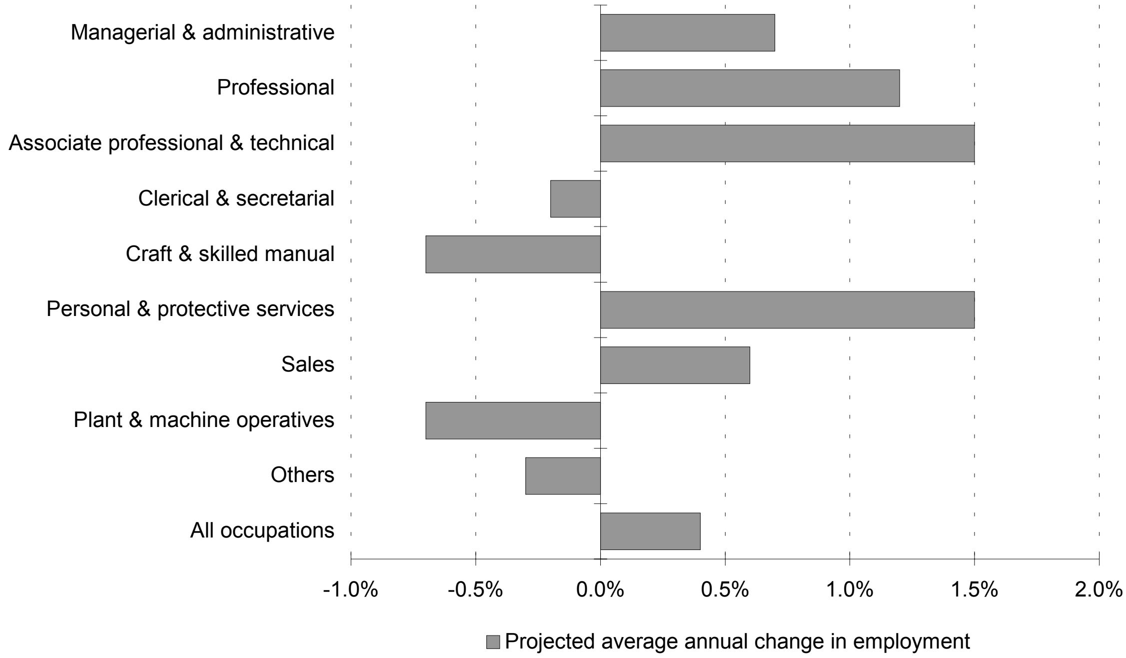
- A **broadening** of the S&T labour market away from traditional concentrations of S&T employment in the public sector and large industrial firms to private smaller firms in industry and services. (*Nb:* in some countries such as Italy, small firms have traditionally been the main employment sector and so this shift is less apparent). Most countries have cut back their public expenditure on science and education and therefore there are fewer public sector openings for graduates. Meanwhile there has been a growth in employment opportunities in the services sector generally, especially in IT services.

- There are noticeable **differences** between the demand for the different S&T occupations and disciplines. Scientists, especially life scientists, have fared less well than engineers and technologists on the whole. This is especially the case in countries where teaching was previously the dominant destination for new science graduates and where public expenditure budgets have been cut back.

- An exceptionally high growth in demand for IT specialists. In most countries there has been widespread growth in the IT sector and the consequent growth in the demand for **IT specialists**. This has been particularly the case in recent years with the concerns about the 'millennium bug' problems and with the introduction of the Euro. Many press reports have also highlighted the growth in concerns about shortages of IT specialists (see also Chapter 4). However, the extensive reviews of the literature shows that despite this level of concern there have been few studies that have focused on the actual trends, while those that do exist focus more on estimates and expectations of trends. For example, a Microsoft report on IT business in Europe forecast growth rates for IT skills (this included all IT staff, not just those not qualified at graduate *ie* ISCED level 5 or above) at 8 per cent per annum over the 1997-2002 period (IDC, 1998), but the basis of the forecast is unclear. A survey of French IT business organisations estimated that there was a need in 1997 for 10,000 'IT experts', up from 6,500 in 1996 (*Le Monde*, 1998). In Ireland a government report indicated that 1,000 more graduates in electronics and computing would be needed to meet demand in their rapidly growing IT and telecommunications sectors (Department of Enterprise and Employment, 1997). In the UK the changing nature of the skills needed for IT has also been highlighted but it has not been quantified (Dench, 1997; Rick *et al.*, 1996). As such, there are no hard statistics from which to generalise such trends.

- There have also been reports of growth in the demand for engineers in some countries. In Germany, the vacancy data from the public employment service shows a gradual increase in the number of vacancies for **engineers** but this has been more than compensated for by the massive increase in supply resulting from the closures of East German establishments

Figure 2.7: Projected occupational change, 1997-2007 — UK



Source: IES/BSL, 1997

following reunification (see Chapter 4). In the UK, there has no evidence of such growth although while engineering employment has continued to fall overall, there has been little aggregate change at professional engineer level (EMTA, 1998).

- Looking ahead, econometric projections point to a growth in the employment of professionals, with a slightly slower growth for scientists and engineers, in the UK (BSL, 1998) (Figure 2.7) and other developed economies (OECD, 1996), mirroring trends in the United States (BLS, 1998).

2.5 The employment of research scientists and engineers (RSEs)

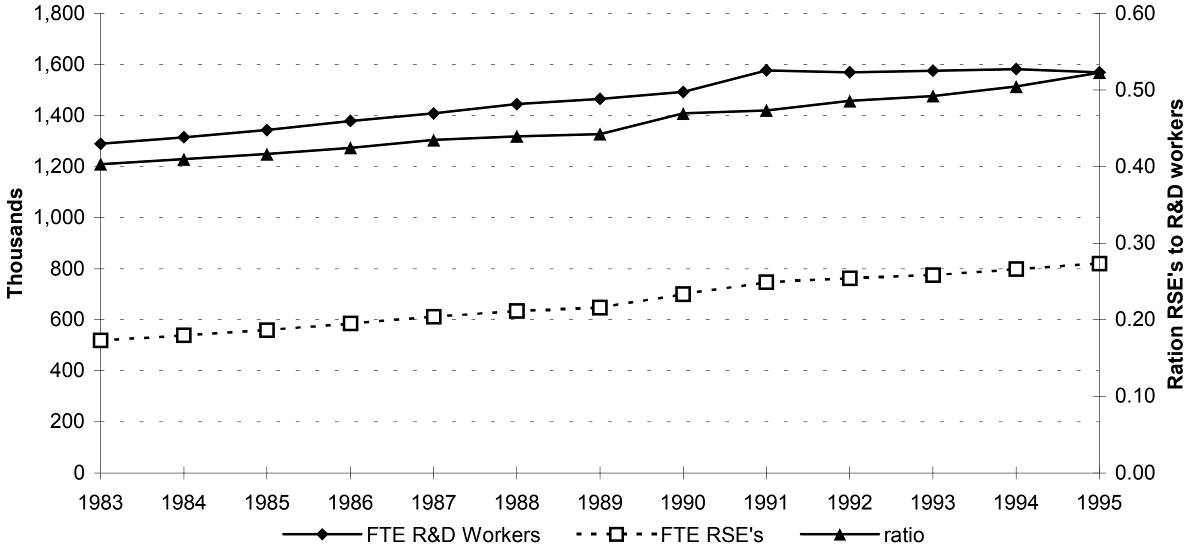
2.5.1 Overall trends

The rest of this Chapter now focuses on R&D employment, and in particular RSEs, as this is the group where the best data exists.

The number of **R&D personnel** in the EU has grown steadily from around 1.3m in 1983 to around 1.57m in 1997 although the numbers has been broadly static during the first half of 1990s (Figure 2.8). This trend however conceals variations between countries.

Within these slowly growing overall totals, there has been a noticeable occupational shift with a rising proportion of the R&D workforce being Research Scientists and Engineers **(RSEs)** (Figure 2.8). Their numbers have grown fast from 520,000 in 1983 to

Figure 2.8: Ratio of RSEs to R&D workers for EUR 15, 1983 to 1995

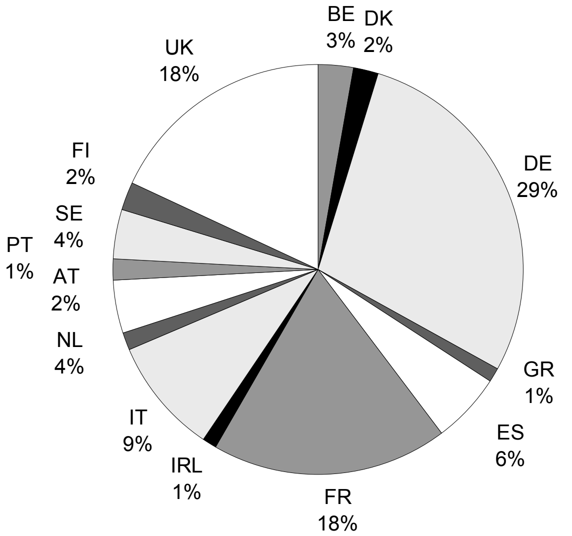


Source: IES/Eurostat (1999) Research and Development Statistics 1998 and *OECD (1999) Main Science and Technology Indicators*

818,000 in 1995. Since one of the definitions of RSEs is that they are R&D workers with university level qualifications this suggests an increasingly graduate R&D workforce. At the same time, the evidence from contacts with employers suggests that increasing numbers of qualified graduates are also entering lower-level technician posts reinforcing this picture.

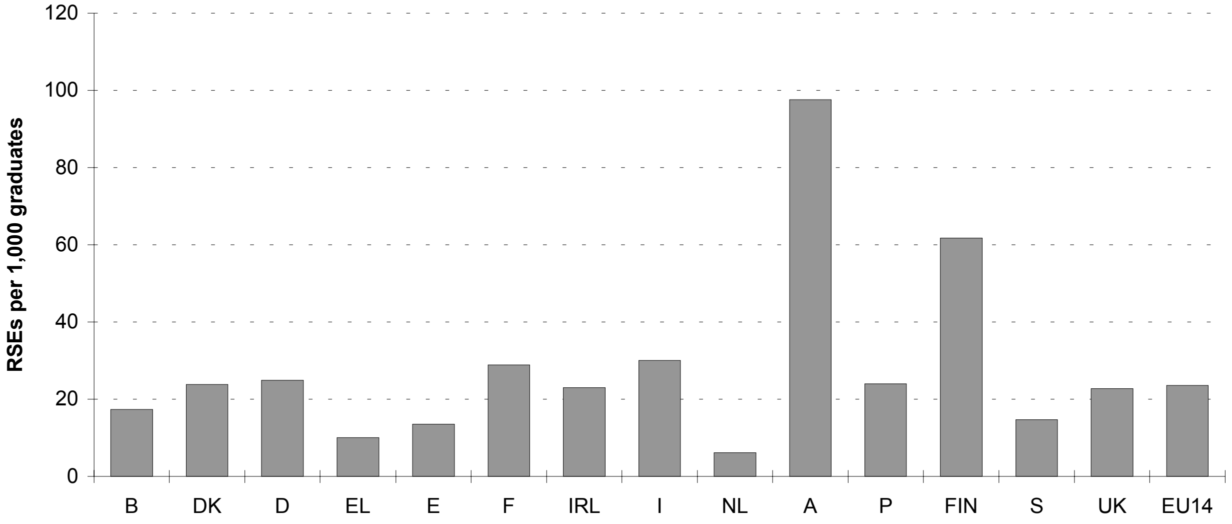
Within the total of 818,000 RSEs there is another pattern across Europe, with Germany (29 per cent), France (18 per cent) and the UK (18 per cent) accounting for almost two-thirds of the EU total (Figure 2.9). This is a higher share than that for professionals. (Section 2.3).

Figure 2.9: The RSE population by country 1995*



** Note: Generally 1995, Denmark 1996 and Greece and Portugal 1993*
Source: IES/Eurostat (1999) Research and Development statistics 1998 and OECD (1999) Main Science and Technology Indicators

Figure 2.10: RSEs* per 1,000 graduates **, 1997



** Note: Latest data mainly 1995 except Denmark 1996, Greece and Portugal 1993*
*** Note: Those in employment with an ISCED Levels 5, 6 or 7 qualification*
Source: Eurostat (1998) Labour Force Survey Results 1997 and Eurostat (1999) Research and Development Statistics Annual Statistics 1988, OECD (1999) Main Science and Technology Indicators

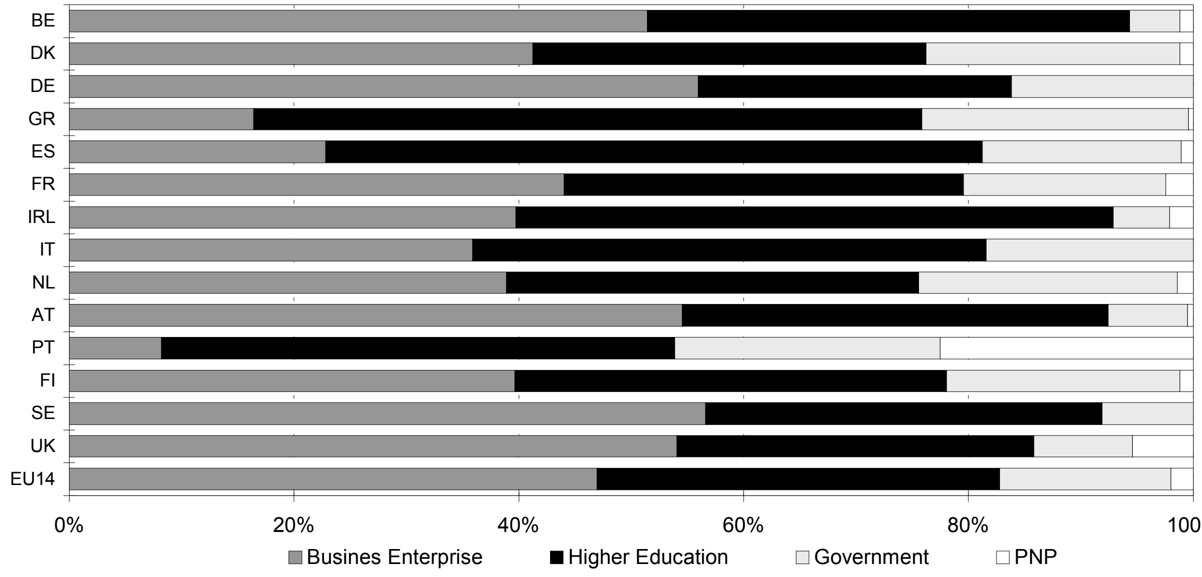
When these figures are normalised in relation to countries' overall population of graduates, Austria has the highest densities of RSEs in relation to graduates and the Netherlands the lowest (Figure 2.10). This is mainly a reflection of the low numbers of graduates in Austria and the relatively high numbers in the Netherlands.

There are also marked differences between the sectoral distribution of RSEs between countries. For example, in Belgium, Germany, Sweden and the UK the Business Enterprise sector contains over half of all RSEs, while in Portugal and Greece only 8 per cent and 16 per cent respectively are in the Business Enterprise sector. In Greece, Spain and Ireland the Higher Education sector represents over half of all RSEs compared with 28 per cent of RSEs in Germany (Figure 2.11). Finally, there are variations in the proportion of RSEs employed by Private not for Profit (PNP) R&D establishments, which varies from none to 22 per cent in Portugal.

2.5.2 The IES Survey of R&D Establishments

Given the paucity of published data, a special *IES Survey of R&D Establishments* (see Annex 1 for further details) was undertaken for this study to examine adequacy issues in more detail, and to provide data for the econometric forecasting work (Chapter 5, Annex 2). The survey generated responses from 210 R&D establishments in 14 EU countries (Luxembourg was excluded) covering the Business Enterprise, government and HE sectors. Between them they employed almost 15,000 (9,000 FTEs, or 1 per cent of the population of RSEs. These data are now used to address the gender, age and qualification profile of these R&D establishments as a proxy for the profile of RSEs in Europe. Since

Figure 2.11: RSEs by sector, 1995*(percentages)



** Note: Denmark 1996, Greece and Portugal 1993*

Source: IES/Eurostat (1999) Research and Development Statistics 1998 and *OECD (1999) Main Science and Technology Indicators*

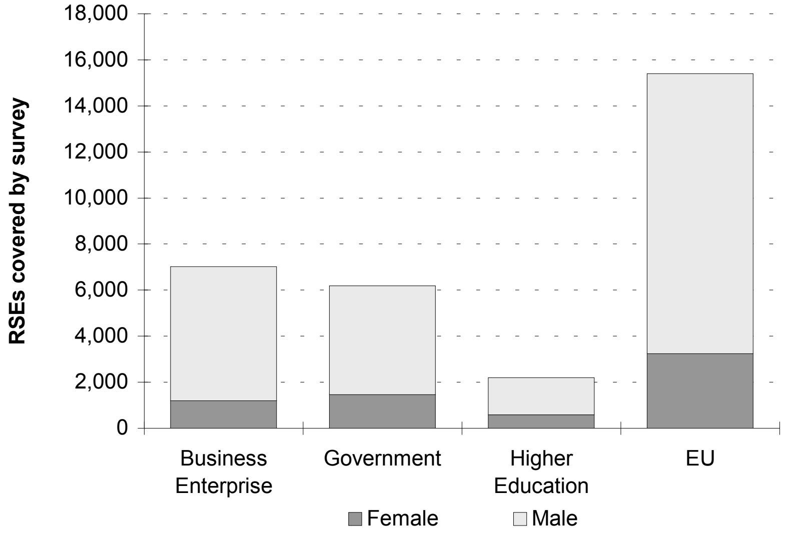
there is no accurate census of R&D establishments it is impossible to say how large the population of establishments is or how it is composed. This in turn means that it is not possible to accurately estimate the reliability of the estimates presented here. Where relevant the statistical reliability of differences between sectors or countries is given. The numbers of cases on which the estimates are based are contained in Annex 1.

2.5.3 Gender profile

The R&D establishment survey reported on 15,000 RSEs (9,000 FTEs) employed in 210 R&D establishments. They were predominantly male, with only one in five RSEs employed being female**.** The HE sector was the most likely to employ women (27 per cent) and the business enterprise sector the least likely (17 per cent), (Figure 2.12).

On a national basis, women formed only 14 per cent of the total RSEs in the German and Dutch R&D establishments. This rose to almost 40 per cent in Italy, Spain and Finland, and almost 60 per cent in Ireland. The diversity can be related to at least two factors: differences in the sector distributions and in the age profiles of R&D employment in each country as noted below. Younger growth sectors like IT have much higher recruitment rates and therefore higher percentages of female employees than more traditional sectors with low recruitment levels, such as motor vehicles and steel making. This low average representation of women among RSEs is consistent with a range of other studies on female participation in science and engineering, and with the current low percentage of women among science and engineering

Figure 2.12: Gender profile of RSEs in establishment survey, 1998



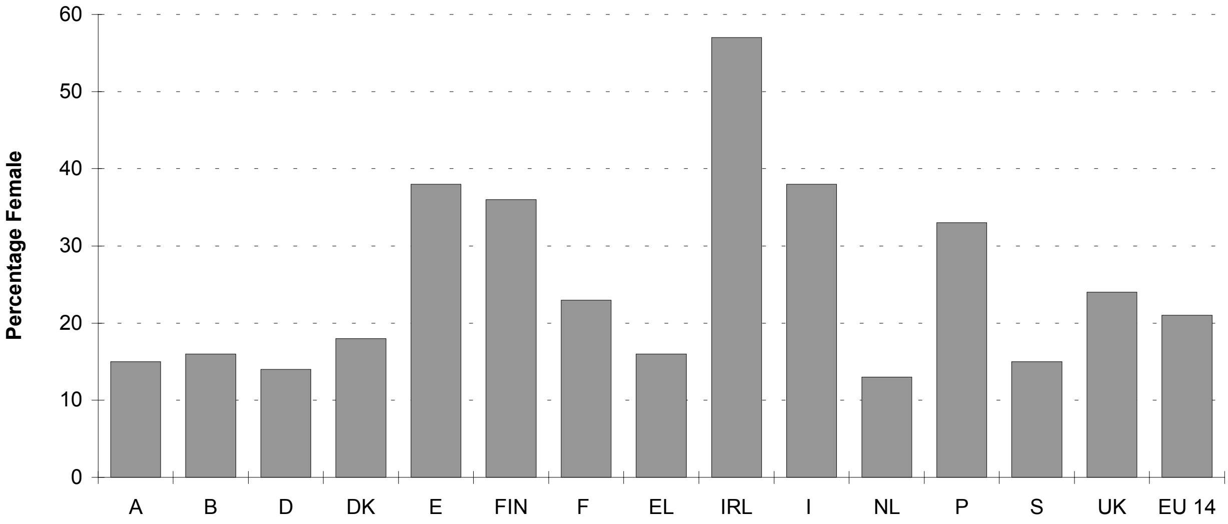
(n = 210, see Annex 1.4)

Source: IES R&D Establishments Survey

graduates (25 per cent overall for the EU [European Commission, 1997]).

The sectoral composition of national systems of R&D also partly determines the national gender balance. Countries such as Germany where the Business Enterprise sector accounts for a large proportion of RSEs, and where the RSEs are generally older, have a correspondingly lower percentage of female RSEs (Figure 2.13). Countries like Ireland which have both a young RSE population, and a larger proportion of RSEs in the HE and government sectors also tend to have a relatively large percentage of female RSEs.

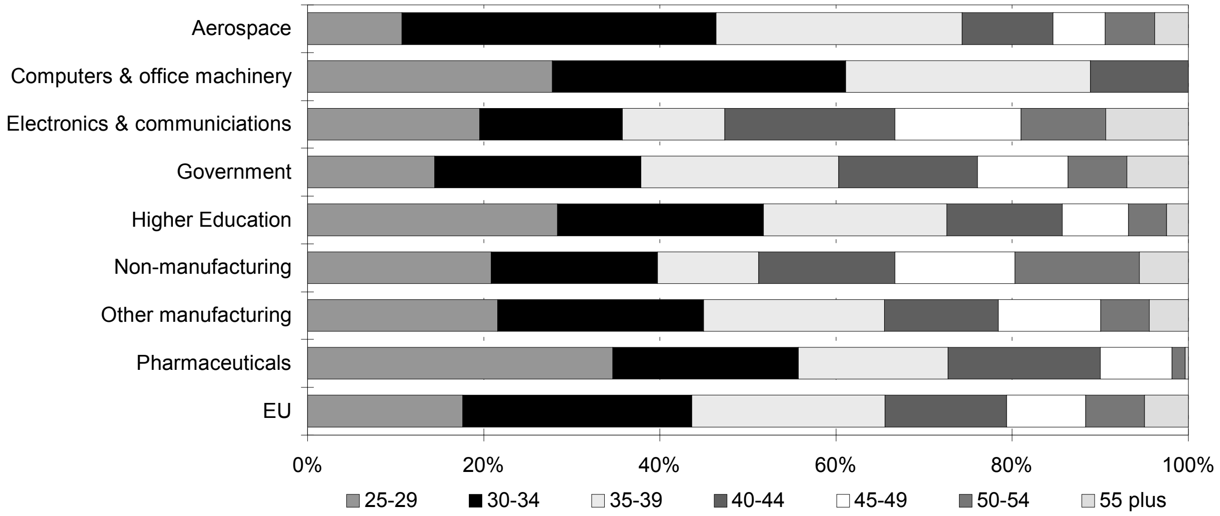
Figure 2.13: Gender profile of RSEs in establishment survey by country; 1998



(n = 210 see Annex 1.4)

Source: IES R&D Establishments Survey

Figure 2.14: Age profiles of RSEs in establishment survey by sector, 1998



(n = 210, see Annex 1.4)

Source: IES R&D Establishment Survey

2.5.4 Age profile

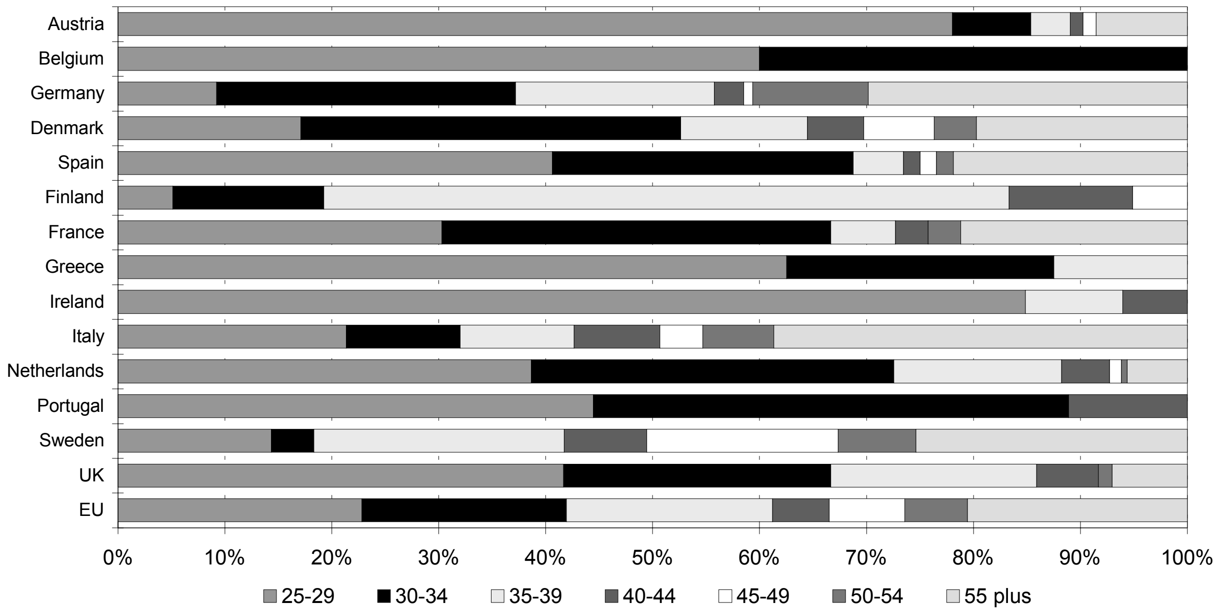
There were noticeable differences in age between sectors as reported in the establishments survey. The government sector has a much older profile, with 24 per cent of their RSEs aged 45 and over, compared with 21 per cent in the BE sector and 14 per cent in the HE sector. Within the business sector, computer and office machinery and pharmaceuticals had younger age profiles than electronics and communications and the non-manufacturing sectors. (Figure 2.14).

There were also noticeable differences between countries' age profiles (Figure 2.15). The German age profile was markedly older than those of other countries; in Finland and Sweden the RSE workforces were also, on average, older. These variations can partly be explained by the different sector distributions as discussed above. The older German age profile, however, is partly explained by the effects of re-unification, which has led to relatively static numbers, a curtailment in recruitment and a consequent ageing of the workforce. Another explanation for the German age profile is the long time it takes to acquire a Doctorate and the consequent starting of a research career.

2.5.5 Qualification profile

The proportion of RSEs in the establishments survey with **PhD qualifications** was much lower in the Business sector R&D establishments (only 15 per cent), than in the government or HE R&D establishments (around 50 per cent). This is consistent with some national studies, which have shown that most of the employment opportunities for PhD scientists is in universities and

Figure 2.15: National age profiles of RSEs in establishment survey, 1998



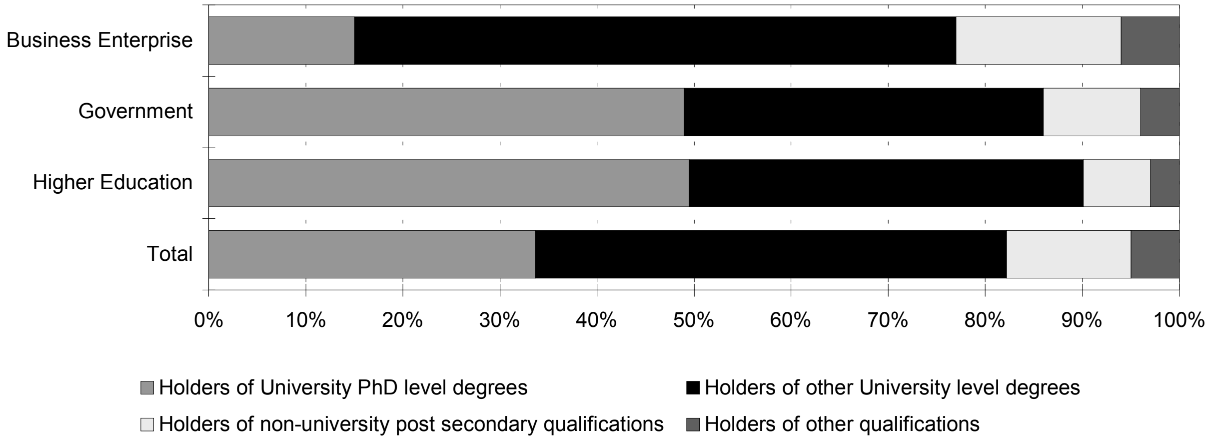
(n = 210, see Annex 1.4)

Source: IES R&D Establishments Survey

public laboratories (in France, for example, [Bénichou, 1998] and the UK [Connor *et. al.* 1994]) (Figure 2.16).

On a country basis, the highest percentages with doctorates were found in Austria, Netherlands and Spain (each almost 60 per cent or more) (Figure 2.17). Again, these different qualification profiles are partly explained by the different sector distributions within countries. However, they also relate to differences in historical recruitment patterns, age profiles, and the variations in the growth of output of S&Ts with different HE qualifications in national education systems.

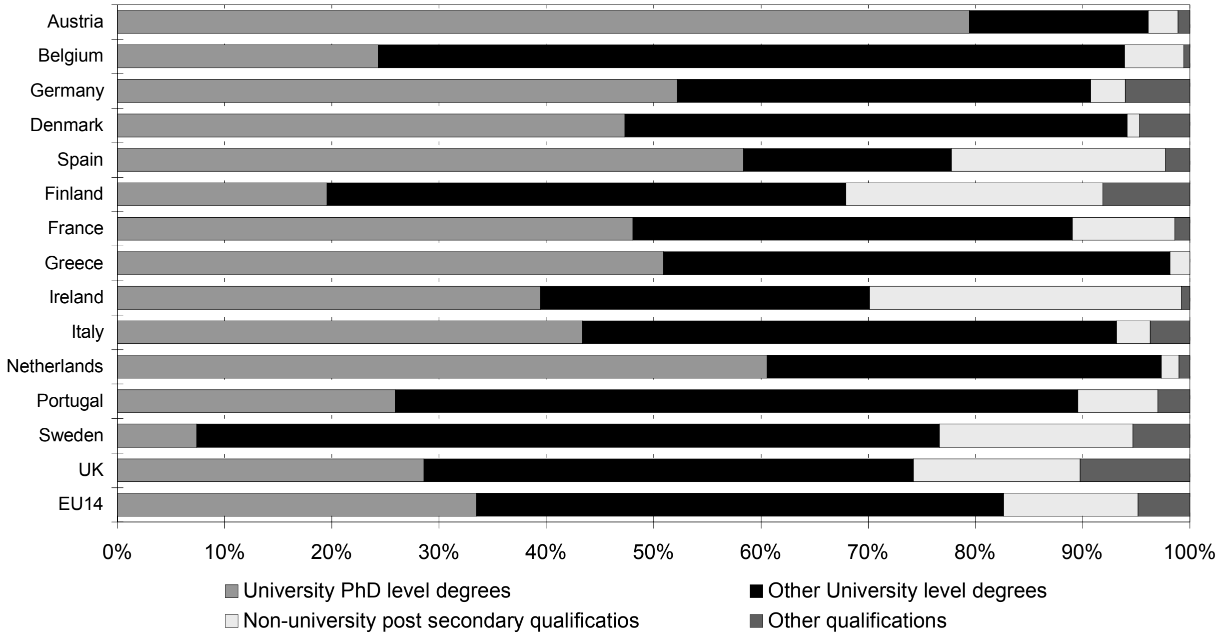
Figure 2.16: Qualification profiles of RSEs in establishment survey by sector, 1998



(n = 210, see Annex 1.4)

Source: IES R&D Establishments Survey

Figure 2.17: Qualification profiles of RSEs in establishment survey by country, 1998



(n = 210 see Annex 1.4)

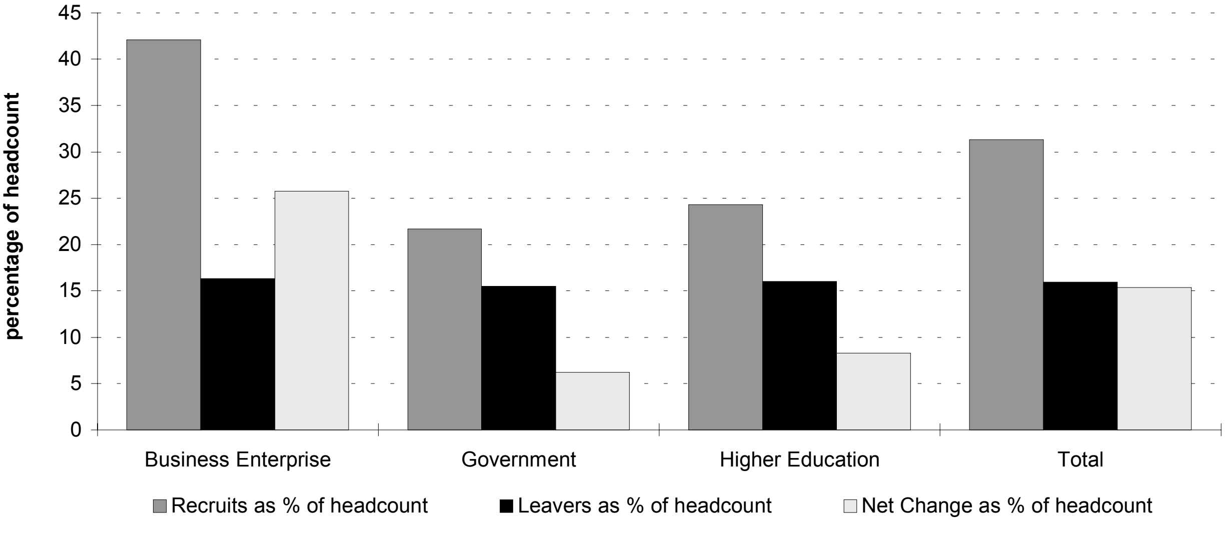
Source: IES R&D Establishments Survey

2.6 RSE recruits and leavers

2.6.1 Recruitment levels of RSEs

Turning to recruitment patterns, the establishments survey provided evidence on the levels of recruitment over the last 5 years. Across the R&D establishments, the annual **number of recruits** averaged 6 per cent of headcount, with leavers averaging

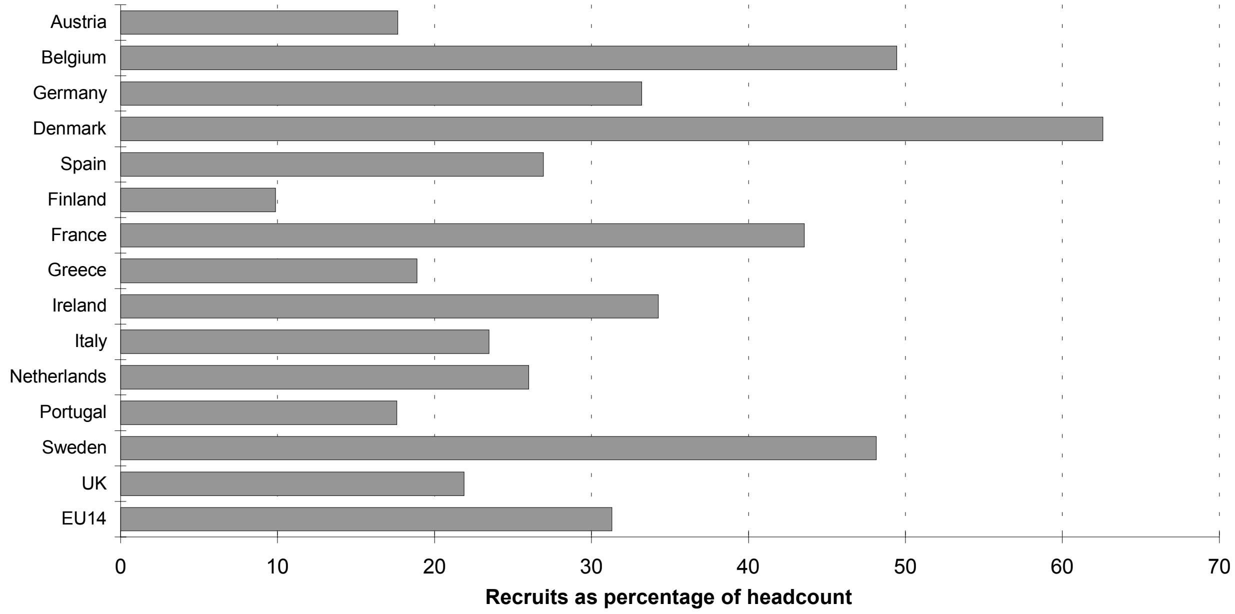
Figure 2.18: Recruits, leavers and changes as a percentage of headcount in establishment survey, by sector, 1992-97



(n = 210 see Annex 1.4)

Source: IES R&D Establishments Survey, 1998

Figure 2.19: Recruits as a percentage of headcount in establishment survey, by country, 1992-97



(n = 210 see Annex 1.4)

Source: IES R&D Establishment Survey

about 3 per cent p.a. The net effect was for headcount to grow by about 3 per cent annually. Headcount growth and recruitment levels were highest in the Business sector (over 40 per cent overall) and lowest in the government sector (just over 20 per cent over the period 1992-97) (Figure 2.18). These figures reflect the broader sectoral changes noted above, with the demand for RSEs having reduced in the public sector because of cutbacks in public expenditure on R&D and education.

The analysis by country shows wide variations in recruitment levels over the last five years, from an overall 63 per cent of headcount in Denmark, to 10 to 25 per cent of headcount in Finland, UK, Portugal, Greece and Austria. These differences indicate the extent to which patterns of demand at a country level are likely to vary, being caused by a combination of factors including structural changes and economic trends, as well as factors relating specifically to sectoral demand for particular groups of RSEs (Figure 2.19).

2.6.2 Recruitment sources of RSEs

As noted above, it is important to recognise that recruitment levels are influenced not only by changes in overall employment but also by retirements and other staff turnover. To fulfil their recruitment plans, employers utilise a wide range of recruitment sources. The IES survey and other research have shown that not all recruitment is focused on new entrants to the labour market (*ie* newly qualified graduates). Firms recruit experienced staff from other organisations, both from within and outside of their country. The most important categories of recruit were identified

Table 2.2: Key recruitment sources for RSEs in establishment survey (percentages)

	Used	Rated as very important
Recent PhD level university graduates from own country	86	36
Recent PhD level university graduates from other EU countries	70	11
Recent PhD level university graduates from other non-EU countries	53	5
Recent non-PhD level university graduates from own country	89	34
Recent non-PhD level university graduates from other EU countries	66	4
Recent non-PhD level university graduates from non-EU countries	43	1
Recent post-doctorates	68	16
From other parts of parent organisation	60	10
Other R&D organisations in own country	81	14
Other R&D organisations in other EU countries	67	4
Other R&D organisations in other non-EU countries	51	2
Other non R&D posts or retirement	37	1
Sponsored students	77	13

(n = 210 see Annex 1.4)

Source: IES R&D Establishment Survey

in the *IES R&D Establishment Survey* as university graduates at PhD and other levels from their own country, while the least used sources were those from outside the EU, non R&D posts or from retirement (Table 2.2).

There was also variation between sectors. Government and the HE sector place most emphasis in recruitment on PhDs, particularly those from their home country, and recent post-docs, and government is more likely to recruit sponsored students (Table 2.3) (see also Connor, 1994, Jagger 1998).

Employer interviews here and elsewhere have indicated that the recruitment of university graduates has become more selective. It focuses on particular universities and courses with good reputations, both in employers' home and, in a small but growing number of cases, other European countries. Through research links they often recruit PhDs rather than advertise openly. Graduates who have been on 'stage' placements or work experience are also seen as a valuable source of recruits where the company has already been able to judge their skills and the graduates assess the careers on offer. For example, one major international pharmaceuticals company takes 1,800 students as industrial trainees each year for 'stage' placements. On the whole, the number of graduates recruited from outside the establishment's country is, however, usually very small in comparison to those recruited from the domestic market. There are a few exceptions, *eg* Shell who run a joint UK — Dutch recruitment campaign. Numbers of non-nationals were higher among experienced recruits, when relatively rare and very specific

Table 2.3: The importance of different recruitment sources for RSE staff, in the establishment survey, by sector, 1998

	Business Enterprise	Govt	Higher Education	Total
Recent PhD level university graduates from your country	3.3	3.8	3.9	3.6
Recent non-PhD level university graduates from your country	3.6	3.9	3.4	3.6
Other R&D organisations in your country	3.1	3.2	2.7	3.0
Sponsored students 8	2.9	3.3	2.7	2.9
Recent post-doctorates *	2.3	3.3	2.8	2.7
Recent PhD level university graduates from other EU countries	2.2	2.7	3.0	2.6
From other parts of your parent organisation	2.4	2.3	2.3	2.4
Recent non-PhD university graduates from other EU countries	2.3	2.4	2.2	2.3
Other R&D organisations in other EU countries	2.4	2.3	2.1	2.3
Recent PhD level university graduates from other non-EU countries	1.7	2.0	2.4	2.0
Other R&D organisations in other non-EU countries	1.9	1.7	1.8	1.8
Recent non-PhD university graduates from other non-EU countries	1.7	1.7	1.7	1.7
Other non R&D posts or retirement	1.6	1.5	1.4	1.6

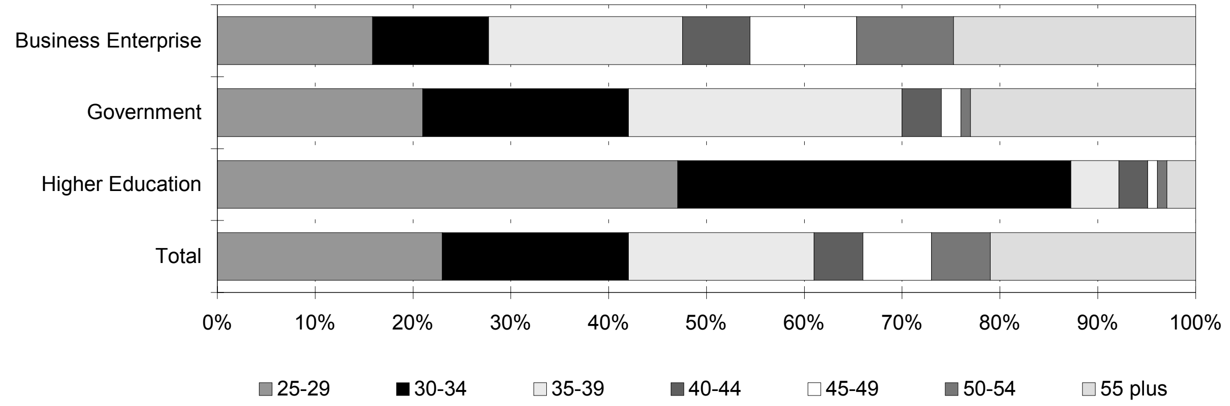
Scores are on a scale 1 to 5 where 5 is the most important
*statistically significant difference at the 10 per cent level ** statistically significant difference at the 1 per cent level*
(n = 210 see Annex 1.4)

Source: IES R&D Establishments Survey

expertise and skills were being sought, *eg* in computer modelling systems, bio-informatics, and process control.

While mobility of labour between European countries is, in principle, unconstrained there are many implicit language, cultural and in some cases administrative barriers. Although the level of international mobility of labour is still relatively low and varies between countries, it appears to be a growth area. This is being encouraged by a number of EC and national initiatives to encourage the mobility of researchers, students and academic staff such as the EU Erasmus and COMETT programmes, and the degree programmes of the French Grandes Ecoles and other universities. The evidence of international recruitment practices in the early 1990s (see Pearson, 1992; CSU/EC 1992) showed that the level of employers' recruitment of graduates from other European countries had been overstated in the press. It was in fact very small in comparison to domestic recruitment, and was concentrated in engineering and business related disciplines. A more recent study (Court and Jagger 1995e) showed that up to 10 per cent of RSEs employed were non nationals. While there have been no recent updates of these European-wide surveys, individual employers have reported small increases in intakes through, for example, targeting specific prestigious European universities. This process is being further encouraged by the growth in international recruitment fairs. At the same time, more non-nationals are approaching employers directly via their national recruitment activities.

Figure 2.20: Age profiles of RSE leavers in the establishment survey by sector, 1998



(n = 210 see Annex 1.4)

Source: IES R&D Establishment Survey

2.6.3 Leavers

Leaving rates as reported in the establishment survey were similar across the sectors (Figure 2.18), but the age profiles differed significantly. The age profiles of leavers by sector shows that the vast majority (88 per cent) RSEs leaving the HE sector over the period 1992-97 were under 35 years old, this probably reflects short-term post-doctoral appointments. There is a similar pattern in government R&D establishments where the bulk (71 per cent) of RSEs leaving an active research position are aged under 40 and few leavers aged 40-55. In both the government and business sectors, one in five of the leavers were aged over 55, presumably retirees (Figure 2.20).

However, this pattern appears to be very dependant on national patterns (based on the age profile of the stock and patterns of tenure and pension rights). German and Italian RSEs tend to remain until retirement, while the majority of Belgian and Irish RSEs left their then current post aged under 40.

2.7 Employer's changing skill requirements

2.7.1 Key skills

Demand is about more than the employment of people, it is also about the skills and attributes that are needed in work. As noted below various research studies have highlighted the increasing importance employers are giving to non-technical as well as technical skills in S&Ts in a wide range of occupations from IT staff through to environmental scientists.

From the available evidence, the main growth in requirements in technical skill areas during the 1980s and 90s has been in IT and communications technology (especially networking, internet, and desktop publishing skills), biotechnology, materials science and environmental science. Research has also shown strong support among employers for development of a broader range of scientific skills in higher education scientific curriculum (Coles, 1998). Given the pace and complexity of economic and technical change and organisational responses, employers find that trying to forecast future skill trends using the methods of manpower planning, as well as occupation and skill set modelling, are increasingly problematic and in many cases irrelevant (Hirsh, and Reilly, 1998). However, they usually can identify some broad trends. The *IES Survey of R&D Establishments* confirmed the importance to employers of a broad range of scientific knowledge. It showed that when seeking graduates the general level of scientific knowledge and research skills were more important than specific areas of technical/scientific skills. Business enterprises put the most emphasis on general scientific knowledge, while government establishments emphasised research skills as being the most important (Table 2.4). Interviews with individual employers highlight the need for good laboratory skills (Mason, 1998).

At a more general level employers are increasingly looking to recruit and train people who have the ability to adapt rapidly and learn different skills, sometimes within a very different conceptual framework to that in which they are already working. Recruiters are looking for logical and analytical ability, and a level of intellectual capacity. These are seen as the best indicators of potential, rather than specific existing skills. In addition, technical skills alone are rarely enough, and a range of generic abilities are increasingly being sought including the ability to recognise a business problem, analyse the need for, and introduce an

Table 2.4: Importance* of RSEs technical skills among graduate recruits in the establishment survey, by sector

	Business Enterprise	Govt	Higher Education	All organisations
General level of scientific knowledge	4.0	4.0	4.2	4.1
Specific areas of scientific knowledge *	3.9	4.0	4.1	4.0
Research skills	3.7	4.1	4.3	4.0
Mathematical and/or computing skills	3.6	3.6	3.8	3.7
Ability to perform specific procedures *	3.5	3.1	3.5	3.5
Level of appreciation of other technical areas	3.4	3.3	3.4	3.4
Engineering/materials science skills *	3.9	2.9	3.1	3.4
Ability to use specific types of equipment	3.2	3.0	3.5	3.3
Physical science skills	2.8	3.2	2.9	2.9
Environmental science skills *	2.2	2.8	2.2	2.3
Biological/biomedical skills	2.0	2.6	2.3	2.2

Mean scores from a scale of 1 to 5 where 1 is unimportant and 5 is Essential
*statistically significant difference at the 10 per cent level ** statistically significant difference at the 1 per cent level*
(n = 210 see Annex 1.4)

Source: IES R&D Establishments Survey

Table 2.5: Importance* of personal skills for R&D establishments

	Business Enterprise	Government	Higher Education	All organisations
Problem solving	4.4	4.5	4.3	4.4
Team working	4.2	4.3	4.1	4.2
Written communication skills	3.9	4.1	4.0	4.0
Oral communication skills	4.0	3.9	4.1	4.0
Planning and organising	4.0	4.0	3.6	3.8
Project management skills *	4.0	4.0	3.5	3.8
Foreign language skills	3.6	3.9	3.8	3.7
Information technology	3.7	3.7	3.7	3.7
Leadership *	3.7	3.9	3.2	3.5
Time management	3.7	3.5	3.2	3.5
Business awareness *	3.5	3.5	2.6	3.2

Mean scores from a scale of 1 to 5 where 1 is unimportant and 5 is Essential
*statistically significant difference at the 10 per cent level ** statistically significant difference at the 1 per cent level*
(n = 210 see Annex 1.4)

Source: IES Survey of R&D Establishments 1998

appropriate technical solution (Dench, 1998). Greater emphasis is also being given in recruitment and selection to 'employability' which can include a number of things such as work attitudes, team working, client relationship skills and commercial awareness (Jagger, 1998).

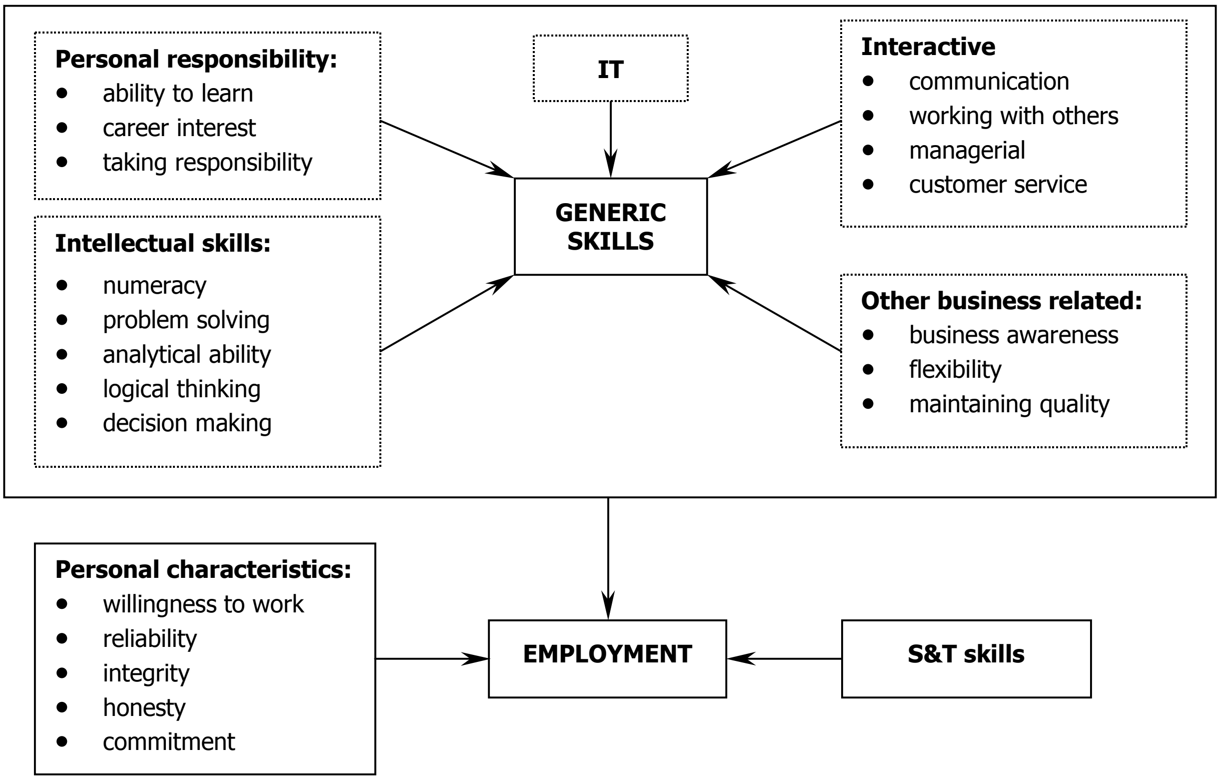
The IES survey of R&D establishments found that problem solving and team working were the most prized personal skills amongst RSE recruits (Table 2.5). Importantly, in comparison with the technical skills in Table 2.4 these personal skills generally score as being of higher importance than the technical skills. Higher education R&D establishments were looking for a different balance of personal skills, with Business Enterprise and government gave significantly higher scores than Higher education to 'Project management', 'Leadership', 'Time management' and 'Business awareness' skills.

This is illustrated in the UK, for example, where recruiting the 'right' people and not just the right technical skills has become ever more important. Jobs become increasingly demanding and an organisation's competitive strength relies on the overall quality of the workforce. Consequently, many employers have begun to define much more rigorously what they are looking for, in terms of the potential to develop, and the necessary underlying personal and behavioural characteristics or values.

This also applies to many large multinational companies recruiting from across Europe, *eg* Shell and IBM. A key need is for recruits who are flexible and can adapt and respond to the changing needs of the workplace. Articulating and defining such skills is, however, fraught with difficulties. There is a lack of a common terminology, with terms such as behavioural, generic, key, transferable, soft, and non-occupational all being used interchangeably. The labels themselves can often hide more than they reveal with, *eg* 'business awareness' being capable of a multitude of definitions. As such many employers struggle to define their needs in terms of their own organisations, providing adequate and clear messages for those in the education system is an even greater challenge. The breadth and complexity of the key skills that are often talked about is illustrated in Figure 2.21. The extent to which an individual needs such a skill will vary according to the role, organisation and context within which they are employed (Pearson, 1999a).

These are areas where HE has been criticised in a number of countries for not responding sufficiently to business needs. For example, Dutch engineering courses are seen to be weak on developing social skills partly because of the heavy academic workload (Anon, 1993). German university curricula have been criticised for their lack of awareness of social and business needs (Anon, 1996f). UK chemistry degree courses are criticised by laboratory managers for their poor development of analytical and laboratory skills, and communication skills among their students (Mason, 1998). For further discussion see (UNESCO, 1998) and the discussion on responsiveness of HE in Chapter 4.

Figure 2.21: The breadth of graduate skills in demand in the UK



Source: IES/Pearson, 1999

2.7.2 The incidence of vocational training

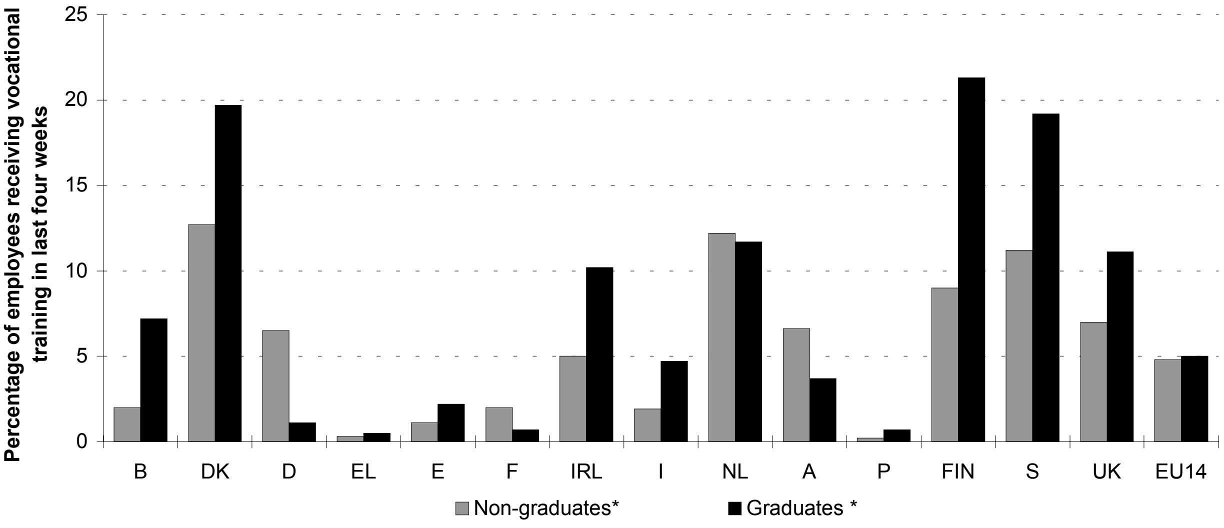
One indicator of employers' need for new skills and their investment in the development of their staff's skills is the incidence of training undertaken. This is only a partial measure, as it takes no account of the quality, relevance, or duration of the training, nor what is learnt. Neither does it take account of less structured methods of learning and development such as coaching, on the job experience, self-development *etc.*

It has been suggested that the higher levels of training generally received by graduates compared with non-graduates reflect inadequate preparation by their university education. However, in practice graduates tend to enter sectors and occupations with traditionally high levels of training. In addition, employers indicate that they feel graduates are the most likely to benefit from training and hence they are more likely to be trained.

The Eurostat *Labour Force Survey* asks a question about whether the respondent has received any training over the last four weeks. The national contexts vary, but a wide variation in such training can be seen across countries, with the highest incidence of training being provided in Denmark, Finland and Sweden, and in general graduates receiving more training than non-graduates (Figure 2.22).

Chapter 3 now turns to assess the supply of those graduating from higher education and Chapter 4 assesses the adequacy of this supply in meeting the expressed needs of European employers.

Figure 2.22: Vocational training in the last four weeks for those in employment by educational status, 1997



** Notes: Graduates have an ISCED levels 5 to 7 qualification,*
Source: IES and Eurostat special tabulation of the 1997 LFS

3. Graduate Output and Transitions into Employment

3.1 Introduction

As has already been highlighted in earlier chapters, adequacy is a function of a wide range of factors relating to employers' demand and to the supply of qualified and skilled S&Ts. The availability of suitably qualified S&Ts is an important factor influencing decisions by companies to open up or develop further new R&D and manufacturing plants, and especially foreign owned companies to invest in countries, *ie* inward investment. Conversely, an inadequate supply can also be a constraint on their businesses. Employers often have a tendency to blame the inadequacies of the education and training system for their recruitment difficulties. National governmental responses to problems of adequacy have often been focused on making changes to the supply rather than the demand side, *eg* increasing student numbers, or the development of new training programmes and in some cases encouraging immigration. However, as noted in Chapter 1 there are also many demand side adjustments that employers can make, these are considered further in Chapters 4 and 6.

In contrast to the paucity of research on S&T occupations, there is a substantial body of literature at a national and European level on developments in higher education and considerably more on trends in numbers. However, much of the literature relates to the 1980s and earlier and does not deal with the situation from the mid-1990s onwards which followed a substantial expansion in higher education. Unfortunately there is much less data disaggregated by field of study.

This chapter first gives a brief overview of recent developments in HE systems. It then presents the main trends in graduate output. This is followed by a discussion on the transition from HE to employment.

3.2 The diversity of European higher education

It is important first to emphasise the diversity of higher education (HE) across Europe and the significant differences between higher education in different countries. As such it is difficult to reach a consensus about influences which shape graduate output at a European level (see, *eg* Gellert, 1993a; Teichler, 1996; OECD, 1995b and 1998b; NCIHE, 1997). Key dimensions of these differences in national systems of education include:

- National higher education structures
- The relationship with national governments
- Responsiveness of higher education.

These are dealt with in turn below.

3.2.1 National higher education structures

The structure of higher education systems vary greatly in terms of the types of courses, the time students take and are officially allowed to complete studies, qualifications, approaches to teaching and learning and types of institutions. For example:

- **Institutions**: Dual systems operate in most, but not all countries, including in Germany and Austria, universities and the more vocationally orientated Fachochshules; in France Universities and Grandes Ecoles; in the Netherlands Universities and Hogescolen; in Greece Universities and Technical Educational Institutes. The exceptions are Ireland, Italy, Spain and the UK, which have mainly unitary systems, the former 'binary' system in the UK being merged in 1992. However, to complicate matters further, many countries have specialist science and technology institutes within their university sector. These vary in their size and relative significance in term of graduate output: Denmark has a Technical University (mainly engineering) and five of their traditional universities offer most sciences; France has specialist Institutes of Engineering and Institutes of Technology; a few UK universities are more technology orientated, *eg* Imperial College, London.
- **Mode of study**: Most countries only have full-time degree study; only Ireland, Sweden and the UK have any significant part-time study sector.
- **Entry routes into HE and participation rates**: Most European students have a 'right of access' to higher education if they reach a certain school qualification level (*eg* France, Germany, and Netherlands). In a minority of countries, there is selective, competitive entry (*eg* Ireland and the UK), while others operate open access in principle but with selective, competitive access to specific institutions or courses (*eg* France).

- **Age of entry to higher education:** This varies between countries reflecting differing patterns of secondary education and the extent to which entry occurs immediately after secondary school or whether it can occur through someone's lifetime. The median age of entry in 1996 to university level education was ranged from 18.6 in Ireland, through 20.2 in the Netherlands to 23.6 in Denmark (OECD, 1998b).
- **Length of courses**: German degree courses are well in excess of four years in length, in the Netherlands they are six years, while in Ireland and the UK the normal length is three, or in some cases four years.
- **Qualifications and levels**: While there have been attempts to standardise these through the use of titles, *eg* 'Doctor', Masters/ Maîtrise, Ingenieur/Ingenjör/Ingenjør, there are still major anomalies. For example, in some countries first degrees (ISCED 6) are at similar level to masters (ISCED 7) in others. At the same time, some countries offer intermediate qualifications (*eg* Italy) and short and long programmes or cycles (France) (for more detail of qualifications and equivalencies see Annex 1).

3.2.2 The relationship with national governments

Higher education's' relationship with national and regional governments affects their funding, management and governance, and hence their development. Traditionally, European HE systems have been strongly regulated by the state. An exception is UK, which has only recently had more centralised state control. Some are closely regulated, for example, setting curricula and even content of specific courses as in Italy and Denmark. For some, the governance is more at a local or regional level, *eg* Germany and their Länder system. However, for most countries, strong central government management remains the norm, *eg* France, Netherlands and Denmark, though this is changing as noted below. Another difference is the public/private sector balance: in some countries, universities are almost all public institutions as in Germany and the UK, but in others there is a more established independent private sector, *eg* Italy and Portugal.

An important influence on subject pattern in many countries, especially in northern Europe, has been the influence of governments in educational planning and setting student intake numbers for universities in different subjects. These often made use of labour market forecasts, especially in the S&T area, but, these are less use nowadays. This is mainly because of the greater uncertainties and complexities in the graduate labour market and the failure of forecasting models at this level of detail to be able to cope adequately with this complexity. Various examples illustrate this. The Swedish government took steps to increase engineering admissions during the 1980s to meet the requirements of industrial expansion, and because of concerns from employers about future shortages in engineering. (However, recently it has stopped relying exclusively on labour market statistics [Reuterberg and Svensson, 1994]). In France, national targets for growth in engineering have been set to meet a forecast labour market demand (*ie* a doubling of science and engineering graduates between 1990 and 2005) (Beltramo *et al.,* 1992a). The UK government has also encouraged greater growth in engineering than other subjects because of forecast labour market demand (Cabinet Office, 1993). However, the impact has been less because of the greater autonomy of universities in the UK, and because of weaker student demand for places on engineering courses. Germany continues to regulate the system through its regional funding mechanisms, but this varies between Länder. By contrast, in Spain, where universities also have more independent control over admissions, engineering schools took it on themselves to put restrictions on numbers during the 1980s mainly to avoid an oversupply and thus safeguard salaries and jobs of existing engineers (see Munoz *et al.*, 1993). This has meant that engineering output in Spain is still relatively low. In the Netherlands, a special ICT Task Force has drawn on the evidence of modelling to illustrate future demand (Van der Aas, 1998). There has, however, been a general reduction in state regulation of HE so their role in determining output has also diminished.

Restructuring of higher education systems has taken place in many countries, mainly through the development of their non-university HE sector (Anon, 1996a). This has been driven partly by expansion and is associated with the greater diversity among students and their needs, the 'massification' of HE. However, it is also partly as a result of attempts to introduce more labour market relevance to higher education. The non-university institutions generally (though not always) have greater emphasis on vocational study, often requiring lower entry qualifications, shorter courses and more involvement by industry. In some countries, the non-university sector produces the majority of engineering graduates, *eg* 2 out of 3 in Germany, and this sector has been growing more rapidly than the universities in several countries. Various developments are taking place to make courses in the non-university sector even more relevant to industry's needs as a direct consequence of criticisms from employers about the relevance of engineering degrees (discussed further below).

There are also moves by some governments (*eg* the Netherlands and Denmark) to create more equivalence between the 2 sectors but with mixed success to date. However, in Austria, France and Germany they are continuing to develop separately. One of the difficulties in trying to blur boundaries is that employers and students generally regard universities as the more prestigious institutions. This was evident in the UK when the former polytechnics became designated as universities in 1992. Many ex-polytechnics are seen as 'second-class universities'. Finland is currently encouraging its HE colleges to merge in order to strengthen the sector and appeal more to students.

France provides a specific example where restructuring has taken place within its university rather than non-university sector as a response to labour market demand. In 1991 the Institutes of Engineering (IUPs) were set up with more links with employers to offer longer term vocational training and help produce more engineers. Within the Grandes Ecoles system there has been the creation of Ecoles d'Ingenieurs to boost the number of engineering graduates.

Change has also been forced on HE systems in most European countries as a consequence of reductions in public expenditure. Universities have been encouraged by national governments to improve efficiency and increase management accountability. This has led in places to shorter completion rates (*eg* in the Netherlands) larger class sizes (*eg* Germany) and pressures on facilities and resources (*eg* lab equipment). Where larger class sizes have led to 'overcrowding' problems, it is thought that these may have acted as a rationing device in contributing to higher dropout levels. Specific changes to funding schemes for higher education have also acted as a market mechanism. In general, funding of institutions is based on numbers of students, but some countries have introduced a quality dimension (*eg* UK and Netherlands) or rewarded institutes for innovation (*eg* France). Changes to student grant systems and student fees have affected student choice, with more opting for shorter courses or staying within their region, *eg* Germany, Netherlands (Anon, 1995a), and the UK, (see Van der Aas, 1998).

In recent years, several countries have announced major reviews of their HE systems or university systems, including France, Spain and Germany; and the UK has just completed one. It is likely that many HE will remain in a state of flux for some time to come as further changes in their funding, legislative frameworks and provision take place. This in turn will impact further the scale and nature of graduate output.

3.2.3 Responsiveness of higher education

The need for HE, and particularly universities, to be more responsive to employer needs is a prominent issue in debates about the development of HE in many countries. A particular criticism in the past has been that HE was too slow in reacting to industry's changing needs. This was partly caused by the strong national state regulation of HE in many countries over 'inputs', *eg* approving new courses, setting admissions and selection criteria. This was particularly evident in the Nordic countries and in Austria.

The current trend is towards national de-regulation with control and planning being devolved and Ministries providing more a general steer and supervision than direct control. It is hoped that this will encourage institutions to be more in touch with their employment market. Changes are slowly taking place. the Netherlands, Finland and Denmark have all moved in this direction in recent years and Italy is expected to do so through its reforms to funding systems which allow more freedom for universities to spend their own funds.

The extent to which education is linked to employment outcomes and 'industrial training' is included in the curricula varies greatly. In many countries, such as Germany, it is felt that HE is undertaken for its own sake and is not vocational. This has led to a growing gulf between industrial practice and what is taught, leading to the establishment of corporate university level study centres. Examples of improving responsiveness include: the development of new institutions in geographical areas not served by higher education, particularly in areas of economic difficulty (*eg* Portugal, Sweden and Finland); greater consultation with employers on curriculum areas; and more involvement of employers on university boards of management (*eg* Denmark). Other examples include developing specific links between employers and academics; the growth of short courses; provision of work experience; the development of work-relevant skill as an integral part of degree courses, and making the curriculum more employment relevant. However, difficulties are being experienced in several countries because of resistance from the academic community as in, *eg* Spain, Germany, and France.

By contrast, in the UK the government and the funding agencies are putting increasing emphasis on 'employability'. Here industrial, or corporate, relevance of what is taught is increasingly important in almost all universities. The UK government has been one of the leaders in this area, with several large national and regional HE-employment initiatives to help graduates prepare better for the world of work (*eg* their £5 million Enterprise in Higher education (EHE) programme encouraged partnerships between employers and over 60 institutions in the 1990-95 period).

While considerable efforts are being made in many countries, the level of HE-employer activity is very patchy and, on the whole, Europe is a long way behind other competitor countries, such as the United States.

Another important trend is the growing internationalism in HE. This is being encouraged by EU education and industrial policy, in particular its Erasmus programme of student exchanges and the Framework Programmes which focus on the role of networks between firms, research institutes and universities for stimulating the development of innovation and greater co-operation between sectors and countries. Individual countries have also encouraged their HE systems to be more internationally orientated. For example, Finland and Denmark both give it high priority, a reflection of these countries general policy to develop more international collaborations in research and business through IT, as do the Grande Ecoles in France.

3.3 Student choice

3.3.1 Mathematical and scientific skills of school children

An important part of the science and engineering supply chain or 'pipeline' is the role of the early years of education. This determines how well students are prepared for subsequent education and training opportunities in scientific and technological subjects, their attitudes to these subjects and hence their ability and likelihood of choosing such study. Key influences are clearly the curriculum and the quality of teaching. In particular, if science and mathematics are viewed as 'hard' or 'boring' subjects potential students are less likely to study these subjects at a higher level.

To test and compare attainment levels across a wide range of countries The International Association for the Evaluation of Educational Achievement (IAEEA) a consortium of bodies undertook the Third International Mathematics and Science Study (TIMSS). In this they used a series of internationally comparable tests administered to eighth and seventh grade school pupils (ages 13 and 14) from a representative sample of schools. Two series of

Table 3.1: Mathematics achievement, mean scores, 1995

		Eighth grade		Seventh Grade
Belgium (Flemish speaking)		565		558
Belgium (French speaking)	*	526		507
Denmark	**	502	**	465
Germany	***	509	***	484
Greece	**	484	**	440
Spain		487		448
France		538		492
Ireland		527		500
Netherlands	*	541	*	516
Austria	*	539	*	509
Portugal		454		423
Sweden		519		477
England		506		476
Scotland	*	498		463

** Did not satisfy guidelines for sample participation rates*
*** Unapproved sampling procedures at classroom level*
**** Did not meet age/grade specification (high percentage of older students)*
Source: Beaton et al (1996) Mathematics Achievement in the Middle School Years: IEA's TIMSS

tests were undertaken one covering mathematical achievement the other scientific achievement. These tests lack methodological rigor in terms of sampling and coverage in some countries, and are not measures of high level skills. However, they do indicate the variable success of the national educational systems in teaching mathematical and scientific skills and concepts to the broader population. This base of scientific and mathematical skills is seen as important for the utilisation and widespread diffusion of scientific and technical advances. The indicators presented here are the average correct scores (Table 3.1 and 3.2).

The highest scoring groups in mathematics are Belgium and Netherlands, and the lowest are England, Scotland, Spain, Greece and Portugal. In science, the highest scoring group includes Belgium, Netherlands and Austria, while the lowest group is Portugal, France, Denmark and Greece.

3.3.2 Labour market influence on student demand

The impact of labour market signals on student demand for HE, that is, on the decision to go on to higher education study, is unclear. However, employment prospects are one of many factors individuals consider when making choices about entering tertiary education (Connor *et. al.,* 1999). Despite rising graduate unemployment in the early 1990s, in most European countries graduates are still less likely to be unemployed than non-graduates (OECD, 1998b). Even in Germany, where university

Table 3.2: Science achievement, mean scores, 1995

		Eighth grade		Seventh Grade
Belgium (Fl)		550		529
Belgium (Fr)	*	471		442
Denmark	**	478	**	439
Germany	***	531	***	499
Greece	**	497	**	449
Spain		517		477
France		498		451
Ireland		538		495
Netherlands	*	560	*	517
Austria	*	558	*	519
Portugal		480		428
Sweden		535		488
England		552		512
Scotland	*	517		468

** Did not satisfy guidelines for sample participation rates*
*** Unapproved sampling procedures at classroom level*
**** Did not meet age/grade specification (high percentage of older students)*
Source: Beaton et al (1996) Scientific Achievement in the Middle School Years: IEA's TIMSS

graduates have increased fourfold since 1980 and graduate unemployment is relatively high, the unemployment rate for university graduates has been growing at a slower pace than non-university graduates. In 1995 it was considerably lower than that of unskilled workers (List, 1997). Although the empirical evidence is sparse, most students (and their parents) believe that they stand a better chance in the job market with a degree than without, and accept the cost of studying as a fact of life (Miekle, 1997).

The evidence is stronger on the relationship between labour market trends and choice of subject to study, although for many the decision-making process is complex. Other factors such as subjects taken at an earlier education stage, and type of institution previously attended, are generally more influential than employment factors (Woolnough, 1994; Pearson, 1997). Also, it needs to be stated that the labour market information available to students is often not specific enough or too uncertain to help in making rational choices about degree courses (Pearson, 1998). In Denmark it has been suggested that engineering has become a very popular degree mainly because of its good employment prospects, while in Germany engineering is now less popular because of high graduate unemployment (Teichler, 1995).

3.3.3 The image of S&T

Another factor affecting demand in S&T has been the image and attractiveness of engineering as a career, especially for women, compared with other sectors. The gender imbalance in engineering has been a matter concern for many years and despite numerous initiatives by industry and government to encourage take-up, and growth in numbers of female students has been relatively low. For example, only 13 per cent of admissions to engineering and technology degrees in the UK were female (HESA, 1998). In the Netherlands, the poor image of engineering as a career among young people (male and female) has negated national government efforts to increase supply (ROA, 1995a). Denmark is also suffering from negative images of technical careers among young people. In a survey of 16-19 year olds studying maths, science and technical subjects, fewer wanted to go on to study these fields but instead were more interested in 'literary/cultural' career areas because of higher socio-economic status (Thermann, 1996). This is thought to be a factor behind the drop in admissions to engineering courses by 45 per cent in the last 5 years and by 20 per cent in natural sciences in 1 year alone. Other European countries also have similar or lower levels of female participation (Ruiva, 1994, Anon, 1995d). Although the natural sciences is comparatively better represented, women are rare in the top ranks of science, *eg* just 7 per cent of science professors in UK universities are female.

3.4 Key trends

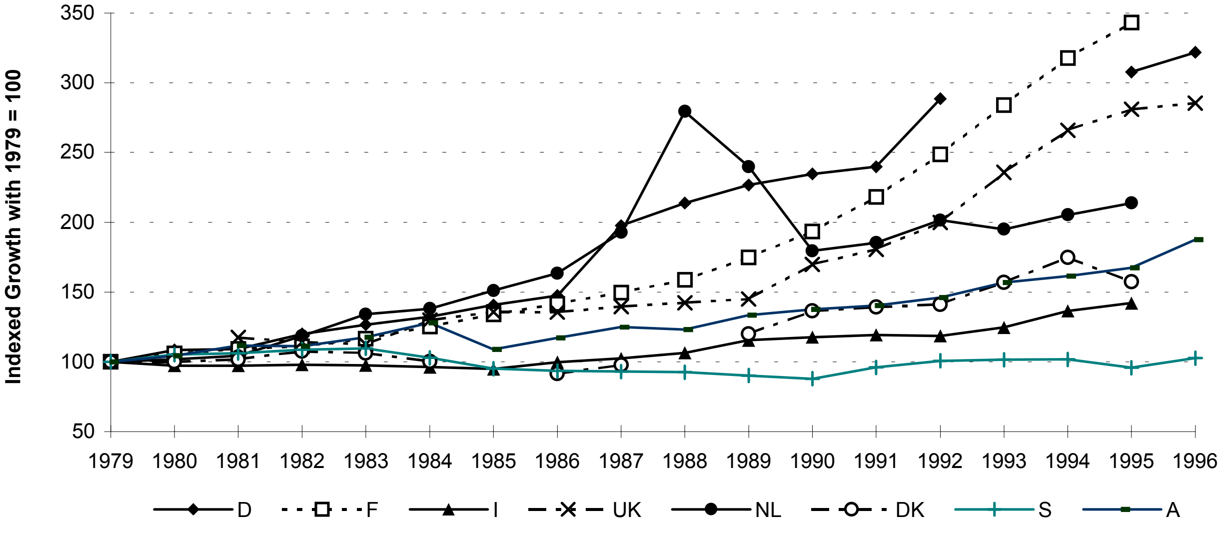
Despite this diversity, it is possible to identify several common, inter-related, themes in HE across many European countries that have an influence on supply and adequacy issues.

3.4.1 Expansion

Most countries have experienced expansion in HE student numbers over the last 2 decades, some much greater than others. However, there have been many changes in the ways in which countries allocate qualifications to ISCED 76 levels, and in the introduction of new qualifications in various countries. This means that the historic ISCED 76 data reported to UNESCO is considered incompatible with the current data from the returns. National time series have therefore been developed here using nationally consistent definitions where possible; unfortunately these time-series are not necessarily consistent with ISCED 76. For instance: for France the data only relates to Licence qualifications; for the UK only first-degree data is used; while for the Netherlands, Italy, Germany, Austria and Sweden the data covers university level (or ISCED 76 levels 6 and 7) qualifications. To enable comparisons to be made the data has been indexed from a figure of 100 in 1979 (see Figure 3.1).

The greatest growth (at least at the level of Licence qualifications) was in France where the 1995 numbers graduating were over 300 per cent more than in 1979. The UK also showed strong growth, as did Germany, however this was partially driven by reunification.

Figure 3.1: Changes in graduate (ISCED 5, 6 and 7) numbers, 1979 to 1996* (percentages)



Source: IES/INSEE (various years) Annuaire Statistique de la France/Statistisches Bundesamt (various years) Statistisches Jahrbuch fur die Bundesrepublik Deutschland/Centraal Bureau voor de Statistiek (various years) Statistical Yearbook of the Netherlands/Istuto Centrale di Statistica (various years) Annuario Statistico Italiano/Instituto Nacional de Estadistica (various years) Anuario Estadistico de Espana/Statistisches Zentralamt (various years) Statistisches Jahrbuch fur die Republik Ostereich/Statistiska Centralbyran (various years) Statistisk Arsbok for Sverige/Danmarks Statostik (various years) Statistisk Arbog Danmark.

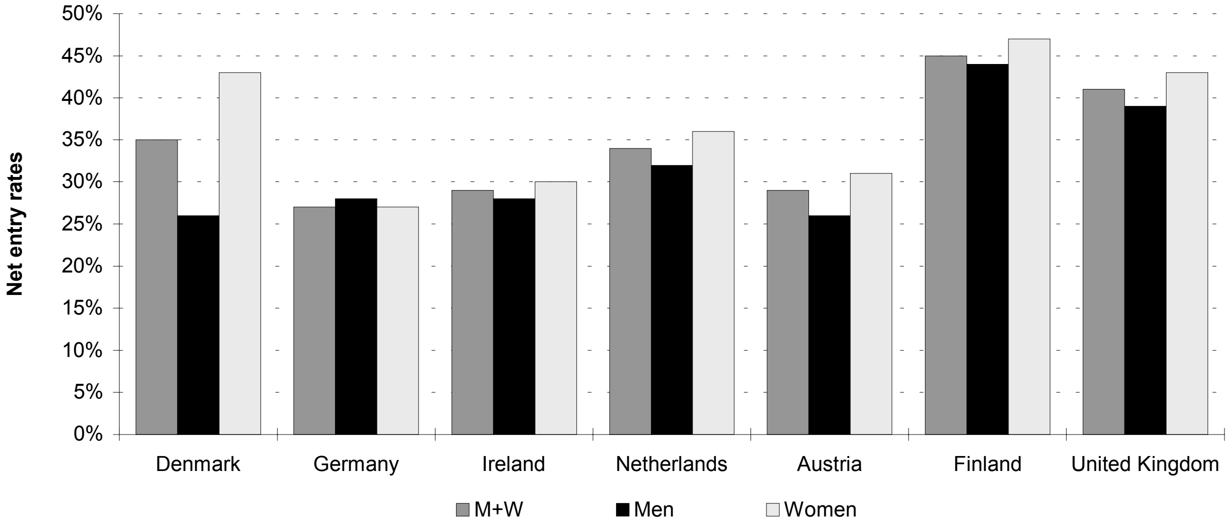
The Netherlands shows a rapid rise in their output in the late 80's, which reflects the introduction of their 'shorter' qualifications at that time. The main exceptions to the overall trend were Sweden and Italy In Sweden one explanation is the effect of government policy on intake numbers designed to bring HE output more in line with perceived economic needs (Statistics Sweden, 1996). This policy limits places in key subjects such as medicine to avoid an oversupply. Italy seems to have suffered from a rising dropout rate leading to only low growth in output, despite a significant growth in student numbers.

Increased participation by young people

A significant point is that HE continued to grow in the early 1990s against a backdrop of demographic decline in the youth population in Europe and the economic recession that reduced graduate employment opportunities. Largely, the decline in the youth population was offset by increasing numbers of young people gaining school leaving qualifications and the increased tendency to stay on in further studies. Equally, participation rates have grown amongst older ('mature') entrants entering higher education after a period outside formal education. Rising participation rates have been directly linked to increased attainment levels (see Beuchteman, 1993) and they have played a particularly important role where open access policies exist. For example, in Germany 34 per cent of students gained the Arbitur (HE entry qualification) in 1991, compared with only 18 per cent in 1975.

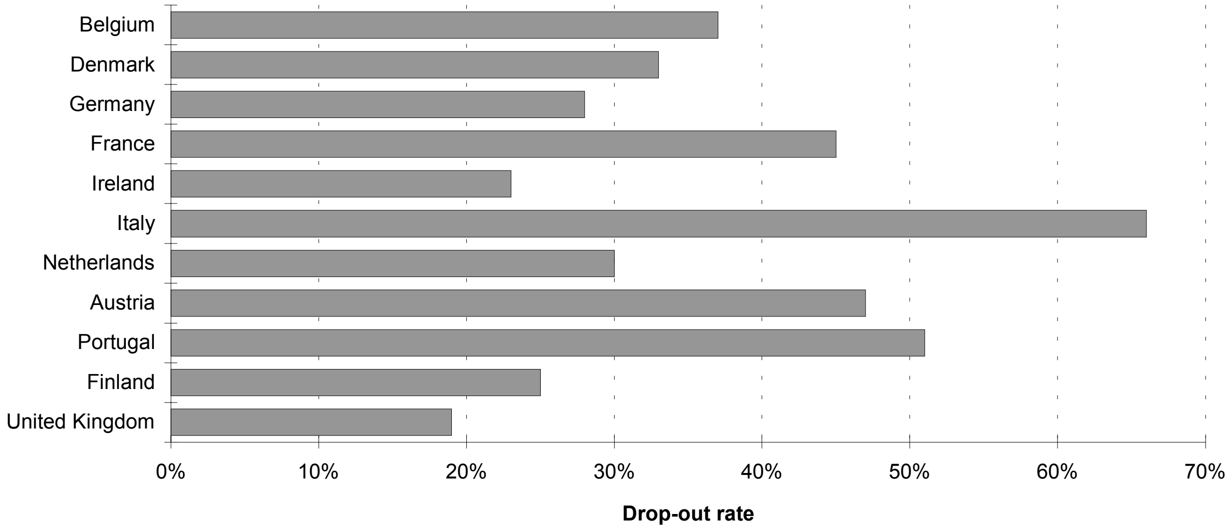
In terms of initial entry, Finland has the highest lifetime probability of entry to higher education (a cumulative figure which takes account of the participation rate at each age) at 45 per cent, followed by the UK at 41 per cent. This compares with Germany where the figure is 27 per cent (Figure 3.2).

Figure 3.2: Lifetime probability of entry to higher education, 1996



Source: IES/OECD (1998) Education at a Glance

Figure 3.3: Dropout rates from higher education, mid 1990's



Source: IES/OECD (1998) Education at a Glance; not all countries were able to supply this data

However, open access to higher education, such as Italy, is often linked with higher levels of dropout and non-completion of courses. In Ireland and the UK, with selective entry and shorter courses, dropout rates are relatively low at 23 and 19 per cent respectively. This compares with 'open access' countries such as Italy and Portugal with rates of 66 and 51 per cent (Figure 3.3). Therefore, the output figures are significantly lower than initial enrolments.

The main entry group to higher education are young people, and in all but Denmark, Luxembourg and the Netherlands, the numbers of 15-19 year olds are projected to remain static or decline by 2020. All the large EU countries project a decline in this critical university entering age range. This means that to maintain

Figure 3.4: The changing 15-19 year old population, 2020 compared with 1995

Source: IES/Eurostat (1997) Demographic Statistics 1997 – data are not available for all countries, as such an EU total is not given.

the current absolute output of graduates either the proportion of the cohort entering higher education and/or the proportion completing higher education will have to increase.

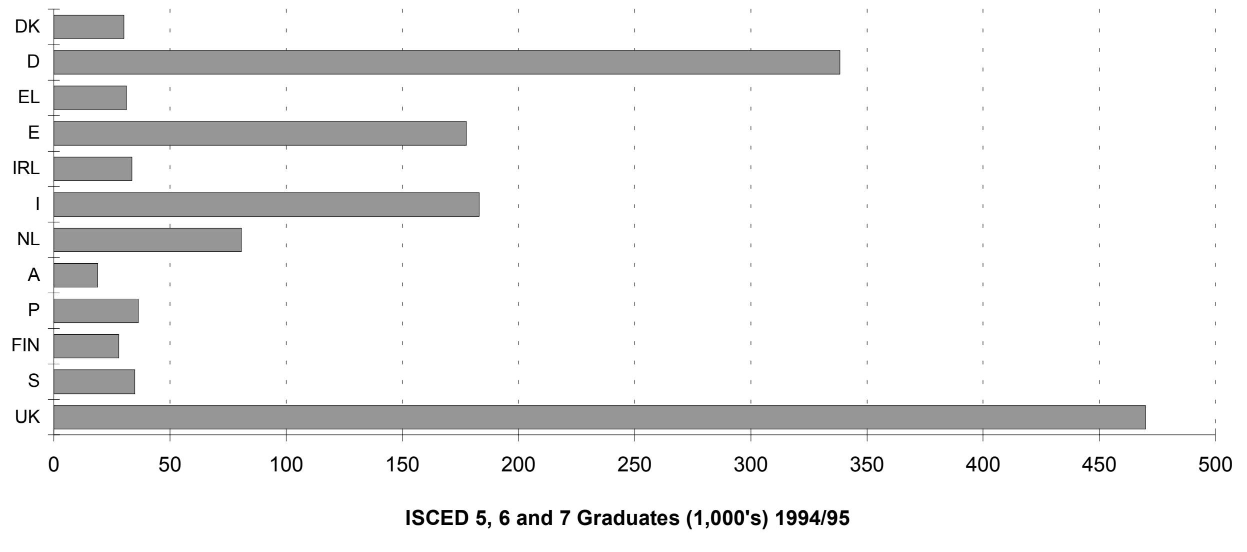
Widening access

Another important contributing factor to increasing numbers has been the widening of access to higher education for previously under-represented groups, in particular women, older people, ethnic minorities and those from lower socio-economic groups. Various governments have taken initiatives since the mid-1980s to encourage wider access in general, and specifically to S&T. For example, there have been UK initiatives to encourage greater flexibility in acceptable entry qualifications and in choice of study (location, subjects, mode, *ie* more part-time) and improved careers advice. These have had an influence on the participation of female and mature students but less so of those from lower socio-economic groups. In other countries, women have benefited from the overall growth in higher education places (*eg* Belgium, Portugal, and Spain) rather than through specific access initiatives. In engineering and science, there has been a range of specific initiatives on increasing the relatively low female participation rates. In particular there have been government programmes in schools to raise awareness and change negative attitudes (*eg* Netherlands, UK, Spain (Van der Aas 1998)).

3.5 Graduate output

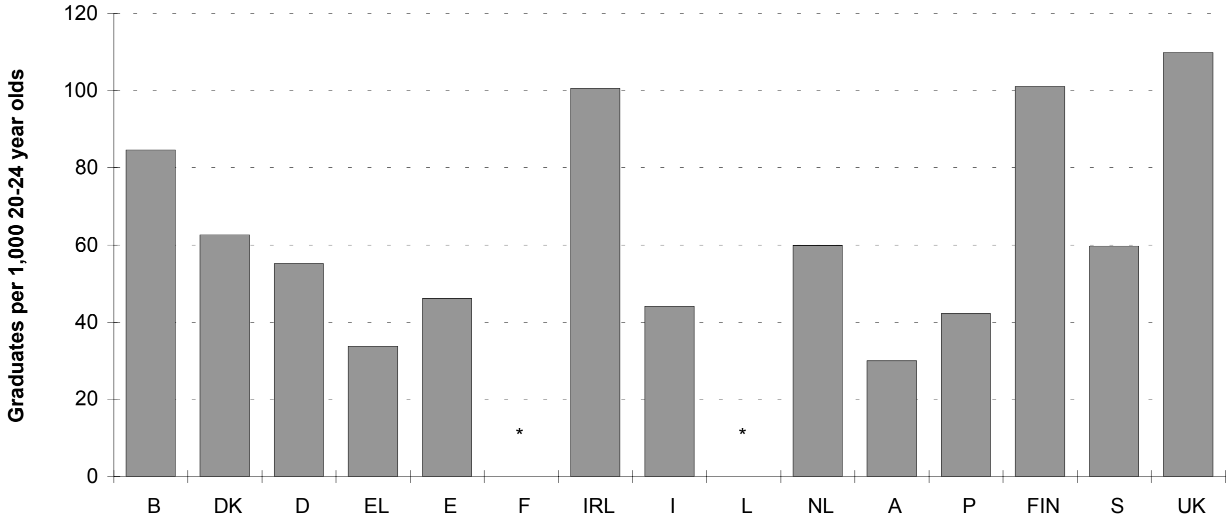
As has been highlighted above, graduate participation and output has grown in most countries over the last two decades and these reflect a number of changes to HE systems. The countries with the

Figure 3.5: Graduate output* by country, 1994/95



Note: Total graduates at ISCED levels 5, 6 and 7; not all countries were able to supply this data – an EU total is not available
Source: IES/Eurostat (1998 and 1997) Education across the European Union

Figure 3.6: The graduation rate (HE output* in relation to 20-24 year old cohort), 1994/95

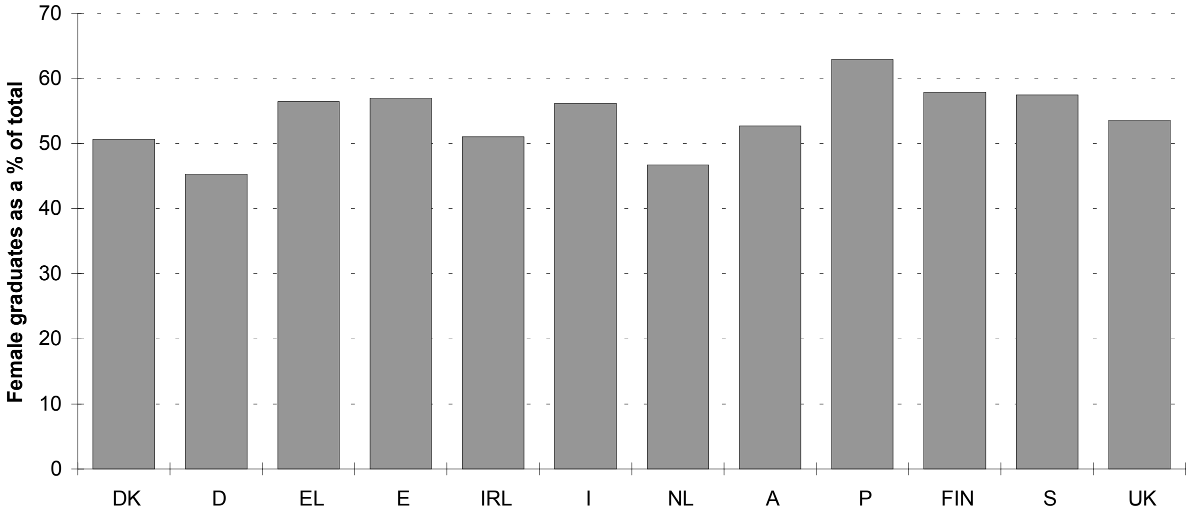


** Note: Total graduates at ISCED levels 5, 6 and 7, No graduate data for France or Luxembourg – an EU total is not available*
Source: IES/Eurostat (1998) Education across the European Union 1997 and Eurostat (1995) Demographic Statistics 1995

largest output of graduates are Germany and the UK, followed Italy (Figure 3.5). Although, France did not provide Eurostat with the data, based on national data their output ranked them third between the UK and Italy.

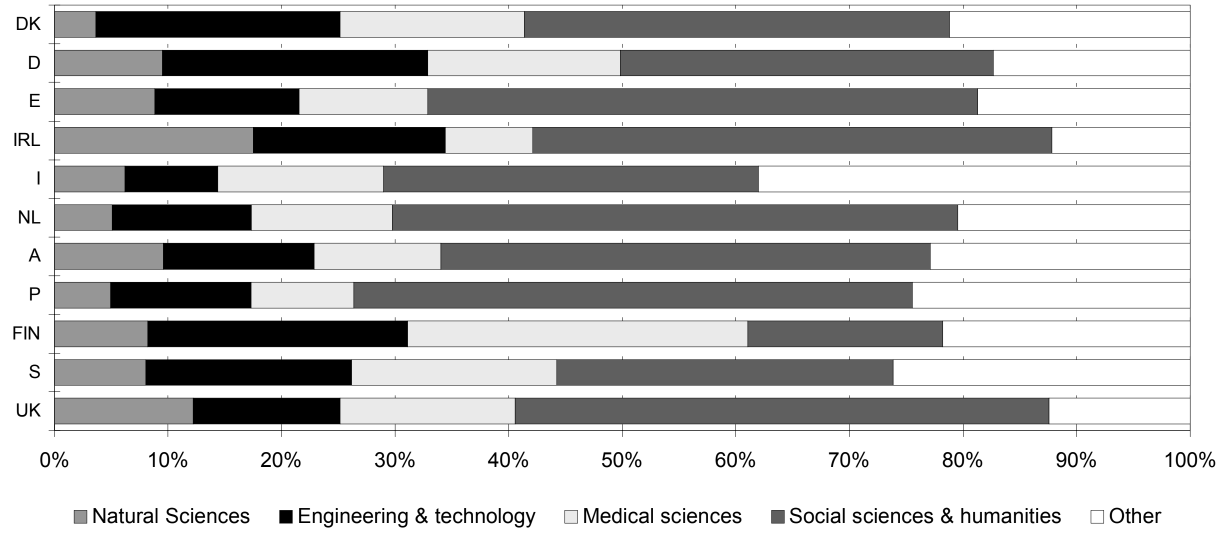
These numbers, however, need to be seen in the light of the relative size of and changes in the 20 to 24 year old populations, the normal age range of those graduating. By normalising in this way, it can be seen that the UK, Finland and Ireland have the highest graduation rates at 110, 101 and 100 per 1,000 respectively. The lowest graduation rates are to be found in Austria, Greece and Italy with 30; 34; and 44 per 1,000 respectively (Figure 3.6).

Figure 3.7: Female graduates as a percentage of total graduates, 1994/95



Note: Total graduates at ISCED levels 5, 6 and 7, No graduate data for France or Luxembourg – an EU total is not available
Source: IES/Eurostat (1998) Education across the European Union 1997

Figure 3.8: Graduate output* by field of study and country, 1994/95



** Note: Total graduates at ISCED levels 5, 6 and 7; not all countries were able to supply this data – an EU total is not available*
Source: IES/ Eurostat (1998) Education across the European Union 1997

One of the important drivers of the recent increase in graduate output has been the increased participation of females in higher education. This is reflected in the fact that in all but Germany and the Netherlands females represent over 50 per cent of graduates and in many countries they account for well over half of those graduating (Figure 3.7). This means that, apart from influencing subject choice (and possibly level of study), there is little scope for further growth in graduate output on the basis of encouraging greater female participation.

Turning now to look specifically at output by field of study, the first point to note is the wide variation between countries in the subject profile of their graduate output (Figure 3.8). Natural science represents 18 per cent of the output in Ireland, but only four per cent in Denmark. (Note, France is not shown, because no comparable data are available. Historically it is known to have one of the highest proportions in the natural sciences). Engineering and technology represents 24 per cent of the output in Germany compared with only eight per cent in Italy. As discussed in Annex 1, there are problems in harmonising the data due to differences between national classifications and this is likely to be part of the explanation behind the differences. In particular there is a large number in 'other fields' in some countries, (*eg* Sweden, Portugal, Italy) which is believed to include a large number of education science graduates (*ie* teachers). In other countries, prospective secondary school teachers study in their main S&T discipline. Other reasons for the diversity in the pattern of output by field of study relate to the social and cultural differences between countries, historical trends and especially national priorities discussed in the earlier part of this chapter. Unfortunately, it has not been possible to provide any trend data at a European level, because of a lack of harmonised data by field of study.

Table 3.3: Data collected on Graduates' first destinations

Country	Code	Data collection methods
Belgium	B	Surveys of individual institutions and subjects
Denmark	DK	Administrative data
Germany	D	Irregular sample surveys
Spain	E	Household Panel Survey
France	F	Surveys of individual institutions, and a cohort survey
Ireland	IRL	Leavers Surveys
Italy	I	Sample survey
Netherlands	NL	Surveys of an individual institutions
Austria	A	Survey of an individual institutions
Portugal	P	Sample survey and surveys of an individual institutions and subjects
Finland	FIN	Administrative data
Sweden	S	Sample surveys of leavers
United Kingdom	UK	Surveys of all leavers

Source: IES

3.6 The transition from higher education into employment

Traditionally it has been assumed that there is a linear relationship between HE, graduate output and their subsequent employment with graduates taking up jobs appropriate to their qualifications. However, the process of transition from education to employment has become more complex with the rapid expansion of higher education over the last decade and the broadening of labour market.

Currently there are no EU-wide data that allow the monitoring of the transition from higher education into employment. For this reason, reliance has to be placed on exemplar national data. A summary of the available data by country is shown in Table 3.3.

As in many other areas there is a paucity of consistent data about newly qualified graduates entering the labour market, some general trends can be illustrated.

First, it is important to highlight some structural, national differences that affect graduates transitions into employment. In most of the EU countries the transition process is integrated into wider labour market transitions with, *eg* public job placement services playing a strong role in Germany and informal networks a key mechanism in Italy. In France and Germany, 'stage' or work placements during the period of study are also important parts of the recruitment process. By contrast, in Ireland and the UK there is a more clearly defined graduate labour market, with highly developed campus career services in all universities, who help job search, and many major companies regularly visit campuses to recruit. These distinctions are, however, starting to blur with many more countries developing careers advisory services for graduates linked to campuses. There are growing numbers of national and international recruitment fairs targeted at graduates and more companies targeting individual courses/facilities for potential recruits.

In most countries, there has been a traditionally strong link between subject of study and the subsequent profession or occupation entered, with many of those studying in the humanities entering teaching or public administration. In this respect, Ireland and the UK have been unusual in the relative weakness of links between the subjects studied and the careers entered by many graduates. Careers in areas such as finance, marketing and many areas of IT are open to graduates from any degree discipline. In the UK, over 40 per cent of all graduate vacancies are estimated to be open to any discipline (CSU, 1993). Entrants to science and technology jobs, with the exception of IT, do however require a relevant degree subject as in other countries. Recently there has also been more flexibility over aspirations and job choice by graduates generally. They have been taking up a wider range of jobs in terms of sector and types of work, and graduates who have enrolled in certain disciplines are no longer staying in that discipline in their occupational choice. For example, chemistry students are working as accountants; however, there is little quantitative international data on such trends (see, *eg* Teichler 1996; Mason 1998).

Second, the process of both job search and, more broadly, occupational and career choice is taking longer. In Germany, for example, it is reported that the average young graduate spends seven months looking for his or her first job (List, 1997). In France it is no longer considered unusual for graduates from the elite universities to spend 5 or 6 months job-hunting (List, 1997). In France, graduates in biology experience difficulties more than those in natural sciences or mathematics, and Grandes Ecoles engineers have the best chance of finding employment soon after their final examination. In the UK job search can now extend up to 2 or 3 years (Connor, 1997). In some cases, there is also an increased tendency to take temporary, fixed-term contracts, or casual employment which is relatively poorly paid and lacks security while seeking the 'right' job or moving into 'normal' positions. These are sometimes at low levels in order to get 'easy money' (often to pay off student debt), but others take them to gain much needed work experience (Purcell, 1997). Getting started by this method is often seen as a way of gaining professional experience, thus improving career chances in the longer term.

Finally, more first degree graduates are staying on to take postgraduate qualifications and thus delaying their entry to the labour market by a year or more. Partly this has been driven by the expansion in higher level courses and places available but also it has been used as a way of improving perceived employability and of avoiding short term 'unemployment'. In some countries, notably the UK, it has also been driven by an increase in the requirements of many professions to have postgraduate qualifications, *eg* teaching and in some respects engineering.

3.7 Graduates' initial employment

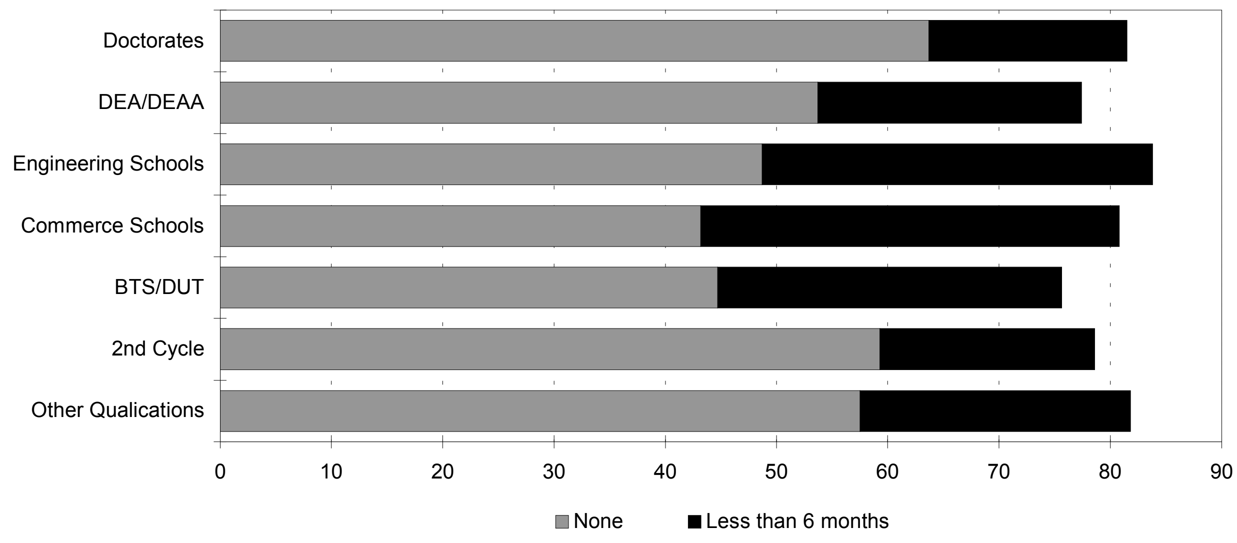
3.7.1 Employment after graduation

There is no common approach on how data on the flow of graduates into employment is collected. Some countries use follow-ups surveys of graduate cohort years, others undertake ad hoc retrospective population surveys on a sample basis, yet others use employment records. Some surveys are based only on specific subjects, courses or individual institutions while others are virtually national censuses covering the whole of the HE sector (see Table 3.3). Countries also use different definitions and classifications and collect data on employment destinations at different points in time. Some, such as the Irish and the UK annual First Destinations Surveys (FDS), collect employment information from all graduates six months after completion (UK) and nine months (Ireland). The others have more variable and partial sets of data as in France, Portugal, and Sweden, where they seek employment status after 12, 1 and 2 months after graduation respectively. Some also undertake further follow-ups at after 2 or 3 years. Despite the difficulties, data on employment destinations of graduates can be a key indicator relating to adequacy. Some common themes have been identified as follows.

First, noticeable variations exist by **field of study**, in particular between engineers and scientists and between different branches of engineering. For example:

- In **France** Céreq (Centre d'Études et de Recherches sur les Qualifications) has undertaken a series of retrospective sample surveys of French graduates (CEREQ, 1993, 1994; Martinelli, 1998; Vergnies, 1998). These shows that the labour market experience of French graduates is both determined by the level of the qualification and the subject studied. Doctorates were the most likely to have no period of unemployment followed by graduates from the second cycle (Figure 3.9) although here further study may account for the pattern. However, science doctorates were more likely to be unemployed than law and economics doctorates. This shows that the 1995 cohort was more likely to be post-docs and unemployed and less likely to be engaged in university teaching.
- In **Italy**, engineers and scientists in aggregate take less time to find work than do other graduates. Scientists are more likely to be unemployed three years after completing studies than are engineers: 27 per cent of scientists, compared with 12 per cent of engineers [1992 graduates] were looking for work three

Figure 3.9: Duration of unemployment of French graduates, 1994



Source: IES/ Vergnies and Sigot (1998) Table 2

years after graduation (Table 3.4). There are also significant differences between different kinds of engineers, *eg* 14 per cent of civil engineers were looking for work after 3 years compared with 6 per cent of electrical engineers.

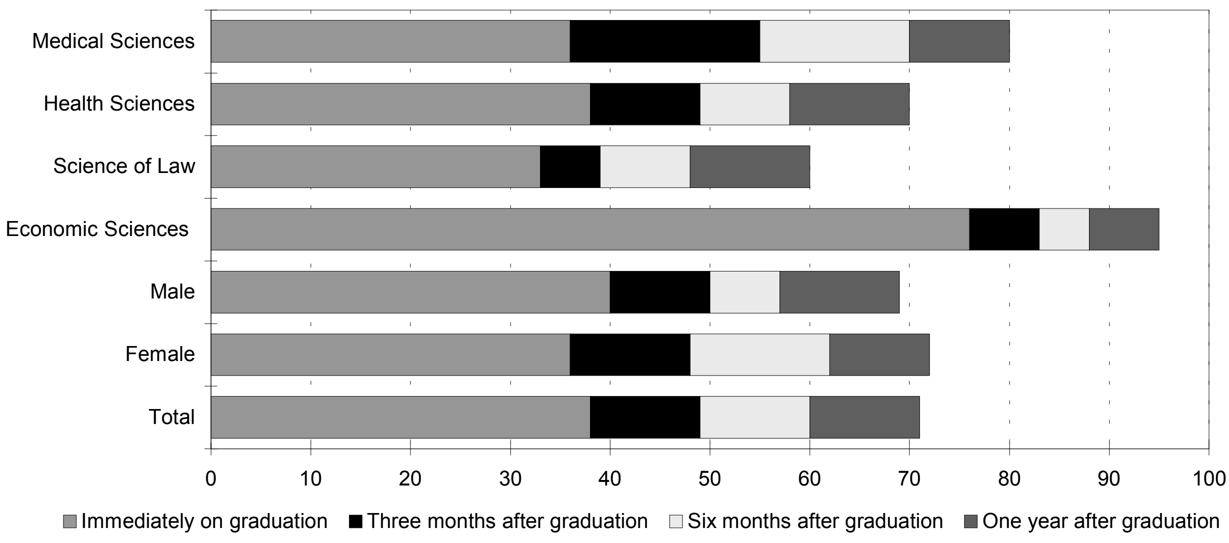
- In the **Netherlands**, data from Limburg University showed that economics graduates were more than twice as likely than lawyers to have started work immediately on graduation (Figure 3.10).
- In **Portugal**, some 75 per cent of applied mathematicians had obtained a job before graduating compared with 53 per cent of naval engineers and 47 per cent of civil engineers (Figure 3.11).

Table 3.4: 1995 labour market status of 1992 Laureate graduates, subject groups, Italy

Group	Returned to previous job	3 months and under search	4 to 12 months search	13 to 24 months search	Total in Work	Looking for work	Not looking for work	Numbers
				Percentages				
Science	9.4	19.0	21.0	15.2	64.6	26.5	8.9	11,310
Medical	3.5	3.5	18.6	16.1	43.6	12.6	43.7	8,806
Engineering	14.9	16.0	25.9	21.6	83.8	12.0	4.2	12,792
Agricultural	10.1	16.7	25.3	20.4	78.6	15.7	5.7	2,617
Economics	12.2	13.9	27.4	18.8	77.5	19.0	3.5	15,148
Political science	28.4	7.8	15.5	16.3	70.7	24.8	4.5	5,231
Law	11.6	13.8	10.3	10.3	48.7	36.8	14.5	14,145
Humanities	23.8	9.3	19.1	13.2	69.6	26.2	4.1	18,269
Total	14.6	11.9	20.3	15.8	66.8	22.9	10.3	88,318

Source: IES, data from ISTAT (1996) Inserimento professionale dei laureati Indagine 1995, Tables 1 and 6

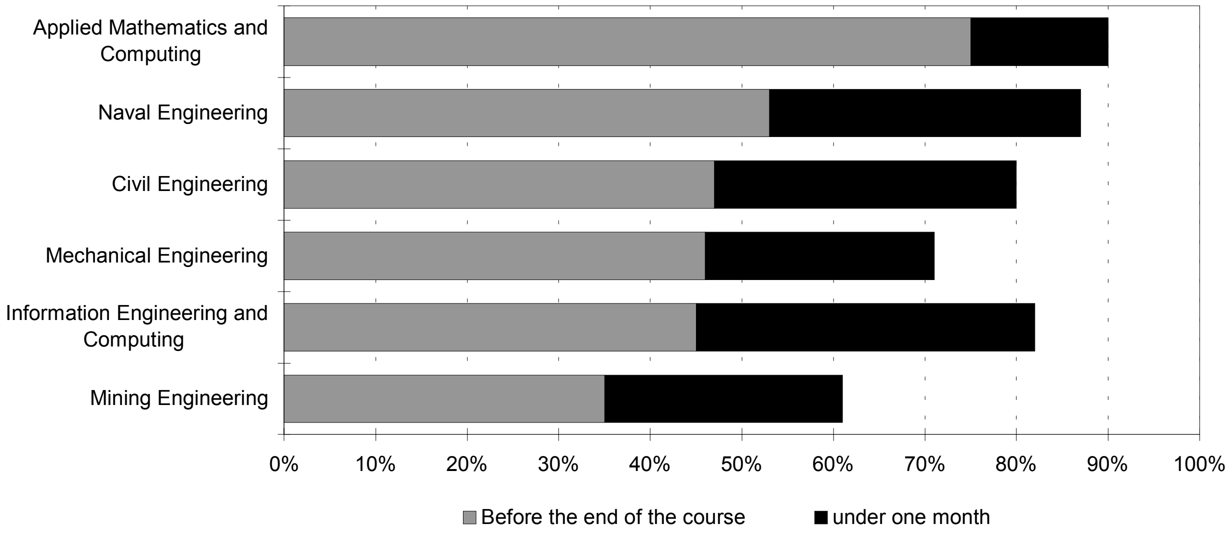
Figure 3.10: Limburg graduates (Netherlands) in employment by subject and gender, over time



Source: IES based on Heijke and Ramaekers (1992) Table 3

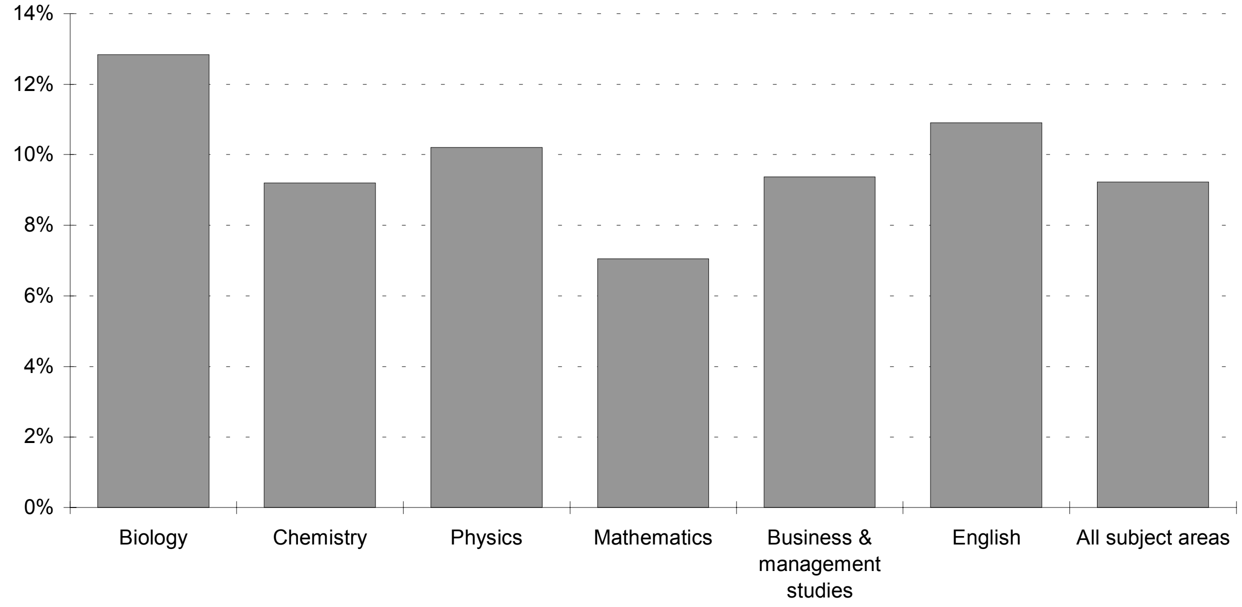
- In **Sweden** unemployment rates vary: 15 per cent of mathematicians and natural scientists graduating in 1992 were unemployed three years later, compared with six per cent of engineering degree graduates (though 32 per cent of engineering graduates were unemployed).
- In the **UK**, the levels of initial unemployment and unemployment fluctuate with the state of the economy (Para 3.7.2). They were particularly high in the recessionary period of the early 1990s but have since halved, to average just over 9 per cent across all subjects. Three-quarters of engineering graduates (75.1 per cent) were in employment compared with only 56.5 per cent of science graduates 6 months after completing first degrees and less likely to be unemployed (HESA, 1998). Scientists, particularly life scientists, are more

Figure 3.11: Speed of finding a job by subject in Portugal



Source: IES/Nunes et al (1995), (1996a), (1996b), (1996c); Barbosa and Rodrigues (1996); Amado et al. (1997)

Figure 3.12: Unemployment six months after graduation, 1998, United Kingdom



N.B. ILO definition of unemployment is used

Source: HESA

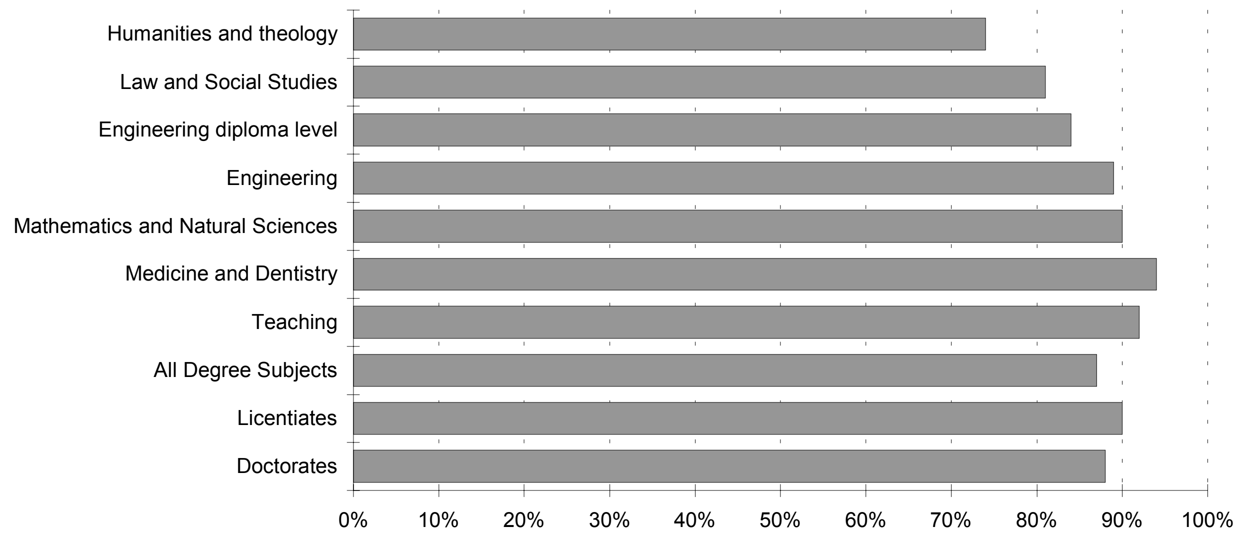
likely to be undertaking further study, mostly studying for masters degrees or doctorates (HESA, 1998). The differences reflect a range of factors including the greater need for specialist postgraduate qualifications in many pure science disciplines, but not in engineering, along with differing recruitment needs of employers. There are also great differences between disciplines within the broad subject groupings. For example, over 12 per cent of biologists were unemployed but only 9 per cent of chemists, while in maths the figure was nearer 7 per cent (Figure 3.12). Other differences are that 78 per cent of computer scientists going straight into employment and only 8 per cent into further study. Among physical scientists, 34 per cent go on to further study and 50 per cent enter jobs). Experiences 5 and more years after graduation are considered in Section 3.7.2.

Second, there are variations in the **matching of qualification with employment**, that is, the extent to which graduates enter professions that are relevant to their discipline. For example, in Sweden 89 per cent of engineers were in their 'target' professions (Figure 3.13). Elsewhere, apart from medicine and nursing, there appears to be an increasing move for those qualifying as scientists and engineers to obtain work in the commercial sector in occupations other than science and engineering.

3.7.2 Trends over time

Consistent annual data are rarely collected outside of Ireland and the UK. However, it is clear that the state of the economy has profound impacts on the initial employment of graduates. Figure

Figure 3.13: Graduates entering 'target' professions — Sweden

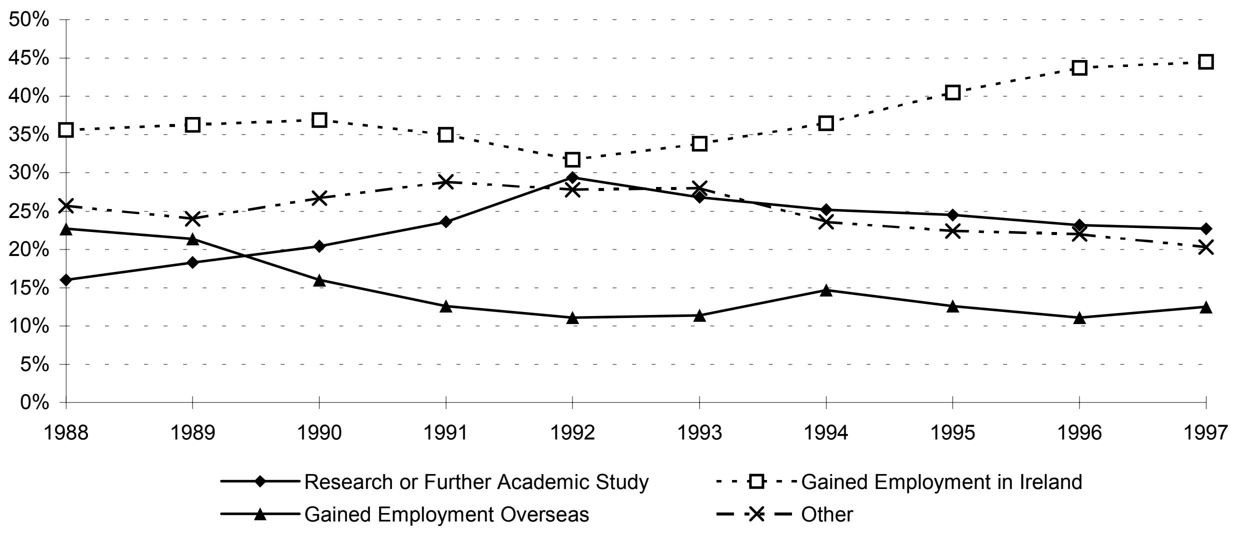


Source: Statistiska centralbyrån (1996) The Entrance to the Labour market, Table 8

3.14 illustrates the changing destinations over time of Irish first degree graduates. This shows that recession of 1992 saw a decline in Irish employment and a increase in the numbers entering further study. Interesting, the tradition of emigration has shown a fairly consistent decline over the period from about 22 per cent to 12 per cent.

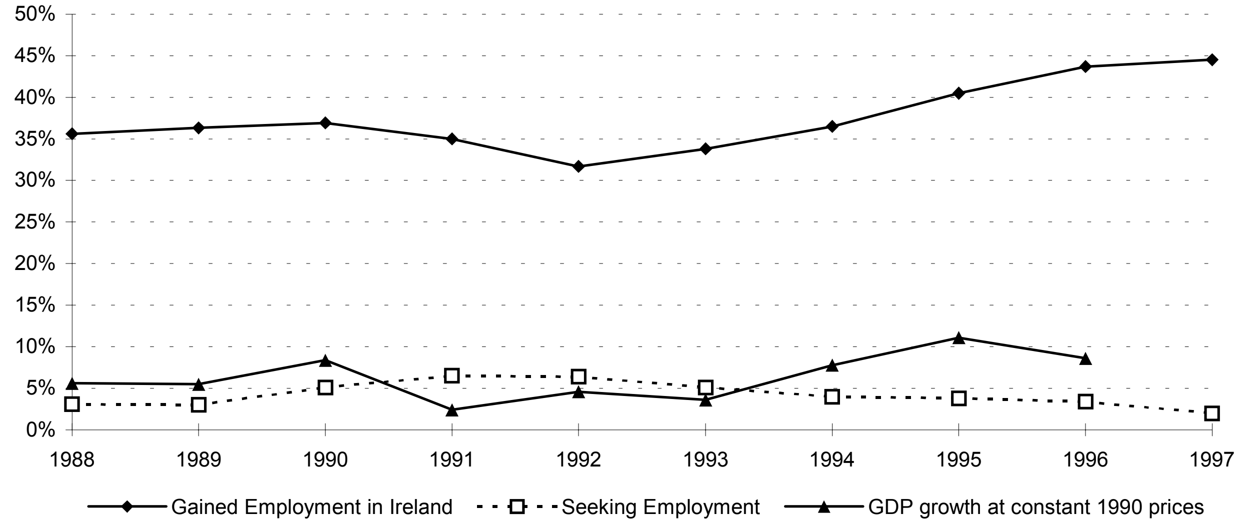
There is also a relatively consistent, inverse relationship between GDP growth and graduate initial unemployment. As well as the more direct relationship between the proportion gaining employment in Ireland and Irish GDP growth (Figure 3.15).

Figure 3.14: First destinations of Irish graduates 1988 to 1997



Source: IES/HEA (various years) First destinations of award recipients in higher education

Figure 3.15: New first degree graduates entering employment, unemployment and GDP, Ireland



Source: IES/HEA (various years) First destinations of award recipients in higher education

3.7.3 Other data sources

There is a range of other types of data sources covering graduates labour market entry. These now include the Labour Force Survey, and historically administrative data in Finland and Denmark (see, *eg* Zangenberg and Zeuthan, 1996).

A new variable is being introduced to the Community Labour Force Survey, which record the year when the highest qualification was obtained. This variable has been in the UK LFS for a few years and this allows, in conjunction with the individuals age, a series of synthetic cohorts to be constructed from the UK LFS. Additionally, the UK LFS records the subject of the highest qualification that allows science and technology first degree graduates to be distinguished from all first degree graduates. The subject data will not become part of the community LFS but the analysis is included here as an example of the sort of analyses that will be possible when the new variable becomes functional.

Table 3.5 shows the labour market status of individuals up to fifteen years after graduation. This shows that graduates are more likely to be employed over time until 15 and more years after graduation when economic inactivity starts to push down the rates of employment. In addition, across the board, medical science graduates are more likely to be in employment, than natural scientists and engineers, who in turn are more likely to be in employment than are other graduates.

Table 3.5: Labour market status of first degree graduates 5, 10 and 15 years after graduation by subject group — UK

		In employment		Unemployed		Inactive	
		’000	**%**	**’000**	**%**	**’000**	**%**
5 or fewer years	Medical sciences	63	93.1	2	2.9	3	3.9
	Natural Sciences & Engineering	176	91.6	8	4.3	8	4.1
	Everything else	513	90.3	27	4.7	28	5.0
6 to 10 years	Medical sciences	50	93.6	0	0.0	3	6.4
	Natural Sciences & Engineering	163	92.6	3	1.7	10	5.6
	Everything else	355	89.5	12	3.0	30	7.5
11 to 15 years	Medical sciences	53	94.3	0	0.0	3	5.7
	Natural Sciences & Engineering	159	92.9	3	1.5	10	5.6
	Everything else	412	88.7	12	2.6	40	8.7
15 years plus	Medical sciences	143	88.4	1	0.5	18	11.0
	Natural Sciences & Engineering	549	85.5	14	2.2	79	12.3
	Everything else	1,451	86.0	40	2.4	195	11.6

Source: IES/ UK LFS Spring 1998

4. The Adequacy of Supply in Meeting Employer Demand

4.1 Introduction

As discussed in Chapter 1 the focus of the research is on the adequacy of the supply of S&Ts in relation to employers' demand. It is not about adequacy in the widest sense — *eg* as in fulfilling the broader needs of the economy, society and, or the environment. It is about the availability of the right people with the right mix of skills and experience, at the right time, who want to take up and are deemed suitable to fill the available job openings as specified by employers. When all the factors affecting the supply, demand and the labour market matching process are taken into consideration, it can be seen that the notion of achieving adequacy involves a complex process. It is not simply a case of counting S&Ts and S&T jobs and seeing if the numbers are in equilibrium.

As discussed in Chapter 2 the needs of employers are varied and have been influenced over time by a range of factors, often working in different ways, affecting occupations, organisations, countries and regions differentially. Employer demand is also not easy to measure with any precision. In part this is because it is not always articulated clearly by employers, but also because there is a lack of consistent data collected by individual employing organisations, countries, or at an international level. This then creates even more uncertainty about the extent to which demand is, or is not being met for different categories of staff by the educational system in different countries.

There are numerous examples of highly publicised claims about labour or skill shortages in scientific and technical areas that have turned out to be overstated. This can come about in several ways. It may be due to vested interests, *eg* an employer or trade body lobbying governments to take specific initiatives to increase supply by exaggerating actual recruitment difficulties or turnover problems. Recruitment problems may not actually relate to shortages of supply. For example, an employer perceives a shortage of applicants but the main cause could be the unattractiveness of the jobs on offer. This might be due to low salaries, poor career prospects, unattractive locations or poor working conditions. Alternatively, the labour market may not be operating effectively, so potential recruits may be unaware of the vacancies. A related issue is that employers can be over-specific in their recruitment, only seeking S&Ts from particular institutions or courses when they could be equally or more successful recruiting from a broader pool or broadening their requirements (Pearson, 1999a).

Conversely, there can also be problems of unmet or hidden demand where the articulated level of vacancies understate actual needs which may never be advertised. For example, demand may not be articulated as explicit vacancies with an employer who is '*just always on the look out for a good PhD to do x*'. Likewise, an employer who is experiencing a hard-to-fill vacancy may choose to deal with it internally by using existing staff and skills, or by subcontracting the work to another organisation. This may not be as effective, but nevertheless meets the short-term need. Finally, an employer may not even bother advertising, as they do not believe they could fill the vacancy in the prevailing circumstances.

Another set of issues that have recently become more prevalent, is around mismatch between skills in demand and those available. There may be a sufficient numerical supply of graduates from HE but they are deficient in aspects of their subjects (*eg* up to date laboratory experience, or in the personal skills/attributes they offer). Employers then have difficulties filling their vacancies. Hence the paradox of relatively high graduate unemployment levels co-existing with employers reporting graduate shortages.

Finally, there is a an adequacy problem which does not focus so much on problems of recruiting staff, but relates to skill gaps within organisations. Here, the skills of existing employees are a constraint on the development of the business. For example, insufficient skills of existing staff to meet modern competitive needs, result in reduced competitiveness or delays in bringing new products to the market. This may not manifest itself as a recruitment issue, it may not even be fully recognised by employers. However, it can be as much a handicap on businesses or, more widely, on national economic development, as some of the more readily identifiable recruitment or skill shortage problems. This type of adequacy problem lies outside of our definition as above and is hard to quantify.

Despite the complexity of the subject and the problems of measuring a 'true' level of adequacy and, more importantly inadequacy, concerns about current or impending shortages of S&T graduates, have been a consistent theme. This is especially so in times of economic upturn, both in Europe and in the US (*eg* US Bureau of Statistics, 1998). This chapter now looks at the evidence relating to recruitment difficulties and shortages, then at evidence that there may be more than enough scientists and technologists, the issue being one of oversupply.

4.2 Recruitment difficulties and shortages

It is very rare to find a time when there have been no reported shortages, real or inflated, or when the S&T supply/demand equilibrium has been perfectly in balance, or nearly so, for each subject, discipline, sector and country. There have almost always been a number of short-term or very specific shortages in existence.

In the late 1980s, employer reports of recruitment problems and skill shortages reached a peak as most economies, and demand for staff, expanded. There were reported shortages of graduates generally, and engineers and IT staff in particular, in many European countries. The extent of problems varied between countries because of differential rates of growth in demand, and different graduate supply situations. For example, the earlier growth in graduate supply was the main reason for Denmark and Germany experiencing fewer problems at that time (OECD, 1993). Most of the recruitment problems quickly abated in the early 1990s as European economies moved into recession.

By the mid- and late 1990s, there was evidence of some re-emerging problems as economies moved out of recessions and labour markets tightened. However, apart from IT, there has not been the same level of reported difficulties generally. This is in part due to the increases in graduate supply (Chapter 3). However, there have been more widespread reports of employers needing graduates with better personal skills, and criticisms of the overall quality of the graduates available. This problem also affects a graduate's ability to move quickly into employment.

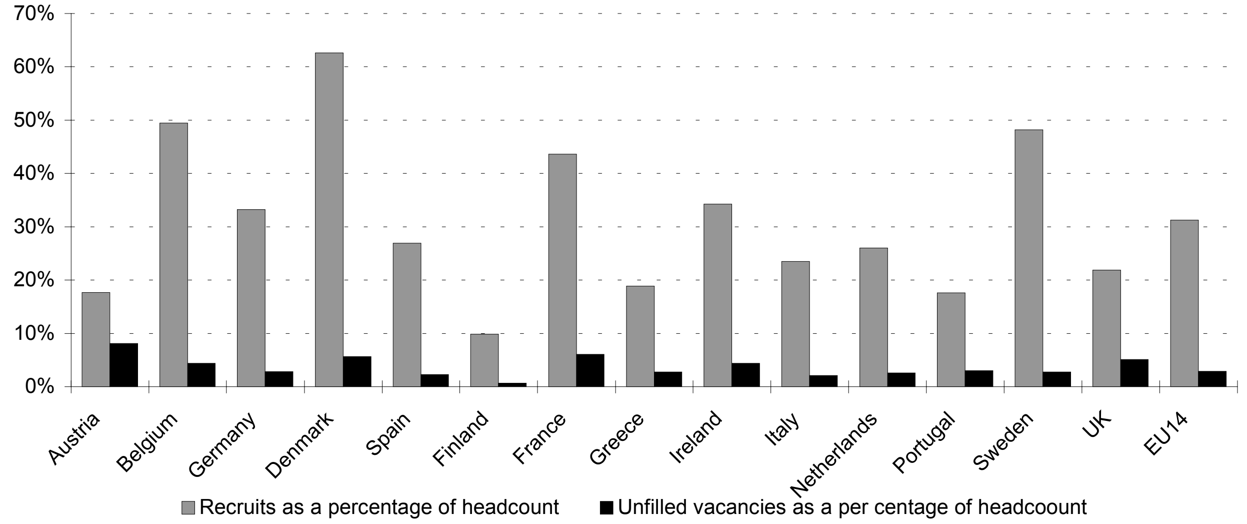
Chapter 1 discussed a number of potential measures of adequacy. In the event, an extensive trawl of the literature, data sources and contact with national experts, highlighted the paucity of data in relation to many of the potential indicators of adequacy, such as salaries, staff retention and mobility and advertising trends. Reliance therefore has to be placed on the limited evidence from:

- employer surveys and reports of unfilled or hard-to-fill vacancies
- graduates' ease of transition from education into employment
- econometric models, and
- other *ad hoc* indicators.

Each provides a different perspective and some are more reliable measures than others as discussed below.

Surveys of employers and employer bodies provide the most evidence of recruitment difficulties. However, there tends to be a bias in response towards those with most recruitment problems, and larger firms, and they can overstate the actual amount of difficulty being experienced. For example, at times of economic

Figure 4.1: Recruits and unfilled vacancies as a percentage of headcount, by country 1992-97



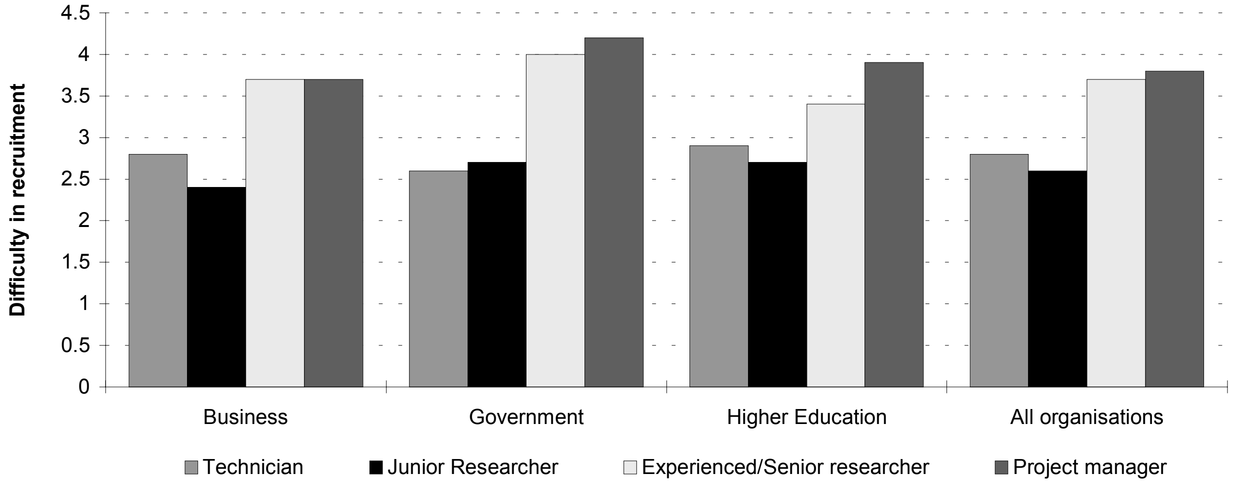
n= 210 see Annex 1.4

Source: IES Survey of R&D Establishments, 1998

expansion, virtually every company in a sector bases its vacancy projections on the assumption that it is going to increase output and market share. In this way, the likely level of new vacancies may be significantly overcounted.

The survey of R&D establishments carried out for this study reported that the level of unfilled vacancies as a proportion of total vacancies was estimated at 2.9 per cent across Europe; this is not high. The level of vacancies was highest in the HE sector (at 12 per cent), suggest greater problems there. Countries with higher levels of unfilled vacancies were Austria (8 per cent), although that was based on a small sample, and the UK (5 per cent) (Figure 4.1).

Figure 4.2: Recruitment difficulties by sector 1997



Note: average scores given by employers on a scale of 1 to 5, where 5 is difficult and 1 is easy

n= 210 see Annex 1.4

Source: IES Survey of R&D Establishments, 1998

Overall, more difficulties were experienced recruiting experienced and senior researchers, and project managers than technicians or junior researchers with nearly two-thirds of R&D establishments reporting difficulties. The problems were most commonly reported by the government sector (Figure 4.2). Unfortunately, there was insufficient response to analyse these further at a country level.

Overall, the most important grade of staff was senior researchers, although in Business Enterprise establishments project managers were more important. In terms of difficulty of filling positions, project managers ranked the hardest to recruit, especially by government R&D establishments. The differences between the different grades were also more pronounced in terms of difficulty of recruitment than in terms of importance to the organisation (Table 4.1).

In skill terms the main problems in the technical/scientific area were recruiting staff with **specific areas of scientific knowledge** such as in optics materials/metallurgy, specific industrial processes, physical science, communications engineering, analytical chemistry, and staff with generic research skills (see, *eg* Anon, 1996e). There were also more difficulties in securing sufficient engineers/materials science skills, mathematical /computing skills. These difficulties were being experienced across the business, government and HE sectors. Problems were being experienced less in relation to biological, biomedical and environmental skills (Table 4.2).

As was seen in Chapter 2, **personal transferable skills**, such as project management skills, are becoming increasingly important. The highest rated personal transferable skills in terms of importance to their organisation were 'Problem solving', followed

Table 4.1: The importance of, and difficulty filling different types of research post, by sector

	Importance				Difficulty filling posts			
	Business Enterprise	Government	Higher Education	All organisations	Business Enterprise	Government	Higher Education	All organisations
Technician grade post	3.7	3.7	3.4	3.6	2.8	2.6	2.9	2.8
Junior researcher grade posts	3.7	4.0	4.0	3.9	2.4	2.7	2.7	2.6
Experienced/senior researcher	3.9	4.0	3.8	3.9	3.7	4.1	3.4	3.6
Project managers	3.9	3.7	3.0	3.6	3.7	4.2	3.9	3.8

Note: average scores given by employers on a scale of 1 (easy) to 5 (difficult)

** statistically significant differences between groups at the 10 per cent level and ** at the 1 per cent level*

n= 210 see Annex 1.4

Source: IES R&D Establishments Survey

Table 4.2: Ease of recruiting technical and scientific skills by sector, 1997

	Ease of recruitment			
Skill group	**Business Enterprise**	**Government**	**Higher Education**	**All organisations**
General level of scientific knowledge	2.9	2.8	2.9	2.9
Level of appreciation of other technical areas	3.1	2.9	3.2	3.1
Ability to perform specific procedures	3.1	2.8	3.3	3.1
Ability to use specific types of equipment	3.1	3.0	3.2	3.1
Specific areas of scientific knowledge	3.7	3.5	3.6	3.6
Research skills *	3.5	3.5	3.6	3.5
Mathematical and/ or computing skills	3.1	3.4	3.2	3.2
Biological/ biomedical skills	2.7	2.9	2.8	2.8
Environmental science skills	2.8	2.8	2.9	2.8
Physical science skills *	2.8	2.9	3.0	2.9
Engineering/ materials science skills	3.2	3.4	3.3	3.3

Note: average scores given by employers on a scale of 1 (easy) to 5 (difficult)
** statistically significant differences between groups at the 10 per cent level and ** at the 1 per cent level*
n= 210 see Annex 1.4
Source: IES R&D Establishments Survey

by 'Team working', and 'Written communication skills' (Table 2.4). The ranking of skills importance was remarkably similar across the sectors. Looking at ease of recruitment, the areas with the most difficulty were 'Problem solving', 'Leadership' and 'Project management'. These problems were to be found in all sectors. Problem solving, in particular, was identified both as an area of high importance, and one where recruitment difficulties were greatest. Higher education R&D establishments reported the greatest problems recruiting staff with 'Project management' skills, and more difficulty in recruiting S&Ts with 'Communication skills' than other sectors. The government sector highlighted 'Problem solving' and 'Leadership'. For BE establishments, 'Information technology' was more of a problem than for government or HE R&D establishments. Government R&D establishments were experiencing more difficulties than other sectors in recruiting S&Ts with 'Leadership' and 'Team working' skills (Table 4.3).

The interviews with employers confirmed these skill problems although it was not possible to generalise the particular areas giving the most difficulty. At postgraduate level there were, however, requirements for more in-depth knowledge, for example, on new materials technology composites, complex computing systems, and also practical skills (*ie* 'making experiments work'). However, it was the combination of technical skills and knowledge with the 'soft' skills, or more work-relevant personal skills and attributes, increasingly referred to under the generic term 'employability', where employers appear to have the most problems. As one employer said:

Table 4.3: Ease of recruiting personal transferable skills, by sector, 1997

	Ease of recruitment			
Skill group	**Business Enterprise**	**Government**	**Higher Education**	**All organisations**
Project management skills	3.5	3.8	3.6	3.6
Problem solving	3.6	3.6	3.5	3.6
Leadership	3.6	3.8	3.4	3.6
Business awareness	3.5	3.5	3.3	3.4
Written communication skills	3.3	3.2	3.5	3.4
Planning and organising	3.3	3.5	3.3	3.3
Oral communication skills *	3.2	3.3	3.4	3.3
Time management *	3.4	3.3	3.2	3.3
Team working	3.3	3.4	3.1	3.2
Information technology	3.9	2.9	3.1	3.0
Foreign language skills	3.0	2.7	3.0	2.9

Note: average scores given by employers *on a scale of 1 (easy) to 5 difficult)*
** statistically significant differences between groups at the 10 per cent level and ** at the 1 per cent level*
n= 210 see Annex 1.4
Source: IES R&D Establishments Survey

> *'These days we need more than ceramic skills, we need a blend . . . highly qualified engineers/scientists who know that our main business is manufacturing … the extras are important: practical skills, ability to demonstrate problem solving, real work experience.'*

While another said:

> *'We see too many well qualified applicants with no creativity.'*

And another:

> *'He needs to understand the context … be aware of the business in which customers operate.'*

And another:

> *'Good interpersonal skills means a mix of good communication, leadership and motivational skills.'*

The literature review showed that the problems most consistently highlighted related to an inadequate supply of **IT skills.** However, while there have been many press reports of problems there are few substantive studies or analyses of the problems. For example, in France, as in many other countries, the introduction of the Euro, and the Year 2000 problem, have increased the pressures on the IT labour market already under pressure from the rapid growth in the adoption and upgrading of IT systems. The Syntec Informatique, which represents a major part of the computer services and engineering sector in France, reported in 1998 that employers were having increased difficulties recruiting the IT staff they needed. '*IT staff are in such demand they are receiving many job* *offers. Having been recruited by one organisation they are then snapped up by another'* (*Le Monde*, February 1998). The expectation was that the shortage would worsen during 1998 and 1999 but there was no hard evidence as to scale and nature of the problem. In the UK, Microsoft jointly with CSSA and NTITO (national trade and training bodies relating to the IT industry), surveyed a range of employers, recruitment consultants and education/training providers (1,250 in total). They reported that *'73 per cent of 'people in the computer industry'* ***believe*** *that there is an IT shortage'.* This figure rose to 86 per cent for the finance sector and amongst the recruitment consultants interviewed. The main reasons given were a combination of short-term factors (*eg* EMU, Year 2000) and a long-term problem of under-investment in training and *'inappropriate degree courses'.* However, this is a report on perceptions and does not say how many of these organisations were actually experiencing problems themselves, nor of the magnitude and real cause of the problems, nor for the skills most needed.

The other sources of data are far more partial and limited. For example, the UK computer services industry reports staff turnover at 13 per cent, twice the UK industry average. Again there is no information as to what proportion or number of these vacancies is hard to fill, and what proportion is simply mobility within this rapidly developing part of the labour market. Job advertisements are one of the less reliable indicators of labour market shortages and tell more about market 'churn'. They can be misleading because of double counting (same advert placed in different places). Reliable salary data was notable for its absence although there were regular reports quoting high one off salaries for specific vacancies.

More limited concern has been expressed about **engineering** skills. A recent survey of engineering skills in the UK (EMTA, 1998) pointed to evidence from employers, half of whom had difficulties filling vacancies. These difficulties were more severe for craft workers (49 per cent of all hard-to-fill vacancies were in this occupational group). However, there were also problems relating to professional engineers (*ie* graduates) and technicians (together these represented almost 20 per cent of all hard-to-fill vacancies). The higher level hard to fill vacancies were especially problematic in the electronics and aerospace industries. One large employer, British Aerospace, has gone as far as setting up its own corporate university to ensure an adequate supply of engineers in the future. A UK government survey covering all industries shows the problems are not confined to manufacturing. Increasing levels of 'hard-to-fill' vacancies (up from five per cent of all vacancies in 1992 to 18 per cent in 1997) are part of a general trend across the economy, and related to economic upturn (IFF, 1998). In contrast, the evidence in relation to engineers in Germany suggests the problem is more one of oversupply than shortage (see Section 4.4).

The speed and ease of transition from **higher education to employment** can also be used to indicate whether and where shortages might exist, as discussed in Chapter 3. This showed that the available evidence is very patchy because only a few countries collect relevant employment information on a regular basis. The available data for Ireland, Sweden and the UK, however, showed that that during the 1990s, graduates as a whole have been taking longer to find employment after their studies. In several countries, IT and computer science and related graduates, *eg* in maths, found it easiest to gain employment, along with engineers in the UK and Ireland. Life science graduates fared the worst.

Finally, there are forecasts and projections focusing on likely employment trends and potential imbalances between supply and demand at a national and international level. However, many of these forecasts reveal little about the underlying model and its assumptions and or often focus on very generalised categories as discussed in Chapter 5 (see also Heike, 1997). One model that has focused on shortages is the recent Microsoft/IDC resourcing model that was used to predict a growing problem of shortage of IT skills in Western Europe. This claimed as many as 500,000 unfilled IT vacancies in Western Europe at the end of 1998, up from 320,000 in 1987. This is within a total stock estimated to be 9 million in 1987, thus representing only about 4 per cent, not a particularly high level of vacancy. The assumptions fed into this model are unstated, the types of IT skills included are diverse and include lower level jobs, and it is not clear how many of these vacancies are simply a counting of natural turnover and how many are hard to fill vacancies. Furthermore, some commentators question the independence and validity of estimates coming from such sources that are linked closely to the needs of the industry.

Because of the paucity of existing data on the subject a special econometric modelling exercise was commissioned for this study, this is reported in Chapter 5.

In summary, no dependable evidence has been found of widespread and significant numerical problems with employers failing to attract sufficient S&Ts across Europe. Some selective shortages existed, by far the most significant of which are for IT staff. The R&D establishments survey showed the greatest recruitment problems related to senior/experienced researchers rather than more junior staff.

Linked to the issue of numerical shortages is the issue of **quality** and personal skills. Many commentators have suggested that 'a degree' and 'a graduate' are much less homogenous entities than they were, even from universities within the same country, and that employers are increasingly aware of a much wider range of graduates and their abilities, within the overall supply.

As shown in Chapter 2 there is an increasing demand for graduates who combine both appropriate personal and technical skills. Employers frequently raise criticisms of graduates' personal and social skills (Table 4.3) and they are more likely than in the past to rank graduates' social skills high among criteria for recruitment and promotion (Teichler, 1997, Pearson, 1999a). At masters and doctorate level too, employers are putting more priority on 'good personal skills' as well as academic excellence in particular fields (Jagger, 1998).

Concerns about the unsuitability of content and design of many academic courses in science and technology in various European countries have also been highlighted. For example, a study of S&Ts in the less favoured regions of Europe identified criticisms by companies of the lack of integration across disciplines in academic study and of teaching on innovative processes (Munoz, 1993). French HE has also been criticised for being too theoretical where study does not translate easily into technology needs of industry (NSF, 1996). There are concerns about the education quality of Danish engineers (De Laine, 1998, Hermann, 1996). Dutch engineering courses are seen to be weak on developing social skills, partly because of their heavy workload. There has also been mounting concern in Germany about the adequacy of the now expanded (mass-track) HE system in meeting the changing social and economic needs of the country (Beuchteman, 1993b). Managers of UK chemicals and pharmaceuticals companies have also reported criticisms of the content of chemistry degree courses, notably poor practical laboratory and analytical skills and limited communication skills (Mason, 1998).

The IES R&D establishments survey asked employers specifically about the main area of shortage they were experiencing, in terms of output of their education systems. Most of the replies related to qualitative aspects of supply, and reiterated points made above relating to combinations of good technical and personal skills. For example:

> *'Our main problem: a person competent and highly qualified technically who* ***also*** *has good organisational and management skills.'*
>
> *'Computer scientists* ***with*** *business sense.'*
>
> *'Technicians* ***with*** *language skills.'*
>
> *'Shortages – project management experience, economic knowledge, industrial experience.'*
>
> *'Too little knowledge about how industrial engineering works.'*
>
> *'Inter-disciplinary education is missing.'*
>
> *'Too many theoretical scientists, application experience needed.'*
>
> *'Language skills, team working.'*

> *'Not enough attention to social sciences (taught behaviour),'*
>
> *'Few graduates have self-motivation and management skills to tackle long-term, poorly defined projects.'*

4.3 More than adequate — is there an oversupply of S&Ts?

4.3.1 Too many qualifying?

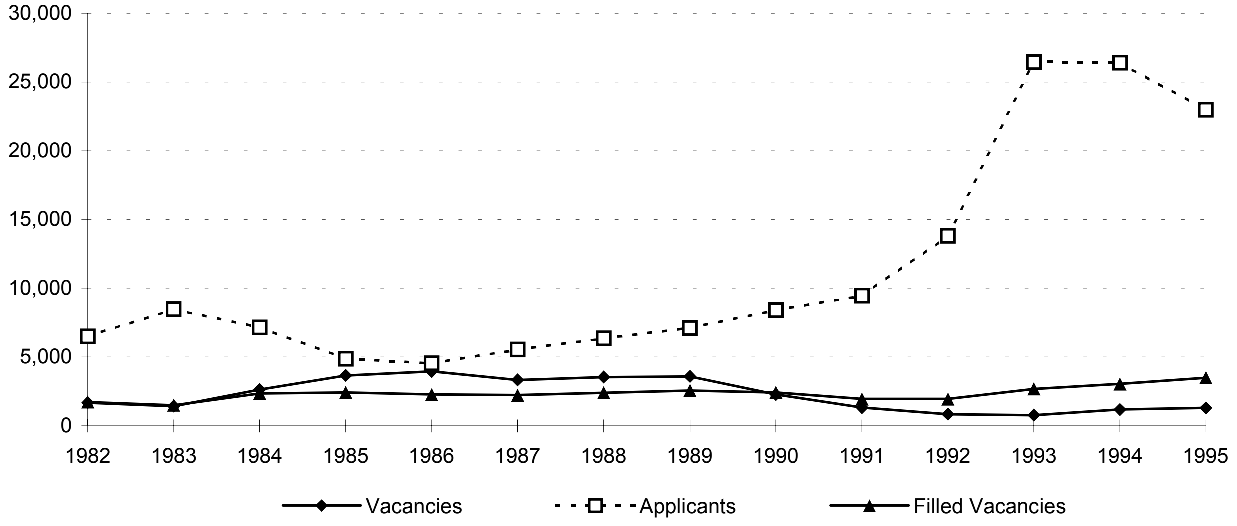
The evidence presented so far suggests that recruitment problems are not widespread, but that there are some selective problems affecting particular disciplines and sectors. These are most noticeably for IT skills, and affect the government and higher education employment sectors more than private industry.

It is apparent that the adequacy or mismatch problem can also be more one of an oversupply than undersupply in places. There are no direct measures of oversupply and under utilisation. However, although the job market for graduates has been improving in recent years, relatively high levels of graduate unemployment persist. The length of time spent in job search has been lengthening, although this has been generally less so for S&T graduates than for other disciplines as noted in Chapter 3. The prospects for graduates were reported in several research studies undertaken in 1996 and 1997 to be still fairly bleak across much of Europe (Teichler, 1997). In France, for example, 19 per cent of doctorates, 16 per cent of engineering school graduates and 23 per cent of DEA/DESS graduates were unemployed six months after graduation (See Figure 3.9). In Sweden, a quarter of maths and science graduates in 1993 took over six months before entering their first job, a similar figure to engineers (20 per cent). In the UK, nine per cent of all new graduates were unemployed six months after graduation in 1998.

In Germany, using another indicator, the number of reported vacancies for engineers has shown little change, ranging from 2 to 4,000. However, the number of applicants has grown five-fold and in 1995, it was seven times as great as the number of vacancies (Figure 4.3). A similar pattern is apparent in relation to electronics engineers and physicists. This may have been due mainly to reunification and the subsequent closure of many East German industrial plants. The data say nothing about the quality and relevance of the skills of the applicants in relation to the reported vacancies. There have also been concerns about poor career prospects for research staff (Anon, 1996f).

There were not many employer comments on this topic in the IES R&D establishments survey. The main ones identified concerned 'over-specialisation', for example:

Figure 4.3: Industrial engineers, vacancies, applications and filled vacancies



Source: Zentralstelle für Arbeitsvertmittlung (ZAV) (1996) Arbeitsmarkt-Information: Machinenbauingenieurinnen Machinenbauingenieure

> *'Time in specific scientific area is too long, people leaving universities are too old.'*
>
> *'Too much emphasis on academic thoroughness, too little on efficiency and industrial relevance.'*
>
> *'Education specialises, general understanding of problems is not well supported.'*

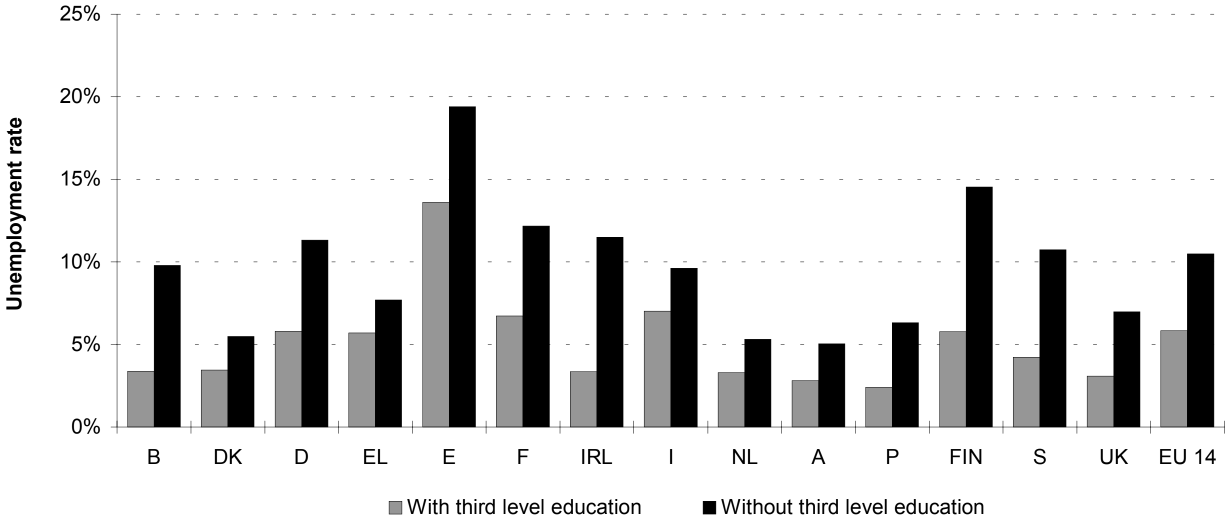
or other problems related to the preferred non-urban residential preferences amongst the highly qualified, *eg*:

> *'RSEs want to re-locate to rural areas, away from main cities.'*

4.3.2 Under-employment

While high unemployment levels and length of job search is one indicator of oversupply, it does not tell the full story. At times of plentiful supply of labour, employers naturally take advantage of it and there is an increasing amount of 'vertical' substitution occurring. Graduates and S&Ts enter jobs which were previously held by less qualified, skilled or experienced individuals. In some cases they may bring additional skills to the performance of that job, thus 'growing' the job. This may not be the position in all cases, and they may simply be pushing non-graduates out of these lower skilled posts. Nevertheless, graduates fare better than non-graduates in most labour markets, in terms of relative unemployment. The unemployment rates for graduates of all ages (not just new graduates) vary from almost 13 per cent in Spain to 2 per cent in Austria. In all countries, they are below the rates for less well-educated people (Figure 4.4).

Figure 4.4: Unemployment rates for those aged 25 to 59 years with and without third level education, 1997



Source: IES/Eurostat (1997) Labour Force Survey

Some have argued that the notion that people can be too educated is akin to saying that one can be too healthy (Dolton and Vignoles, 1997). The argument is that the pay-off to the individual and society has to be positive. However, in a world of scarce resources and high competition, a key issue is the relevance and appropriateness of graduates' education and skills and its relevance to a modern society. Nevertheless, the under-utilisation of graduates, or indeed any other type of person's skills is a serious issue.

There are few objective measures of underemployment, nor is there an agreed set of definitions. Much of the evidence that is available rests on graduates' self-ratings which show quite substantial levels of dissatisfaction with their job status or level. For example, 18 per cent of graduates in a German survey considered their position two years after graduation to be 'inappropriate' for a degree-holder. A further 19 per cent said they could hardly make use of the competencies and knowledge they acquired on their course. In Sweden, 30 per cent of graduates surveyed one year after graduation said that their education was only partially suitable to their present work or did not fit their work assignments at all (Teichler, 1997). In the UK, a survey of 1991-93 graduates found that almost half were in jobs which they did not consider to be graduate level work (Connor and Pollard, 1996). Other European results suggest that in the Netherlands, Spain and Portugal, the incidence of over-education, and hence under-employment, has risen, as the labour force has become better-educated (Dolton and Vignoles, 1997).

There is, however, little evidence that disaggregates the graduate population by subject and clarifies the position for S&Ts. One of the few pieces of survey evidence specifically on engineers comes from surveys undertaken in 1989 and again in 1993 of engineering graduates in Germany, one year after graduation. They show that on the whole, employment opportunities had deteriorated. In 1993, 6 per cent of university and 12 per cent of fachhochschule graduates had accepted first positions of lower level than those typically held by graduates. This compared with one and two per cent in 1980 (Brennan *et al.*, 1996). In part, this is a reflection of changing patterns of employment with a greater incidence of fixed length contracts and short-term working. The status of the available employment was lower, but offering comparable salaries. There were differences however between engineering fields with mechanical and electrical engineers experiencing deterioration over the period, but little change for civil engineers. This emphasises once again the dangers of generalising across disciplines.

Another German study showed there was a lower risk of 'under-employment' for graduates from fachhochschule in technical disciplines and from university graduates in mathematics, natural sciences and physics (Buchel and Matieske, 1996). A recent UK study in chemistry-based industries found that just over a quarter of enterprises employing chemistry graduates had recruited a chemistry graduate to a position which had previously been filled by someone with lower qualifications (*eg* a lab technician, quality analyst). The reasons given were divided between demand side factors (*eg* the job needed higher level skills now) and supply-side (*eg* greater availability of graduates, reduced supply of sub-degree qualifications). This study also showed a very wide range of work was being undertaken by graduate chemists from those requiring proven ability in original research to routine laboratory testing (Mason, 1998). Again in the UK, those with life science degrees were found to be earning less and were less likely to use their skills than those with computer science, and engineering degrees (Purcell, 1999).

4.4 Some employer responses to shortages

These can come in various forms. As seen above, increased salaries or improved conditions are one obvious response to shortages in the IT sector, but one whose effectiveness is hard to measure. In the short term, they may at least simply result in a redistribution of staff between organisations and higher staff turnover. A second response is to invest in more training and retraining, both directly or by becoming more involved in higher education, this has the advantage of increasing the overall supply. Some large, multi national IT companies, for example, have begun to work more with universities and colleges to develop new courses (*eg* a Microsoft-certified professional qualification) or modules in their particular programming languages or systems, *eg* IBM, Fujitsu, Novell. Some are now creating corporate universities, sometimes on a global scale as with British Aerospace in the UK and Motorola worldwide. This is at present more prevalent in the USA, but it is growing in Europe especially where there are country cultures which are encouraging employers to participate in university degree study, although this is still rare in engineering in Germany. However, training investment of this kind is a longer term and expensive solution. Other responses include the reallocation of work between specialists and non specialists, delaying retirements and increasing working hours. Some employers have also turned to other countries to find particular skills as shown in Chapter 2, however, the evidence on international brain drain/gain shows such flows still to be still quite small (Court, 1995d, IPTS, 1998).

It is evident that some of the adequacy problems reported by employers who experience problems finding sufficient graduates 'of the right kind' or 'right mix of skills' relate to a poor 'fit' between educational output and employment needs. This is particularly so where the emphasis is being put on personal/social skills and understanding of the business world combined with technical skills and knowledge.

As noted in Chapter 3, higher education is becoming more responsive to the needs of employers and various initiatives have been launched to encourage this. However, one of the key problems is that although employers point to weaknesses in the HE systems in relation to employment needs, it has proved virtually impossible for them to give reliable assessments of future demand in terms of numbers and types of skills and attributes sought (see also Section 2.7). Most often, any future demand forecasts have been too vague to use in making detailed alterations to courses. Instead, universities and other HE institutions have been encouraged by governments to be more responsive to industry's needs by taking more control of their own planning, and introducing more development of work relevant skills in students (see Section 3.3). Increasingly, the emphasis is about making graduates more 'employable'. However, the traditional education system of many countries is not very efficient at producing technical work-relevant qualifications, especially in rapidly changing work environments (Kwinnenand Rinne, 1993). In particular, multi-skills and the skills of flexibility and adaptability, which are increasingly required by industry, poses a challenge for conventional education systems with relatively rigid organisational structures, and so change is expected to be fairly slow in many places.

5. Modelling Supply and Demand

5.1 Introduction

The previous Chapters reviewed the available literature, data and issues relating to scientists and technologists. It was recognised, however, at the outset of the study that there was a paucity of relevant data and to this end, two special components were added. The first the *IES Survey of R&D establishments*, details of which were reported in Chapters 3 and 4, and Annex 1. The second involved the development of a pilot econometric model to try to assess the quantitative adequacy of the education systems in the Member States of the EU for the period to 1997-2002 in relation to the demand for Research Scientists and Engineers (RSEs). The model draws off existing data sets, trends and statistical relationships between variables and, supplementary data collected via the *IES Survey of R&D Establishments,* along with a series of assumptions about flows and adjustment mechanisms. Forecasts of future demand for, and supply of RSEs have been produced for 14 Member States of the EU, extending to the year 2002.

The next sections describe the general structure of the model and summarise the forecasts for demand and supply under four scenarios. The findings are then linked to those from the earlier Chapters and the conclusions drawn out in Chapter 6. Further details of the model and the constituent data appear in Annex 2. The Annex also details the findings in relation to agricultural science RSEs and medical science RSEs, disciplines which are incorporated in the model but outside the scope of this report.

5.2 The model

From a policy perspective, the availability of reliable forecasts on the adequacy of the education systems in the Member States of the EU to meet the future demand for RSEs, is important. Such forecasts could be an essential tool for policy-makers, as they can serve as an 'early warning system' indicating possible bottlenecks in the labour markets for RSEs giving policy-makers the opportunity to initiate anticipating policies.

This chapter explores the possibilities of developing a forecasting system for the European labour markets for RSEs. It is a pilot study that tries to establish what analyses are possible with the currently available data on R&D personnel and to identify the obstacles that stand in the way of a more reliable forecasting system. For this purpose, the pilot study produces forecasts for future demand and supply of RSEs for 14 Member States of the EU in the period 1997-2002, based on available data up to 1997. It offers an exploratory assessment of the expected quantitative adequacy of the education systems in the Member States of the EU in the period 1997-2002 in relation to the demand for RSEs. It is important to emphasise that, due to the restricted availability of the required data-inputs, these forecasts are not yet suitable for policy purposes. The main purpose is to show the potential features of an early warning system for bottlenecks in the labour markets for RSEs, which play a crucial role in the European knowledge economy.

In order to assess the quantitative adequacy of the education systems in 14 Member States of the EU in the period 1997-2002 in relation to the demand for RSEs, a model was developed to track the relevant flows in the labour markets for RSEs. Under this approach, forecasts were made of the flows entering and leaving the labour market in the next few years, which enabled a confrontation to be made between labour *demand* (the expected job openings for RSEs) and labour *supply* (the expected inflow of new RSEs).

The **demand for RSEs** consists of two components. In the first place, job openings may occur due to growth of R&D employment, called *expansion demand*. In the second, there are job openings because of the outflow of workers due to retirement and the mobility of RSEs to commercial, management and non R&D jobs, called *replacement demand*. Expansion demand and replacement demand are considered in the three sectors of R&D work used in earlier Chapters: the business enterprise sector, the government sector and the higher education sector. The forecasting results for the demand side are summarised in terms of the total number of *job openings* between 1997 and 2002.

In order to get the most accurate forecasts of *expansion demand*, econometric models were developed for each of the 3 sectors in each of the 14 Member States, *ie* excluding Luxembourg. These models use the sectoral expenditure on R&D to explain sectoral expansion demand. The use of expenditure data instead of GDP (or Gross Fixed Capital Formation) allows us to capture effects that are specific for the R&D sector as opposed to the economy as a whole. By distinguishing between three sectors (business enterprise, government and higher education), sector-specific effects can be tracked. As a result, the forecasting results for expansion demand are based on 42 models (14 countries x 3 sectors).

While expansion demand is closely related to the growth of the R&D sector, *replacement demand* depends in large part on the demographics of the R&D sector. The data from the *IES Survey of R&D Establishments* was used to infer the age structure of the RSE stocks. The probability that a person will flow out of the RSE stock depends on several factors including retirement and the mobility of RSEs to non-RSE jobs within or outside the firm. For example, many that start their career as an RSE, move on to commercial and managerial jobs. Since data on the outflow of RSEs were not available from existing sources, relevant data were collected in the *IES Survey of R&D Establishments*.

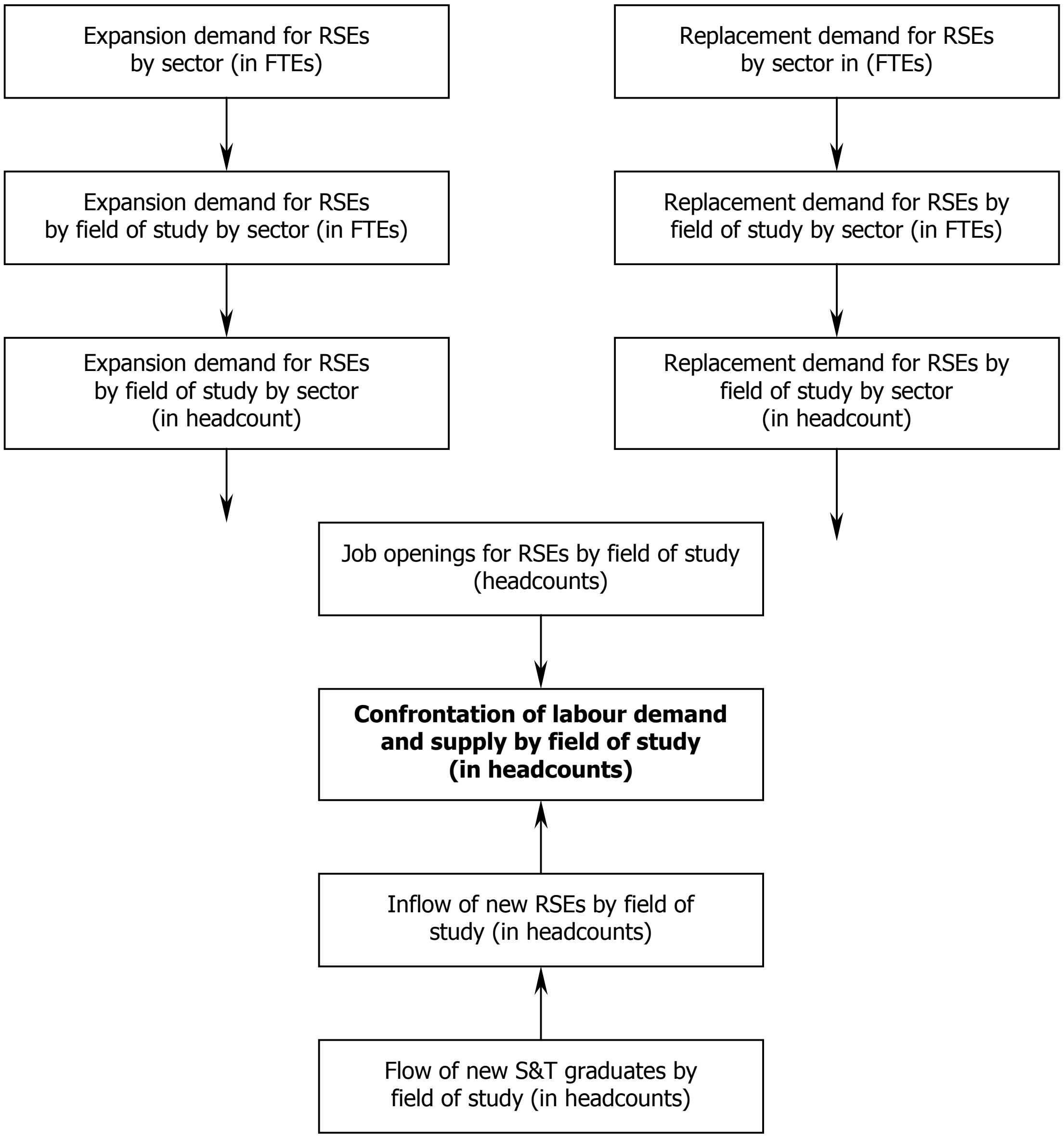
From the **supply side**, the job openings for RSEs will in general be filled by the *flow of new S&T graduates* from the educational system. Both the absolute numbers and the balance between fields of study vary between Member States (Chapter 3). In practice, only a modest fraction of new S&T graduates has the qualifications and ambitions to pursue a career as an RSE. Therefore, it is important for the confrontation between demand and supply to distinguish between the flow of new S&T graduates and the considerably smaller labour market *inflow of new RSEs*. Due to the poor quality of currently available data on graduate destinations, as detailed in Chapter 3, the available data on changes in RSE employment, in combination with the data on S&T graduates, had to be used as a starting point for the derivation of inflow-coefficients.

The model identifies four fields: the 2 core fields of direct relevance for this study, the natural sciences, and technology and engineering; plus medical sciences and agricultural sciences which are covered in more detail in Annex 2. Since the supply side forecasts refer to 'head-counts', the demand for RSEs was adjusted from full-time equivalents (FTEs) to head-counts. As a result, the confrontation between demand and supply takes place for 14 Member States for the period 1997-2002 in 4 fields of study in terms of the number of people.

The model for each of the 14 Member States is shown in Figure 5.1, the full details appear in Annex 2.

The implementation of this general framework is hampered by the lack of adequate data. As a result, we have had to fill the gaps by assumptions and approximations. It is therefore important to distinguish which parts of the forecasting model are firmly grounded in statistical data and which parts are based on hypotheses. In fact, each model component contains a blend of statistical data and *ad hoc* assumptions. This implies that the forecasts generated by the forecasting model should be interpreted with care. As with any model, alternative assumptions will lead to alternative forecasting results. Therefore, the forecasts are primarily an illustration of the type of information that can be provided by a forecasting system for the European labour markets

Figure 5.1: General structure of the labour market forecasting model



Source: ROA

for RSEs. The empirical foundation of the pilot model is not yet firm enough for reliable policy conclusions.

5.3 Scenario analysis

5.3.1 Scenarios for the RSE labour market

Four scenarios[1] were developed based on the combination of two dimensions: an *exogenous dimension* and a *policy dimension*. The *exogenous dimension* relates to overall developments in the global

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[1] For a more detailed discussion on the scenario approach, refer to Annex 2.

economy, which can only be influenced to a limited extent by policy-makers in the EU. The *policy dimension* reflects the choices that policy-makers in the EU face with respect to R&D and education policies. The interaction of the policy dimension and the exogenous dimension, allow an assessment to be made of the effects of human capital policies in the EU in case of both high and low growth paths of the world economy. In this way, the scenarios provide a 'policy-rich' analysis of the labour markets for RSEs up to 2002. The combination of an exogenous dimension and a policy dimension also offers a consistent way of building scenarios, instead of making *ad hoc* assumptions on the various components of the model.

5.3.2 The exogenous dimension: economic growth

According to the OECD (OECD, 1998a) the average economic growth rate for the EU in the period 1985-1995 was 2.0 per cent. In 1996, it was lower at 1.7 per cent, but it picked up in 1997 to 2.6 per cent. The OECD projections for 1998 and 1999 were 2.7 per cent at time of publication. However, the turmoil on the international financial markets in 1998 led to a revision of the OECD economic growth projections, which still had the 1998 growth rate at 2.8 per cent. The 1999 growth rate was reduced to 2.2 per cent, with a slight recovery in 2000 to 2.5 per cent (OECD, 1998b). This volatility of growth expectations highlights the need to use scenarios which can then accommodate assumptions about the effects of, for example, the financial crises in emerging countries, the situation in Japan, the state of the US economy, and economic developments within the EU.

In the forecasting model, sectoral *expansion demand* is based on sectoral R&D expenditure. In case of higher economic growth, it is assumed that more funds will be available for expenditure on R&D. In the business enterprise sector, sales and profits rise, which in turn enables firms to invest in their knowledge base with business enterprise expenditure on R&D (BERD) increasing. In the government sector, the higher economic growth increases tax receipts. If policy on human capital development is formulated in terms of R&D expenditure as a fixed percentage of GDP, the larger public budget leads to higher government sector expenditure on R&D (GOVERD). Since a major part of the higher education sector is funded by the public sector, an increase in economic growth will also benefit the higher education sector expenditure on R&D (HERD). In short, the cross-sector effect of increased (decreased) economic growth is increased (decreased) expansion demand.

If the high expansion demand resulting from high economic growth cannot be met by adequate supply, then efforts will be made to reduce replacement demand. For example, RSEs in the higher age cohorts will be less likely to leave the labour market by early retirement as firms try to keep their RSEs as long as possible.

Table 5.1: Assumptions on the effects of GDP growth on model components

Model component	High GDP growth	Low GDP growth
Expansion demand	high	low
Replacement demand	low	high
Inflow	low	high

Source: ROA

Firms are also likely to induce fewer RSEs to switch to non-RSE jobs. Consequently, the *outflow-coefficients* will be smaller in the case of high economic growth. Thus, replacement demand is assumed to partially compensate movements in expansion demand.

High economic growth also means that job opportunities for new graduates will probably increase both in RSE jobs and in non-RSE jobs. The effect on the *inflow-coefficients* will depend on the relative employment growth of RSE jobs versus non-RSE jobs. It is assumed here that economic growth increases job opportunities in the manufacturing sector more than in the research sector, leading to lower inflow-coefficients. The effects of economic growth under different scenarios are shown in Table 5.1.

5.3.3 The policy dimension: policies on R&D and education

Two types of public 'human capital' policies are relevant here. First, policies on R&D expenditure, which primarily affect the demand side of the labour market for RSEs, and second, policies on higher education spending, which affect both the demand and the supply side of the labour market for RSEs.

Spending on R&D is subject to budgetary pressures: *'… the fact that there is close interdependence between the macro economic policies of the European Union and the research and technological innovation policy, means that public financing of R&D cannot escape the constraints of budgetary reform, which characterise the current economic policy in the Member States of the Union.'* (European Commission, 1997, p. 311).

Educational expenditure is also under pressure*: 'In almost all OECD countries, total education expenditure accounts for between five and eight per cent of GDP. The public portion of this represents between ten and 15 per cent of public spending. This is a substantial proportion of national income by any standard. Under current conditions of tight public constraints, such a large spending item is subject to close scrutiny by governments looking for ways to trim or limit the growth of expenditure …'* (OECD, 1997, p. 10)

It is assumed here that R&D expenditure and public expenditure on higher education will go hand in hand, reflecting a coherent

Table 5.2: Assumptions on the effects of human capital policy on model components

Model component	High human capital growth	Low human capital growth
Expansion demand	high	low
Replacement demand	low	high
Inflow	high	low

Source: ROA

human capital policy. However, budgetary pressures may have different consequences for human capital budgets, depending on the emphasis of the policy-makers. Insights from endogenous growth theory (*eg* Romer, 1990) stress the importance of accumulation of knowledge (through R&D) and human capital (through education) for sustained long-term growth. If these insights are reflected in government policies, expenditures on R&D and education will be less affected than other parts of the public sector. In an international context, the situation is even more complicated, since certain countries are still trying to catch up: *'Other Members, despite budgetary problems and restrictions, are seeking to increase public expenditure on R&D. These include both countries with a 'catching up' policy like Spain, Portugal, Greece and Ireland, and more developed countries that want to increase or keep emphasis on R&D'.* (European Commission, 1997, p. 314)

Two outcomes of the human capital policy dimension are distinguished (Table 5.2).

If the public sector allocates more funds to R&D and education, then there will be an increase in BERD, GOVERD as well as HERD. This will increase *expansion demand* for RSEs in all three sectors. At the same time, it means that there will be more funds available to keep older RSEs employed, hence *replacement demand* will be lower in case of high human capital expenditure. The increase in R&D funds will, ceteris paribus, lead to an increase in the relative wage of RSEs to all S&T graduates. Hence, the *inflow* of RSEs will increase. There is also a long-term effect from the increase in education spending, since it will probably increase the future supply of S&T graduates. However, with only a five-year horizon only, this effect may be ignored here.

5.4 Quantification of scenarios

5.4.1 Growth rates of real GDP

The most recent OECD forecasts (OECD, 1998b) were used to assign specific numerical baseline values to 'high growth' and 'low growth' in the various Member States. The high and low growth rates were chosen at equal distances above and below the OECD projections. A bandwidth of 1.0 per cent (*ie* 0.5 per cent above and below the OECD projections), yields the high and low growth figures (Table A2.8). This bandwidth is in line with the expected impact of the crisis in emerging Asia on real GDP growth in the EU. This was put at –0.4 per cent for 1998 and –0.2 for 1999 in OECD, 1998a. It was also in line with the adjustment between May 1998 and December 1998 of the OECD projection for real GDP growth for the EU. (Because of the effects of the international financial turmoil, this was changed from 2.7 per cent to 2.2 per cent, an adjustment of 0.5 per cent.)

5.4.2 Growth rates of the ratio of R&D expenditure to GDP

The second issue was to assign numerical values to 'high human capital growth policy' and 'low human capital growth policy', making a distinction between R&D expenditure in the public sector (GOVERD and HERD) and R&D expenditure in the private sector (BERD). Constant growth rates of the GOVERD/GDP-ratio and the HERD/GDP-ratio were used during the forecasting period to focus on two different human capital policies: a low human capital growth policy and a high human capital growth policy. The low human capital growth policy freezes these ratios at the last observed level, *ie* a zero growth policy with respect to the share of public sector R&D expenditure in GDP). The high human capital growth policy focuses on the RSE labour market impact of a knowledge-intensive growth path, by setting the growth rate of the GOVERD/GDP-ratio and the HERD/GDP-ratio at their respective averages for the last five observed years (Table 5.3). An exception for the HERD/GDP-ratios of Greece and Spain was made, these were set at a half of the average growth rate of the last five years. At the very high average growth rate of the last few years, these countries would get implausibly high values for the level of HERD/GDP by the year 2002. In other words, we assume that the R&D 'catching up' policies of Greece and Spain in the higher education sector will be sustained in the next few years, albeit at a slower rate such that the R&D expenditure as a percentage of GDP will reach levels comparable to other European countries in 2002.

The effect of human capital policy on the growth rate of the ratio of BERD to GDP depends on the relative role of public financing versus private financing of business enterprise sector expenditure on R&D. In all Member States of the EU, the size of public financing of R&D expenditures in the business sector is modest. However, an aspect of stimulation measures is often to entail co-financing of R&D expenditure by the public and the private sector. Therefore, it is assumed that the amount of public financing of BERD is accompanied by an equal amount of private financing. Consequently, one can distinguish between private financing of BERD which is independent of public financing ('autonomous BERD') and private financing of BERD which takes place in the context of stimulation measures by the public sector. Therefore we can deconstruct R&D expenditure in the business

Table 5.3: Policy dimension: annual growth rates of government sector expenditures on R&D as percentages of GDP, 1998-2002

Country	Per cent	
	High	Low
Belgium	0.0	–7.8
Denmark	6.7	0.0
Germany	4.6	0.0
Greece	11.4	0.0
Spain	12.6	0.0
France	4.3	0.0
Ireland	1.2	0.0
Italy	0.0	–0.7
Netherlands	6.5	0.0
Austria	6.2	0.0
Portugal	13.8	0.0
Finland	8.5	0.0
Sweden	8.1	0.0
United Kingdom	4.3	0.0

Source: ROA, Annex 2 Table A2.9

enterprise sector in three parts, publicly-financed BERD, privately-financed BERD in the context of stimulation measures and autonomous BERD.

In both 'high human capital growth policy' and 'low human capital growth policy' the growth rate of the ratio of autonomous BERD to GDP is assumed to remain constant at the average of the last 5 observed years in the Member State. The effect of human capital policy on the business sector however, works via privatelyfinanced BERD/GDP in the context of stimulation measures and publicly financed BERD/GDP (Table 5.4).

In case of a low human capital growth policy, it is assumed, as in the case of GOVERD and HERD, that publicly financed BERD/GDP is frozen at the current level. Consequently, also privately financed BERD/GDP which takes place in the context of stimulation measures will be frozen at the current level. As a result, the growth rate of total R&D expenditure in the business enterprise sector as a percentage of GDP is below the average growth rate of the last 5 years. In fact, the growth of this percentage exclusively originates from autonomous R&D expenditure in the business enterprise sector.

As in the case of the public sector (GOVERD/GDP and HERD/GDP), it is assumed that a high human capital growth policy leads to a growth rate of publicly financed BERD/GDP

Table 5.4: Policy dimension: annual growth rates of higher education sector expenditures on R&D as percentages of GDP, 1998-2002

Country	Per cent	
	High	Low
Belgium	5.1	0.0
Denmark	10.0	0.0
Germany	4.7	0.0
Greece	16.8	0.0
Spain	13.7	0.0
France	9.1	0.0
Ireland	9.1	0.0
Italy	5.6	0.0
Netherlands	6.0	0.0
Austria	6.2	0.0
Portugal	5.3	0.0
Finland	9.5	0.0
Sweden	4.3	0.0
United Kingdom	8.0	0.0

Source: ROA, Annex 2 Table A2.10

identical to the average of the last 5 years. The same holds for the growth rate of privately financed BERD/GDP which takes place in the context of stimulation measures. In this case, the growth rate of BERD/GDP (as a whole) is identical to the average of the last 5 years. An exception was made for the BERD/GDP-ratios of Greece and Spain, which were set at a half of the average growth rate of the last 5 years, otherwise these countries would get implausibly high values for the level of BERD/GDP by the year 2002. A similar exception was already made for R&D expenditure as a percentage of GDP in the public sector in Greece and Spain.

An overview of the resulting growth rates for BERD/GDP during the forecasting period in the various EU Member States, both in case of ‘high’ and ‘low’ human capital growth policy, is presented in Table 5.5. Two interesting features emerge. Firstly, countries with business sectors which depend more on public financing of R&D expenditure show larger differences between high and low BERD/GDP growth rates (*eg* Greece, France and the United Kingdom). In other words, the business sector is considerably less affected by a contractive human capital policy than the government sector and the higher education sector. Secondly, in case of the ‘low’ human capital growth policy BERD/GDP growth rates increase over time. This is due to the fact that the share of privately funded BERD increases, as the level of publicly financed BERD is being frozen. Therefore, the BERD/GDP growth rate will

Table 5.5: Policy dimension: annual growth rates of business sector expenditures on R&D as percentages of GDP, 1998-2002

Country	1998		1999		2000		2001		2002	
	High	Low	High	Low	High	Low	High	Low	High	Low
Belgium	5.1	4.9	5.1	4.9	5.1	4.9	5.1	4.9	5.1	4.9
Denmark	10.0	7.4	10.0	7.5	10.0	7.7	10.0	7.9	10.0	8.0
Germany	4.7	4.0	4.7	4.0	4.7	4.0	4.7	4.1	4.7	4.1
Greece	16.8	9.2	16.8	9.9	16.8	10.5	16.8	11.1	16.8	11.7
Spain	13.7	10.3	13.7	10.6	13.7	10.9	13.7	11.2	13.7	11.4
France	9.1	5.3	9.1	5.5	9.1	5.7	9.1	5.9	9.1	6.1
Ireland	9.1	8.4	9.1	8.4	9.1	8.5	9.1	8.5	9.1	8.6
Italy	5.6	5.5	5.6	5.5	5.6	5.5	5.6	5.5	5.6	5.5
Netherlands	6.0	3.9	6.0	4.0	6.0	4.1	6.0	4.1	6.0	4.2
Austria	6.2	4.7	6.2	4.8	6.2	4.9	6.2	4.9	6.2	5.0
Portugal	5.3	4.8	5.3	4.8	5.3	4.8	5.3	4.8	5.3	4.9
Finland	9.5	8.0	9.5	8.1	9.5	8.2	9.5	8.3	9.5	8.4
Sweden	4.3	3.4	4.3	3.4	4.3	3.4	4.3	3.4	4.3	3.5
United Kingdom	8.0	3.9	8.0	4.0	8.0	4.2	8.0	4.3	8.0	4.5

Source: ROA, Annex 2 Table A2.11

in the course of years move towards the growth rate of the ratio of autonomous BERD to GDP.

In Section 5.3, 4 scenarios were formulated for the labour markets for RSEs in the Member States of the EU. These were quantified in Section 5.4, by assigning specific values for the growth rates of real GDP (the exogenous dimension) and the growth rates of the ratio of sectoral R&D expenditure to real GDP (the policy dimension). In order to make forecasts, the scenarios then have to be translated in terms of the 3 modules of the forecasting model: expansion demand, replacement demand and labour market inflow of new RSEs. For a detailed discussion on the implementation of the scenarios in the labour market forecasting model (see Annex 2).

5.5 Forecasts for the EU and potential adjustment mechanisms

The forecasts for the demand and supply side of the labour markets for the natural sciences, and for technology and engineering are given in Tables 5.6 and 5.7. (Further details of the other disciplines and the individual countries are given in Annex 2, Tables A2.14-A2.73.)

Table 5.6: Forecasts for EU labour market for the natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	461,500	776,700	1,199,600
High GDP growth low human capital	481,700	752,700	1,199,600
Low GDP growth high human capital	608,500	870,100	1,199,600
High GDP growth high human capital	640,200	849,000	1,199,600

Source: ROA Annex 2 Table A2.14 Aggregate forecasts

Each row of the table corresponds with one of the 4 scenarios. In each row the three key numbers in assessing the quantitative adequacy of the education system of the Member State are given. The first column ('job openings for RSEs') is the number of job openings (head-counts, not full-time equivalents) for RSEs in this field of study between 1997 and 2002. The second column ('inflow of new RSEs') gives the forecast supply of new RSEs in this field of study. The third column ('flow of new S&T graduates') displays the number of new S&T graduates in this field of study.

The difference between the second and the third column can be explained as follows. The types of jobs that a S&T graduate can apply for can roughly be classified in 2 categories: RSE-jobs and non-RSE jobs. Not every S&T graduate has the abilities or ambitions to get an RSE-job. On this point, moreover, there are large differences between the fields of study distinguished as noted in Chapter 3. For an assessment of the quantitative adequacy of the education system to produce sufficient numbers of new RSEs, obviously only the fraction of new S&T graduates that will apply for RSE-jobs is relevant. This can be done by comparing the first column ('job openings for RSEs') and the second column ('inflow of new RSEs'). However, the third column ('flow of new S&T graduates') provides additional information on the **potential pool of graduates** that can be attracted to RSE jobs under different wages and other job characteristics. Of course, there will always be considerable numbers of 'competitive' non-RSE jobs for S&T-graduates outside the R&D-sector, as noted in Chapter 2 and Chapter 4. Therefore, it is unrealistic to consider a large increase of the percentage of S&T graduates that applies for an RSE job as an easy option.

Table 5.7: Forecasts for EU labour market for technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	341,600	800,700	2,306,700
High GDP growth low human capital	356,600	776,000	2,306,700
Low GDP growth high human capital	449,800	915,900	2,306,700
High GDP growth high human capital	473,100	888,500	2,306,700

Source: ROA Annex 2 Table A2.15 Aggregate forecasts

In each of the fields of study, the forecast inflow of new RSEs exceeds the number of job openings for RSEs, no matter which scenario will unfold between 1997 and 2002. In other words, under perfect labour mobility within the European Union, the higher education systems of the Member States produce adequate numbers of S&T graduates to meet the demand for new RSEs to 2002. There are however country differences (Section 5.6).

5.5.1 Potential adjustment mechanisms

These forecasts should be interpreted, however, as ex-ante forecasts. In practice, labour markets will exhibit adjustment processes that will bring the difference between labour demand and supply down as detailed in Chapters 1 and 4. This does not mean that there will be no ex-post shortages. It also does not mean that ex-ante shortages matter less: adjustment processes may require high costs. Adjustment processes may take place within the labour market for RSEs of a specific field of study, between labour markets for RSEs with different fields of study, between firms and sectors, and between labour markets for RSEs in different countries. Such adjustment processes are considered in turn. Two particular forms of adjustment are now considered in relation to the modelling exercise.

An important adjustment process on the **demand side** of the labour market for RSEs with a specific field of study is the time spent by RSEs on non-R&D tasks. The ratio of headcount to full-time-equivalent indicates the scope for a reduction of the time spent on R&D. Such a reduction would require a reorganisation of R&D and non-R&D tasks, such that activities which specifically require, for example, natural scientists, are performed by natural scientists. Workers with other qualifications (lower level of education or other field of study) can be recruited to perform the non-R&D tasks. This adjustment process is particularly relevant for the higher education sector where a considerable part of the working time is spent on teaching. Another example of this adjustment process can be found in the IT sector, where academically trained IT-graduates focus on tasks which require a thorough academic background in information technology, while workers which have other educational backgrounds perform activities which require less formal training. When the ex-ante shortage is not too large, this adjustment process may reduce the number of job openings in the ex-post situation to match the level of RSE inflow. A closely related adjustment process is an increase in total working hours, by stimulating overtime of qualified RSEs. Other adjustment strategies that employers may follow to reduce shortages include the use of lesser-qualified staff, substituting physical capital for human capital, or subcontracting, relocating or even reducing R&D activities, as noted in Chapter 4.6 (see also Borghans, de Grip and Van Smoorenburg, 1998).

Adjustment processes may also take place on the **supply side.** When the ratio of RSE inflow to total flow of S&T graduates is relatively small, there may be a hidden potential of S&T graduates who do not yet apply for RSE jobs in the ex-ante situation, but who may decide to do so in the ex-post situation. Motives may be the good employment opportunities as an RSE or changing job preferences induced by for example, promotional campaigns or deterioration in the alternative opportunities. Higher relative wages and improved conditions may also be used to attract more RSEs. An additional pool of S&T graduates from which new RSEs may be recruited is the unemployed. However, according to the labour queue theory (Thurow, 1972), a longer duration of unemployment, on average implies a lower quality and loss of skills. Hence, some supply side adjustments may be accompanied by a loss in quality and productivity.

Adjustments may also occur **between labour markets for those with different fields of study**. As noted in earlier chapters, S&Ts are not homogenous can be overlapping skill and knowledge sets. For example, a shortage of chemistry RSEs (natural scientists) may be alleviated by an excess supply of chemical engineering RSEs (technology and engineering). From the demand side, this may some reorganisation of the R&D tasks of natural scientists and on the supply side, it implies that graduates are willing outside their field of study.

Another adjustment process is **international labour mobility**. A shortage of natural scientists in one Member State may be reduced by an excess supply of natural scientists from another. In practice, however, there often are various barriers to mobility such as mutual recognition of qualifications and experience, geographical distance, differences in language and culture and fiscal differences. On the other hand, within-company mobility may facilitate international mobility. Incentives for international migration are differences in wages and benefits. After the full introduction of the Euro the lack of transparency of the real wage differentials will decrease, which will probably further facilitate international mobility. To date, however, international mobility among scientists and technologists has not been great (see, *eg* para 2.7, Court, 1995d, Mauhoum, 1999).

5.6 Forecasts for the Member States

The forecasts suggest that there are three groups of countries with respect to the varying capacity of their national education systems to produce adequate numbers of S&T-graduates to meet the forecast demand for new RSEs.

5.6.1 Belgium, Finland, Greece, Spain, UK

These countries are not expected to have any problems up to 2002 under any of the scenarios for the **natural sciences**, or **engineering and technology** (Table A2.18; Table A2.30; Table A2.34; Table A2.62; Table A2.70).

5.6.2 France and Portugal

France is expected to face shortages of **natural science RSEs** in the case of a high human capital growth policy, if no supply/demand adjustments are made. However, since the ratio of inflow to job openings is relatively large (0.96 in the case of low GDP growth and 0.88 in the case of high GDP growth), adjustments on the demand side of the labour market which reduce the average time spent by natural science RSEs on non-R&D tasks by four per cent, would shrink the number of job openings to match the RSE inflow. In addition, on the supply side of the labour market for technology and engineering RSEs, a large excess inflow is forecast, which could also contribute to solving the shortages of natural science RSEs. Hence, the ex-ante shortages will probably not materialise in ex-post shortages, due to adjustment processes on the demand and the supply side. No problems are expected for **engineering and technology RSEs** (Table A2.38).

Portugal is expected to face shortages of **natural science RSEs** in the case of a high human capital growth policy if no supply/ demand adjustments are made. The ratio of inflow to job openings is 0.95 in case of low GDP growth and 0.89 in case of high GDP growth. This means that an average reduction of 5 per cent and 11 per cent respectively of non-R&D activities performed by natural science RSEs could bring the number of job openings down to the level of RSE inflow. An increase in overtime is probably also an effective instrument to accomplish a balanced labour market. The excess inflow of **technology and engineering RSEs** may also contribute to alleviating the manpower problems with natural science RSEs. So the shortages of natural science RSEs in Portugal should be manageable. Under the high GDP growth — high human capital growth scenario, Portugal is also expected to experience shortages of medical science RSEs in the absence of any adjustment mechanisms as detailed in Annex 2 (Table A2.58).

5.6.3 Austria, Denmark, Germany, Ireland, Italy, Netherlands, Sweden

This third group of Member States is expected to face shortages under all 4 scenarios if no supply/demand adjustments are made.

Austria is expected to have the largest problem with **natural science RSEs** occurs under the high GDP growth — high human capital growth scenario. The ratio of the inflow of new RSEs

(8,100) to the job openings for RSEs (9,300) is 0.87. This means that a 13 per cent reduction of the time spent on non-R&D-activities by natural science RSEs would reduce labour demand enough to eliminate the shortages. In addition, there is an excess supply of technology and engineering RSEs, which could also be recruited to solve the shortages of natural science RSEs. Therefore, the problems for natural science RSEs should be manageable. Shortages for medical science RSEs are expected to be more serious, the details are presented in Annex 2. No problems are expected for **engineering and technology RSEs** (Table A2.54).

Denmark is expected to experience shortages of **natural science RSEs** under all scenarios. Even if the public expenditure on R&D is frozen at the current fraction of GDP, the expected rate of GDP growth will drive up the absolute level of R&D expenditure at a rate that causes demand for natural scientists to rise too fast for the inflow of new RSEs from the education system to keep up. The number of job openings is even larger than the total flow of new S&T graduates, so job choice adjustments in favour of the RSE jobs will not be able to meet the excess demand. There is also only limited room for adjustment on the demand side, on average a mere 7 per cent of the working hours of natural science RSEs are spent on non-R&D tasks. At the same time, considerable excess supplies of **technology and engineering RSEs** are forecast. The Danish forecasts for the high GDP growth-high human capital growth scenario yield the largest shortage for natural science RSEs: 3,800. However, the excess supply of technology and engineering RSEs under this scenario is 9,900. Consequently, if about 40 per cent of this excess inflow can be recruited to meet the demands for natural scientists, then the shortage of natural scientists would be eliminated. Probably, this entails a reorganisation of tasks between natural science RSEs with an educational background in natural sciences, and natural science RSEs with a technology and engineering background. However, using more than a third of the excess supply of technology and engineering RSEs to fill natural science RSE jobs would also probably be very difficult. So for Denmark, the ex-ante shortages of natural science RSEs are expected to materialise in problematic ex-post shortages under all scenarios (Table A2.22). An inflow of natural science RSEs from abroad may be a solution to this problem. International labour mobility is discussed separately below.

Germany is expected to face a shortage of **natural science RSEs** under all scenarios. Even if natural science RSEs would perform R&D-activities full-time, which is very unlikely, the number of job openings would still exceed the RSE inflow. Even under the high GDP growth-low human capital growth scenario, which is expected to yield the smallest discrepancy, such a reduction of non-R&D tasks would bring down the job openings to 121,400. This leaves a shortage of 9,900. At the same time, under this scenario, an excess supply of 30,500 technology and engineering

RSEs is forecast. This could also contribute to alleviating the problems for natural science RSEs, although a full elimination of the shortage of natural science RSEs seems unlikely. In the 2 scenarios with a high human capital growth policy, the problems are more severe. The number of job openings for natural science RSEs even exceeds the total flow of new S&T graduates. At the same time the excess supply of technology and engineering RSEs is smaller and offers therefore fewer opportunities for substitution. In these two scenarios there is also expected to be a shortage of medical science RSEs as detailed in Annex 2. An inflow of foreign natural science RSEs would help minimise problems. No problems are expected for **engineering and technology RSEs** (Tables A2.26).

In **Ireland**, the only forecast shortages are of medical science RSEs as detailed in Annex 2. However, there is also an excess supply of technology and engineering RSEs that could potentially contribute to reducing these problems. No problems are expected for **natural sciences RSEs,** and **engineering and technology RSEs** (Tables A2.42).

Italy is also forecast to experience limited shortages of medical science RSEs under all scenarios, again details are presented in Annex 2. No problems are expected for **natural science RSEs** and **engineering and technology RSEs** (Tables A2.46).

The forecasts for the **Netherlands** indicate shortages for **natural sciences RSEs** under all four scenarios. The recruitment problems for natural sciences are expected to be serious because the number of job openings even by far exceed the total number of S&T graduates. The ratio of inflow to job openings varies between 0.31 and 0.40, depending on the scenario. This means that a reduction of hours spent by natural science RSEs on non-R&D tasks will not be an effective instrument to achieve labour market equilibrium. The excess supplies of **technology and engineering RSEs** can also only make a modest contribution to alleviating the recruitment problems for natural science RSEs (Table A2.50).

For **Sweden**, shortages are expected in all fields of study under all scenarios. However, in Sweden there is considerable room for adjustment on both the demand and the supply sides to solve the expected recruitment problems. For **natural science RSEs**, **technology and engineering RSEs** the ratios of inflow to job openings are relatively small. For example, under the high GDP growth, low human capital growth scenario, these ratios are 0.92 and 0.95 respectively. This means a reduction of five per cent to 19 per cent of non-R&D activities by natural science RSEs, and technology and engineering RSEs respectively would bring down the numbers of job openings to match the inflow of RSEs. An increase in overtime may also be an effective instrument to solve the recruitment problems (Table A2.66).

Table 5.8: Overview of expected RSE shortages and effectiveness of adjustment processes

Country	RSE shortages	Effectiveness of domestic adjustment processes	Possible sources of RSE inflow from other Member States
Belgium	none		
Denmark	natural sciences	Limited	Greece, Spain, Italy
Germany	natural sciences medical sciences	Limited sufficient	Greece, Spain, Italy
Greece	none		
Spain	none		
France	natural sciences	Sufficient	
Ireland	medical sciences only	Limited	United Kingdom
Italy	medical sciences only	Sufficient	
Netherlands	natural sciences medical sciences	Limited limited	Greece, Spain, Italy France
Austria	natural sciences medical sciences	Sufficient limited	France
Portugal	natural sciences		
Finland	none		
Sweden	natural sciences technology & engineering medical sciences agricultural sciences	Sufficient sufficient sufficient sufficient	
United Kingdom	none		

Source: ROA, Annex 2 – includes analysis for medical sciences, and agricultural sciences.

5.7 Summary of forecasts for science and technology RSEs

The forecasts can be summarised as follows (Table 5.8). **Belgium, Finland, Greece, Ireland, Italy, Spain** and the **United Kingdom** are not expected to face any shortages of **natural sciences**, and **engineering and technology** RSEs. **France, Portugal** may face some shortages under a high human capital growth policy, but these problems are mild and should be manageable by adjustment processes. For **Sweden**, shortages of RSEs are expected in all fields in all scenarios including the natural sciences, and technology and engineering, but they could be solved by adjustments on the demand side. For **Austria**, shortages of natural science RSEs are less severe due to adequate adjustment opportunities. The forecasts for **Germany** indicate serious shortages of natural science RSEs. **Denmark** is expected to have serious shortages of natural science RSEs under all scenarios. For the **Netherlands**, considerable shortages of natural science RSEs are also expected.

5.7.1 The potential of international mobility

In the discussion of the forecasts so far, the focus has been on the ability of the labour markets of the Member States to reduce the expected shortages, if any, by adjustment processes on the demand side and the supply side with the national labour market. However, not all countries may be able to deal with the RSE problems themselves, specifically, Austria, Denmark, Germany and the Netherlands. International labour mobility also, however, offers the potential to reduce imbalances as it has been seen that there are no forecast shortages expected for the European Union as a whole. For such mobility to work would require not only wage differentials to be in the favour of recipient countries but also other cultural and social barriers to be minimal. If this was the case, then the shortage of natural science RSEs in Germany could be reduced if there was mobility from countries such as Greece, Spain and Italy which have considerable excess supplies of graduates with the required educational backgrounds to fill the job openings. These countries could also contribute to solving the shortages for natural science RSEs in Denmark and the Netherlands.

Of course, international labour mobility is not only important in case of the inability of certain Member States to solve their own RSE problems. It may also be a cheaper alternative to costly intra-national adjustment processes in a Member State facing shortages of RSEs. For example, while Sweden is expected to face mild shortages in all fields of study, Finland has excess supplies in all fields. Since Sweden and Finland are neighbouring countries, and the fact that many Finnish people have a good grasp of the Swedish language, the mobility of Finnish RSEs to Sweden would be an answer to the shortages in Sweden, without the costs associated with intra-national adjustment processes (Table 5.5).

5.8 Conclusion

This chapter described a pilot forecasting system, which tracks the relevant flows entering and leaving the labour market for RSEs up to 2002. The main problems in the development of the forecasting model were the limited availability of relevant data on RSEs and the often poor quality of the data that were available. As a result, the empirical foundation of the model showed gaps. Some of the gaps were filled in by the *IES Survey of R&D Establishments*, while other gaps had to be closed on the basis of assumptions and approximations. It is therefore important that the results are treated with caution. In fact, it is essential for any future modelling of the labour market for RSEs in the European Union, that the availability and quality of data on RSEs is improved as suggested in Chapter 6 and Annex 2. Finally, it is important to note that the forecasts are of a quantitative nature, and take no account of quality issues.

The forecasts show that for the European Union as a whole, the forecast inflow of new RSEs exceeds the number of job openings for RSEs, in the fields of study distinguished, no matter which scenario unfolds between 1997 and 2002. In other words, under perfect labour mobility within the European Union, the higher education systems of the Member States produce adequate numbers of S&T graduates to meet the demand for new RSEs to 2002. This implies that as far as the adjustment processes of the national labour markets for RSEs are unable to eliminate the shortages, inflow of RSEs from other Member States of the EU could balance RSE demand and supply in the country which faces a shortage.

However, the forecasts do indicate some potential shortages of RSEs in individual Member States. The forecasts for Austria, Denmark, Germany and the Netherlands indicate shortages of **natural science RSEs**. In general, there is much less likely to be a problem with respect to **technology and engineering RSEs** in all countries.

These forecasts are to some extent matched by countries in which considerable excess supplies of natural science RSEs are expected, Greece, Italy and Spain. If the specific skills of the RSEs in excess supply match the needs of the shortage countries then international mobility would reduce the discrepancy between demand and supply on the labour markets for RSEs in both countries. In fact, this even holds for countries that could achieve equilibrium on the labour market for RSEs without inflow from other countries. These pilot forecasts have explored the possibilities of quantifying the labour markets for research scientists and engineers in the European Union, in particular with the aim of assessing the adequacy of the education systems relative to S&T employment needs. Tentative policy conclusions aimed at an increase of international labour mobility of R&D personnel between EU Member States can be drawn from this study. However, the pilot model revealed the limitations of the currently available data and suggested interesting topics for further research on the labour market for R&D workers. This is of crucial importance for the knowledge-based economy of the next century, and is considered further in the Conclusions of Chapter 6.

6. Summary, Conclusions and Recommendations

6.1 Introduction

It is widely recognised that Europe needs a strong science and technology (S&T) base to ensure its long term economic growth and international competitiveness. Its strengths, weaknesses and the potential of Europe in relation to its global competitors have been extensively documented and analysed in the *Second European Report on S&T Indicators, 1997* (EC, 1997). Skilled and qualified scientists and technologists (S&Ts) play a key role in the innovation process and supporting the development and application of science and technology. As such shortages of appropriate skills can act as a significant constraint on economic development and prosperity.

This report reviews the evidence that exists on the supply and demand for professional scientists and technologists (S&Ts) and the extent to which there is an adequate supply of suitable people with such skills as perceived by employers. It was recognised at the outset that it is inherently difficult to assess current, far less forecast, demand and supply trends for scientists and technologists because of the wide range of factors that influence them. The position is exacerbated at a European level because of the diversity between countries. The report also highlights the paucity of relevant national and international data that made this study particularly challenging. Such issues need to be borne in mind when reading the report and drawing conclusions.

6.2 Research approach

The study comprised a series of research components:

- a detailed review of the literature: over 450 reference documents are included in the bibliography, and more were identified which were of partial relevance to the study
- a detailed review of national and international sources, covering national governments, training and employer bodies in the EU countries, and the key international organisations (Eurostat, OECD, UNESCO, ILO)

- contact with over 100 international and national experts in all the EU countries
- questionnaire results 210 R&D establishments from across Europe about their recruitment and employment of S&Ts, plus a small number of follow up employer interviews
- a pilot econometric modelling exercise designed to assess quantitative adequacy of supply from higher education in relation to demand covering 14 EU countries up to year 2002
- regular dialogue with DGX11 and Eurostat
- preparation of reports, including two interim reports and this final report.

The detailed work was undertaken over the period 1997-98 focusing on recent and current developments and trends[1].

6.3 The notion of adequacy

The term 'adequacy' can have various meanings. For the purposes of this study it was defined as follows:

> Adequacy was defined to mean 'the extent to which higher education supply of S&Ts meets the articulated needs of employers in the EU in current labour market circumstances'.

It thus included a *quantitative* dimension, *ie* are there enough S&Ts to meet employer demand?, and a *qualitative* one , *ie* are they of the kind employers require?

Adequacy is conditioned by a range of influences. Those affecting the demand for S&T skills include economic, technological and organisational factors, with some of the decisions being taken by multinationals either based outside of Europe or which take a global perspective on their R&D. National and European policies and activities (*eg* support for R&D), were further influences on the employer demand. Supply side factors include demographic and social trends, the choices individuals make towards education, development and career choice, and the provision and priorities of countries' education and training providers and funders. A third area of influence on adequacy is the way S&T skills are used in the workplace, and a fourth is the efficiency of the labour market in matching people, their skills and the available work. In practice, many of the factors are inter-related.

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[1] However, because of time lags in the collation and publication of international and national datasets and research findings, some of the available information used related more to the early and mid rather than the late 1990s.

6.4 Measuring adequacy in relation to scientists and technologists

Adequacy can potentially be measured by a number of indicators such as rapidly rising salaries, unemployment, hard to fill vacancies and evidence of employers experiencing recruitment difficulties.

In the course of the study it became apparent that there were few data on any of the above indicators at a detailed level relating to scientists and technologists. Many of those that supposedly existed were found to lack validity.[1] This was because either the data were non-existent at the required disaggregated level, were too patchy, *eg* only for some countries, or were for certain kinds of S&Ts. Furthermore, it is often collected in different, unharmonised ways that do not allow anything other than broad generalisations to be made. The picture is further confused by a number of highly publicised, *ad hoc* studies, *eg* on the demand for IT specialists, with differences in scope and definition, often using poor survey methods and which are sometimes undertaken for 'lobbying' purposes to get more government resources spent on their sector, rather than as high quality independent research.

The best data was that relating to the supply of graduates[2] leaving higher education, and that relating to the employment of research scientists and technologists (RSEs).[3] There were, however, significant variations between countries in the methods used to monitor the flow of graduates into employment. There was little data specifically on demand for scientists and technologists in aggregate, let alone in terms of detailed occupations, and little on trends. Thus, the available data could only give a partial perspective of the diverse and segmented European labour market for scientists and technologists. Recommendations as to the types of data that might be collected in the future are set out in Section 6.10.

6.5 The employment of scientists and technologists in Europe

The European market for S&Ts is not homogeneous and is fast changing. It is segmented by country and locality, by sector and discipline, and by occupation. Within the main sectors of business

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[1] It was recognised at the outset that this is an area where existing data sources are limited. A survey was therefore undertaken of 1,000 R&D establishments across Europe to supplement existing datasets.

[2] Defined as those educated at ISCED level 5 or higher.

[3] RSEs are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, and in the management of the projects concerned (OECD, 1994a).

enterprise, government and higher education, there are also variations by sub-sectors (*eg* engineering, pharmaceuticals, IT) and types of businesses (*eg* large/small enterprises; R&D, manufacturing, and service based enterprises). Given the (poor) availability of data, the population of scientists and technologists can best be considered in terms of the numbers of **graduates** and in terms of the smaller group of **Research, Scientists and Engineers, RSEs** as defined above.

Employer[1] demand is influenced by both short- and longer-term factors which affect countries differentially. These include national and international economic climate, the historical industrial base of a country, its rate of development, and structural changes, *eg* the contrast between fast developing economies of Ireland and Spain, and the more mature economies of Germany and Sweden; the balance between the public and private sectors, *eg* the contrast between France and the UK; levels of inward investment, *eg* as in France, Ireland and the UK; national and, to a lesser extent, regional social and cultural trends, *eg* the north and south of Italy; and national and European policies on education and industry. As such, there was considerable diversity between countries and between sectors and disciplines. Some general characteristics and trends in relation to scientists and technologists were, however, identifiable as follows:

- There are over 28.5 million **graduates** employed and aged 25-59 in the EU, they account for 19 per cent of the employed population. The largest numbers were in Germany (9.3 million), the UK (6.5m) and France (5.2m). The highest densities were in Belgium, Denmark and Sweden, all over 25 per cent; the lowest were in Austria and Italy, both under 10 per cent of the relevant population.
- There were just over 800,000 **RSEs** in 1995, the number had grown from just over 500,000 in a decade. The largest numbers were again in Germany, France and the UK, they accounted for almost two-thirds of the EU total. RSEs account for a growing proportion of those engaged in research and development.
- A **broadening of the science and technology labour market** with relatively less employed in the large firms and the public sector, and a growth in the services sector employment and small firms.
- A **continuing growth** in overall demand for graduate level occupations, with particularly fast growth for IT specialists, and less growth for life scientists.
- A low level of **female RSEs** in the R&D establishments surveyed, one in five on average, though this was slightly

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[1] Employer here includes organisations from all sectors, including the public sector and higher education.

higher in the HE sector, and in some countries, notably, Finland, Ireland, Italy and Spain.

- A lower incidence of **PhD qualified RSEs** in the business sector R&D establishments surveyed, and in some countries, *eg* Finland and Sweden.
- A growth in requirements by employers for **specific technical skills**, reflecting mainly changes in IT and communications technology, and in the development of new materials and biotechnology. There is also a continuing need for a general level of scientific and research skills among graduates.
- Employers increasingly require RSEs to have **both good technical skills and good personal skills** such as in communication, adaptability, problem-solving and business awareness.
- Employers use a wide range of **recruitment sources** but still mostly recruit from within their own countries.
- There was no evidence of significant net **outflows** from the EU to other countries.

6.6 The supply of scientists and technologists

There is great diversity of educational provision across Europe, including different student participation rates; the content, structure and length of courses in higher education; the level of autonomy and state control; and the responsiveness of higher education to the needs of industry. Furthermore, many parts of higher education are in a state of change and flux. This affects the levels and pattern of graduate output.

A key determinant of the supply of scientists and technologist is the pattern of science education in schools which is not only the foundation for subsequent study, but also influences choice of subjects and careers.

- Patterns of **attainment in maths and science** at the ages of 13 and 14 vary greatly between countries with the more developed countries tending to score better.

The main features of the supply of scientists and technologists newly graduating from higher education were as follows:

- Higher education has **expanded** significantly in most EU countries over the last decade, resulting from increased participation rates, increasing attainment levels of traditional entry cohorts and policies to widen access to non-traditional students, particularly among older age groups.
- While increased numbers have been entering higher education, **drop out rates** can be high, over 50 per cent in Italy and Portugal but with a low of under 20 per cent in the UK.

- The numbers **graduating** have grown dramatically in most countries over the last decade, with particular growth in France, Ireland and the UK where numbers graduating each year have nearly trebled. Ireland, Finland and the UK have the highest numbers graduating relative to population size, Austria, Greece, Italy and Portugal the lowest.
- **Women** now account for more than half of those graduating in most countries.
- The proportions graduating in **science and technology** subjects varies greatly between countries, *eg* from four to 18 per cent in the case of the natural sciences. Ireland and France have the largest shares of natural scientists, and eight to 24 per cent in the case of engineering. Germany, Finland and Denmark have the largest shares of engineering and technologists. Some of the apparent differences, however, relate to definitional issues.
- There is also great variation between countries in the **flexibility** of links between occupational destinations and graduates' fields of study. For example, a large proportion of 'graduate jobs' is open to graduates of any discipline in Ireland and the UK. Many scientists and technologists therefore enter non-scientific and technological occupations such as finance and marketing. In many other countries, there is a strong relationship between subject and occupation.
- Overall in many European countries, there has been a lengthening in the process of initial **job search** and career choice for newly qualifying graduates.
- Initial unemployment rates vary with the economic cycle. Ten per cent or more are still **unemployed** 6 months after graduation. IT specialists find it easiest to find employment, among the other S&T disciplines there are wide variations between countries.

6.7 The adequacy of supply to meet employer demand

The pace of economic and technological change is such that no one can forecast the future with any certainty. Nevertheless individuals, education and training providers, employers across all sectors, and policy makers at local, regional national and European level have to make assumptions when making choices and investments in relation education, training and employment.

The evidence from this study suggests that the rate of change will accelerate and that the demand for science and technology will continue to develop and fragment. There will be a growing emphasis on the need for scientists and technologists to have good 'personal' skills in areas such as teamworking, project management, communications and commercial awareness, alongside their scientific skills and competencies.

Although there were problems of measuring the true level of adequacy, there was no widespread evidence to suggest that there is an inadequate overall supply of scientists and technologists to meet employers' needs in quantitative terms. Although there were claims about current or impending labour or skill shortages in scientific or technical occupational areas, there was little reliable data to support them. Some of the recruitment problems reported did not necessarily relate to a shortage but to the unattractiveness of an employers 'offer' or an over-specificity of requirements.

There were, however, some specific problems identified and areas where the adequacy of supply appears to be more of a issue:

- In IT and communications, there has been a rapid expansion in demand across all sectors, which has been accelerated by the greater use of the internet and telecoms, and the impact of the Euro and the 'millennium bug' problems. The scale of the shortage problem is difficult to assess because of a lack of reliable data but it does not affect all countries.
- Problems for R&D employers who seek people who are good both technically and in their personal skills. Particular recruitment difficulties related to technically competent S&Ts who also had leadership, problem-solving and project management skills.
- More recruitment problems for HE and government R&D centres than business enterprises, especially in recruiting experienced RSEs. The main cause is suggested to be salary differentials and career opportunities.

The pilot econometric modelling exercise took an aggregate numerical approach to assessing needs in very broad occupational groups. It suggested that, taking Europe as a whole, the supply of natural scientists and of engineers and technologists was expected to exceed employer needs. This was true under a series of alternative scenarios relating to high and low economic growth and human capital investment. Problems were projected, however, at a national level in Denmark, Germany and the Netherlands under some of these scenarios over the period to 2002 as the demand exceeds supply for natural scientists unless significant adjustment labour market adjustments take place. One adjustment that could greatly alleviate these selective problems would be increased international mobility if the excess supply in countries such as Greece, Italy and Spain is of the right characteristics, and they move to the shortages countries. Few problems were forecast with respect to engineering and technology RSEs in all countries.

The current and future problems identified were relatively mild and not widespread. There was not significant evidence that they were significantly constraining, or might constrain, economic growth in Europe as a whole, nor in individual countries[1]. Even in IT, where problems appear to be the most severe, some were short-term relating to the Year 2000 problem and the introduction of the Euro, while the market was also beginning to adjust better, through for example, investment in training and education by employers.

6.8 Are there too many S&Ts?

While seeking evidence on adequacy in terms of shortages, it became apparent that a problem of the opposite kind also existed, an oversupply of S&T graduates for the available job openings. This was clearly seen in the data on first destinations of graduates in some countries. Here, unemployment among newly qualifying scientists and technologists has remained relatively high and many graduates have had problems in finding suitable jobs; a situation relatively unknown in previous decades. Evidence on the under-employment and under-utilisation of graduate was found in several countries, particularly relating to both engineers and life science graduates in Germany, Netherlands, Sweden and the UK, and at doctorate level including France. It is believed to be more widespread, but there is a lack of empirical research on this issue. The modelling work also forecast excesses of supply over demand in aggregate in many countries under certain scenarios, affecting both natural scientists, and engineering and technology RSEs.

Such an oversupply may be driven by a number of factors including inappropriate choices[2] (relative to employment prospects) by students when in education, or their choice not to pursue science and technology related careers; or a poor or inappropriate level of skills by these graduates; and/or a failure by employers to appreciate the potential of such people.

A particularly serious concern would be if the basic education and skill attainment of such people is so poor or lacking in relevance that they are unable easily to access retraining and training to upgrade their skills. If employers in the public and private sector lack awareness as to their availability or potential in the workplace, they may fail to take advantage of partially qualified people. Consequently, they may miss the opportunities to make

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[1] It should be noted that this study did not seek to address the hypothesis that employers are in a 'low skill equilibrium', and that if they had higher value-added business strategies then the demand for scientists and technologists would be higher. Then the availability of suitably qualified scientists might be an issue.

[2] This is not to argue that the only purpose of education is economic, there are many valid arguments in favour of the pursuit of knowledge as an end in itself.

efficiency gains or improvements in competitiveness through a better-educated workforce.

Finally, it may also simply reflect the slowness and time lags involved in adjusting the supply to reflect changing needs. Whatever the underlying reasons such a mismatch highlights a potentially wasted investment in science and technology and of human potential.

6.9 Labour market adjustment

The report has shown that there is unlikely to be a serious structural problem across Europe relating to the adequacy of the supply of scientists and technologists in relation to the demand as expressed by employers. There will, however, always be selective and short-term adjustment problems, as in IT at present, and for some organisations where the current extent of problems varies between countries and focuses largely on short term issues.

Market adjustments are constantly taking place both in supply and demand to alleviate imbalances, some are short term, *eg* changing salaries others more longer term, *eg* investing in training; changing attitudes towards S&T careers. However, while the extent, significance and speed of these adjustments is not known at a detailed level, they do vary between countries and organisations. IT skills supply in particular, is being improved by greater investment in training by companies and the continuing growth in the numbers on IT courses in higher education. At the same time there is an apparent oversupply of other skills in some areas of the life sciences and at doctorate level suggesting the need for better information to guide choices and to support adjustment processes. Improvements in the responsiveness of HE to industry's needs, especially the increased requirements for work-relevant skills, are also being made in many countries. They are being encouraged by industry, while governments are introducing reforms to improve the responsiveness of higher education provision to economic needs. Some organisations and countries are also benefiting from flows from other EU countries with an overall excess of supply.

The current under-employment of scientists and technologists is expected (from human capital theory at least) to reduce as firms find ways to exploit better the 'over-educated' graduates, especially if their core skills are adequate, and if wage differentials between graduates and non-graduates fall, and individuals make choices towards courses with better labour market prospects.

6.10 Improving flexibility and responsiveness

National and European policies aimed at knowledge-intensive economic growth should be accompanied by policies aimed at improving the skills base. As the pace of change accelerates, assessing future skill needs and developing appropriate policy responses becomes ever more problematic. This difficulty is being further compounded by potentially contradictory emphasis being placed on the need for both further specialisation, and at the same time for a multidisciplinary approach in science and technology. Other pressures include: the globalisation of research; the growing pattern of collaboration between organisations, between higher education and the private sector, and across national boundaries; and the consequent need for scientists and technologists to have both good scientific skills and good personal skills such as team working, communication skills and business awareness so they can work across traditional boundaries.

Forecasts of the kind produced for this report can only provide very broad indications of likely trends and possibilities under different scenarios. However, given the rapid rate and volatility of change, they are unable to be able to provide a sufficiently reliable and detailed guide to likely trends and needs. As such, consideration needs to be given to helping the different groups involved in the development and employment of scientists and technologists, to increase their awareness of and responsiveness to future trends and likely needs. It is inappropriate to provide a detailed list of actions for each of the relevant groupings as circumstances vary between the individual organisations, groupings across and within Member States. Some generic points can however be made as follows:

- **In Higher education** the need is for individual universities and institutions to build better contacts with employers in all sectors as well as other experts to better understand the changing needs of the work place in the 21st century. They need also need to develop their curricula and teaching methods to be better able to respond to these needs, both technical and 'personal'. This is not to argue that all courses should become more vocational in their orientation, rather course providers should be aware of trends and needs and to incorporate relevant elements in courses.
- **Universities and training institutions** also need to collaborate one with another, regionally, nationally and internationally to seek to better co-ordinate and focus provision and to seek to ensure extremes of oversupply or undersupply are avoided. The costs of equipment in some high-tech areas are such that students will only have access to the state of the art equipment if such collaboration takes place.
- **Employers** in all sectors need to better consider their long-term needs for skills, and to communicate these better to universities and other education and training institutions. They also need to ensure that they use the flexibility within their own organisations in areas such as wages, working conditions, training and retraining, and the use of scarce skills

to minimise their own problems and maximise their effectiveness. Greater attention is also needed to their overall strategies and practices towards the recruitment, employment and development of their staff.

- **Public policy and other institutions** need to encourage further investment in education and training and the development of improved information, to help focus the choices and activities of employers, universities and other education and training institutions, and careers advice for individuals. They also need to ensure that labour market and other barriers to the effective employment and utilisation of scientists and technologists are minimised, mobility and flexibility is encouraged and good practice is widely understood and implemented.
- **Individuals** need to make well-informed choices and to be aware of emerging trends and needs and the relative costs and benefits of alternative careers and education, training and employment strategies.

All this requires that the information base available to these groups is improved as considered below.

6.11 The need for better information

This study was focused largely on existing datasets. However, as has been shown in the report, it has had to piece together a picture from partial data from a number of sources, some of which are not harmonised well across countries, nor use similar definitions. Furthermore, the term adequacy is complex and it is not easy to find agreement on good measures that can be used.

While currently there is not a serious general problem relating to the availability of scientists and technologists, imbalances in the market exist. These can be costly to businesses, individuals and society, while ensuring a continuing supply of high quality S&T graduates relevant to the needs of employers is critical to the economic development of the EU.

If policy makers at international and national levels, education and training providers, employers, individuals and labour market practitioners are to make effective decisions and choices and adjust effectively to changing needs, better information should be regularly collected, analysed and disseminated to help them understand developing needs and issues.

It is **recommended** that better, harmonised information and indicators, be developed at a national and EU level, along with associated further research on:

- the factors shaping the flow of potential scientists and technologists into and out of higher education, the **'S&T pipeline'**
- the numbers **graduating** in different disciplines and at different levels
- **the first destinations** of new graduates in science and technology, in particular the harmonisation of data on initial unemployment levels, employment sectors and occupations for different subjects and qualification levels
- **employers** needs in science and technology by sector, qualification level and field of study, and their underlying causal factors and sensitivities
- **employers** interactions with education and training providers and their use of other adjustment processes including the adjustment of wages to meet emerging needs
- the **recruitment, employment and losses of RSEs** by employers, data collection here could draw from the experience of the survey piloted for this study
- the relative **employment, utilisation, substitution, under-employment and unemployment** of science and technology graduates with details of the subject and highest qualification obtained, and compared with non-graduates, and between graduates by S&T fields of study and qualification level
- the **earnings** and other employment benefits received by science and technology graduates and by non-graduates, and in particular the way employers use wages to signal needs and to facilitate labour market adjustment
- examples of **good practice** among employers, higher education, training providers and other agencies towards the training, development, employment and other means of adjustment towards the employment of scientists and technologists
- the **flows** of both newly qualified and experienced scientists and technologists between sectors, regions and countries, and into and out of the EU.

In this way, assessments of the supply, demand and utilisation of scientists and technologists can be monitored and widely understood.

This is an ambitious list, and a long-term and expensive task given the very serious challenges to be faced in reaching agreement between the different parties involved and national governments. They may all have different priorities for information collection and provision, and research. There are also major challenges in agreeing common terminologies and data harmonisation, while setting up new surveys will have major resource implications and may not be feasible. The new *Eurostat/OECD R&D survey* and improvements in the European wide *Labour Force Survey (LFS)* are steps in the right direction and further work on enhancing these sources would be beneficial. To make some improvements in the short term, consideration should also be given to focusing on improving other existing surveys. This may overcome the problems of small samples for scientists and technologists, and the need to identify subgroups of scientists and technologists, regions and sectors.

A significant first step would be to build on the research reported here and to complement the developments recommended above with the establishment up of an *S&T Skills Observatory*. This could co-ordinate inputs from experts in each Member State who in turn would draw off local information sources in a structured way. Such an *S&T Skills Observatory* could build on the foundation of this report and, by establishing a network of respondents in Member States, monitor trends across the EU countries, undertake comparative analysis, and prepare regular reports to the EU and national governments relating to supply, demand and adjustment issues and advise on future research and methodological needs.

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Annex 1: International Classifications, Statistical Sources and Survey of R&D Establishments

A1.1 Introduction

This annex covers three main areas:

- international statistical classifications.
- international statistical sources.
- the methodology of the *IES Survey of R&D Establishments.*

These are dealt with in turn.

A1.2 International statistical classifications

There is a range of international statistical classifications and definitions that have been used in this report, the most important definitions and sources are as follows.

The OECD Frascati Manual

This manual deals with the ways of measuring R&D expenditures and employment. All OECD countries and increasingly many others including Eastern European, Economies in Transition use the definitions and methodologies for measuring their R&D efforts. The main definitions of relevance to this report are:

Research Scientists and Engineers are professionals engaged in the conception or creation of new knowledge, products, processes, methods, and systems, and in the management of the project concerned.' OECD Frascati Manual paragraph 311 (OCED, 1994a).

The **Sectors** used are based on the System of National Accounts (UN, 1986), it has the following categories:

- Business enterprise
- Government
- Private not for profit
- Higher education
- Abroad.

For further details, see the Frascati Manual paragraph 141 and subsequent references.

The OECD Canberra Manual (OECD, 1995b)

This covers the reasons for, and approaches to the measurement of human resources in science and technology. The manual has been used as the basis for a pilot data collection exercise (Eurostat, 1997), but there remain problems with obtaining consistent data on the basis of these definitions. The main definitions are based on a combination of ISCED for an individual's educational attainment and ISCO for an individual's occupation as noted below. The main problem remains ISCO.

The International Standard Classification of Educational Diplomas (ISCED)

This is used to define an individual's educational attainment and was originally defined by UNESCO (UNESCO, 1976) and recently redefined (UNESCO, 1998). Since all the data used in this report had been collected using the old classification this continued to be used throughout. The main ISCED categories used in this report are as follows:

- ISCED level 5 — a third level qualification which is not an university degree
- ISCED level 6 — a university first degree or equivalent
- ISCED Level 7 — a university higher degree or equivalent.

The International Standard Classification of Occupations (ISCO)

This is used to define an individual's occupation and was defined by the International Labour Office (ILO) (ILO, 1968) and updated to ISCO-88 in (ILO, 1990a). It is used in the Eurostat Labour force Survey (LFS). Unfortunately, most of the national data is collected using national occupational classifications. In practice, the LFS data is often collected using national classifications and then converted to ISCO before transmission to Eurostat. It is known that this often causes minor inconsistencies, but usually at the aggregate level, such as 'professionals' the data is internationally comparable.

The International Labour Office (ILO)

This provides the definitions of economic activity, employment and unemployment (ILO, 1990b). They are used by Eurostat in the Labour Force Survey.

A1.3 International statistical sources

There is a range of relevant international statistical sources. The main ones used in this report are:

The **OECD MSTI (Main Science and Technology Indicators),** this has the full range of indicators from the Frascati Manual.

The **Eurostat Annual R&D statistics** report covers a subset of the Frascati data, but puts special emphasis on providing data at the regional level.

The **UOE (UNESCO/OECD/Eurostat) questionnaire** is a joint questionnaire developed on behalf of the three international organisations following the development of the *Canberra Manual*. It collects a range of data including the following items that are of relevance to this study:

- the number of students by level and subject
- the number of graduates by level and subject
- the number of teachers by level
- the number of non-national third level students and their countries of origin.

The **Labour Force Survey** is a Eurostat defined and co-ordinated series of nationally administered household sample surveys aimed at understanding the state of the national and regional labour markets within Europe. Data are available from Eurostat (Eurostat, 1999b) based on the survey including the following items:

- economic activity coded using ILO definitions
- level of highest qualification coded using ISCED
- occupation coded using ISCO
- age, gender, region of residence and other socio-economic variables.

A wide range of national sources was also used along with the results of individual research studies and surveys.

A1.4 The Survey of R&D Establishments

A1.4.1 Introduction

The *IES Survey of European R&D establishments* was developed to remedy some of limitations of the published statistical sources. The survey had two main objectives:

- to obtain representative data to allow modelling of the pattern of demand by R&D establishments for highly qualified personnel as detailed in Chapter 5 and Annex 2
- to obtain data on the qualitative aspects of the adequacy of the supply of scientists and technologists from higher education to meet employers demand for RSEs.

A1.4.2 The sample

At the outset, there was a need to construct a sample of R&D establishments for the survey that reflected the pattern of R&D establishments in terms of employment of Research Scientists and Engineers (RSEs).

Unfortunately, there were a series of problems that had to be addressed:

- there was no exhaustive list of R&D establishments
- there was no reliable estimate of the numbers of establishments or their average sizes
- there was no reliable estimate of the breakdown of the number of establishments by Business Enterprise, Government and Higher Education
- there were no reliable estimates of the breakdown of RSE employment by Business Enterprise sector.

This, in short, meant that no population data was available from which to create a stratified sample. This, in turn, made it necessary to build a sample based on:

- lists of establishments that have been involved with the EU Framework programmes
- lists of Establishments engaged in contract R&D
- a breakdown of the number of (FTE) Research Scientists and Engineers (RSEs) by institutional type (Business Enterprise, Government and Higher Education)
- informed estimates of the size of R&D establishments by institutional type
- partial data of R&D spend by principal sector within the Business enterprise sector.

The sample frame as thus constructed from lists of R&D establishments from the CORDIS database, supplemented where necessary by the World Research Database, as the sample universe. Establishments were selected from these sources in a random manner to meet a stratified sample design. The stratified sample was developed on the basis of the available data to ensure a reliable and as far as reasonably possible representative sample of R&D establishments.

A1.4.3 Sector distribution of the sample frame

In part, the stratified sample was based on the known data about the population, but it was also designed to take account of expected response biases and to over-sample the smaller EU countries.

There were data available on the numbers of FTE RSEs across the EU, broken down by institutional type, which was used as the starting point. An initial sample of 1,000 establishments was allocated between the EU countries and institutional sectors proportionally on that basis as in Table A1.1.

However, this initial sample design assumes that every R&D establishment is of the same size. It is known that this is not the case and that Business Enterprise establishments are in general smaller than those in Higher Education. It was also expected that this type of survey and the type of information requested would generate a relatively low response rate from Business Enterprise establishments, partly because the respondents would not consider the survey important and partly because some establishments would consider the information confidential, despite the confidentiality guarantees that may be offered.

To take account of the expected response rates and the differing size of establishments by institutional sector, the stratified sample

Table A1.1: Allocating the sample on the basis of FTE numbers of RSE

		Total	Business Enterprise	Government	Higher Education
Austria	A	13	6	1	6
Belgium	B	24	11	1	11
Denmark	DK	18	8	4	6
Finland	FIN	20	7	4	8
France	F	189	86	33	64
Germany	D	297	167	44	87
Greece	EL	10	2	2	6
Ireland	IRL	9	3	1	4
Italy	I	96	36	17	43
Netherlands	NL	39	15	9	14
Portugal	P	8	1	2	5
Spain	E	56	15	10	31
Sweden	S	38	20	3	15
United Kingdom	UK	181	111	18	41
Luxembourg	L	:	:	:	:
Total	**EU**	**998**	**488**	**149**	**341**

Source: IES/Eurostat

was reallocated by increasing the Business Enterprise sector numbers by 25 per cent and reducing the Higher Education sector numbers by 25 per cent.

It is also known that high technology employment is generally highly clustered, both geographically and in larger establishments (Jagger and Perryman, 1997). This, in turn, suggests that the R&D establishments in the larger countries are larger than those in the smaller countries. There was also a desire to over-sample the R&D establishments in the smaller countries so they did not become submerged in the data from the larger countries. For both of these reasons, it was decided to further reallocate the sample to over-sample the smaller countries. This over-sampling of the smaller countries was achieved by firstly assuming that the same number of establishments were to be sampled in each country and then taking the average of this and the previous distribution.

Specific high technology sectors within the Business Enterprise sector have been supported in the past by DGXII funding and are also considered of strategic importance. DGXII therefore requested that specific attention be paid to these sectors. This meant that it was decided to further stratify the sample within the Business Enterprise sector.

Unfortunately there are no equivalent data on the number of FTE RSEs by Business Enterprise sector, the only available data are on

Table A1.2: Breakdown of Business Enterprise R&D FTE employment, latest available year

	Aerospace	Computers /office machinery	Electronics/ comm-unications	Pharma-ceuticals	Chemicals	Motor vehicles	Total manu-facturing	Year
Austria	0	430	878	117	209	287	3,772	1989
Belgium	106	4	1,863	566	1,602	195	7,110	1988
Denmark	..	125	475	1,025	191	..	3,456	1991
Finland	..	..	1,792	..	..	..	4,334	1993
France	7,407	4,054	6,969	5,554	3,845	3,774	55,822	1993
Germany	7,575	8,453	26,081	5,238	11,646	15,480	132,326	1991
Greece	2	149	79	8	36	9	536	1988
Ireland	0	157	758	381	114	25	2,030	1991
Italy	2,546	2,299	6,749	2,721	1,899	1,573	23,668	1993
Netherlands	..	..	..	600	..	..	9,290	1989
Portugal	0	..	59	..	46	..	211	1990
Spain	543	322	1,726	1,203	717	577	8,084	1993
Sweden	..	628	3,562	1,884	438	1,550	12,017	1991
UK	7,000	3,000	8,000	9,000	7,000	5,000	64,000**	1993*
EU	**25,179**	**19,621**	**58,991**	**218,627**	**27,743**	**28,470**	**326,656**	

Notes: .. indicates data not available or suppressed to maintain data confidentiality
** data from national sources (CSO, 1995) presented in thousands, ** subject to error due to rounding*
Source: IES, CSO and Eurostat 1996

total R&D FTE employment by sector (see Table A1.2). There was an additional problem with this sectoral R&D data in that for many countries (especially the smaller countries) data for specific sectors are missing or (more usually) are suppressed because of the need to maintain confidentiality.

A particular problem here was that critical sectors either had missing data or suppressed data, which meant that they could not be used to allocate the sample by sector. However, there are EU level estimates of the R&D spend by sector which, along with the country totals, allowed the missing data to be imputed with a fair degree of reliability. These various manipulations generated the distribution given in Figure A1.3. This distribution was the basis for selecting the sample on a quota basis from the CORDIS RTD-Projects database.

A1.4.4 The survey response

A total of 1,021 questionnaires were mailed out with international business reply paid envelopes during June 1997, after two reminders a total of 210 responses were obtained. This represents an overall response rate of 20.6 per cent, this is a low response for surveys of this type conducted in one country, however it is comparable with other postal surveys carried out across the EU. The response varied greatly from 11 per cent for France to 34 per

Table A1.3: Final BE sample based on imputations for missing and suppressed data

		Total Business Enterprise	Aerospace	Electrical/ onic	Office machinery & Computers	Pharma-ceuticals	Other manufac-turing	Non-manufac-turing
Austria	A	25	0	7	1	1	14	1
Belgium	B	29	1	7	2	3	14	2
Denmark	DK	24	0	2	0	4	10	8
Finland	FIN	21	0	8	3	0	7	3
France	F	74	11	10	2	8	34	8
Germany	D	128	10	31	6	7	67	6
Greece	EL	9	0	2	0	0	4	4
Ireland	IRL	21	0	5	2	4	8	3
Italy	I	40	4	9	2	5	14	6
Netherlands	NL	27	3	10	0	0	10	4
Portugal	P	5	0	2	0	0	2	1
Spain	E	22	1	4	1	2	9	5
Sweden	S	35	9	9	1	5	8	3
United Kingdom	UK	96	11	12	3	18	31	20
Allocated	EU	554	50	118	23	57	232	74
Total	**EU**	**555**	**50**	**127**	**20**	**56**	**235**	**67**

Source: IES

Table A1.4 Response and response rate by sector and country

	Business Enterprise		Higher Education		Government		Total	
	Number	Response rate %	Number	Response rate %	Number	Response rate %	Number	Response rate %
Austria	4	16	4	27	1	33	9	20
Belgium	2	7	7	41	—	0	9	18
Denmark	9	38	2	18	4	40	15	34
Finland	2	10	5	36	5	46	12	26
France	8	11	5	15	1	4	14	11
Germany	13	10	11	28	5	18	29	16
Greece	4	44	4	20	—	0	8	17
Ireland	4	19	4	25	—	0	8	19
Italy	3	8	8	29	4	27	15	18
Netherlands	3	11	6	40	7	50	16	29
Portugal	0	0	6	25	1	10	7	14
Spain	6	27	7	25	3	25	16	24
Sweden	13	37	3	19	—	0	16	30
UK	27	28	6	29	3	23	36	29
EU	**98**	**18**	**78**	**26**	**34**	**21**	**210**	**21**

Source: IES R&D Establishments Survey

cent for Denmark. Similarly, the response varied by sector, with an 18 per cent response from Business Enterprise establishments and 26 per cent from Higher Education establishments (Table A1.4).

As the small countries had been over sampled the relatively low response rates from France and Germany meant that a smaller proportion of their R&D establishments were included. However, a lower response from Business Enterprise R&D establishments had been expected, the over-sampling of this sector accounted in part for this problem.

The response rates from the Government sector were the most varied, ranging from zero in four countries to 50 per cent in the Netherlands. Despite these variations, the overall sample is relatively representative of the R&D establishments in each country and overall representative at the sectoral level. However, given the relatively small numbers involved statistical significance tests were not applied and the data from the survey are reported in the main body of the report as indicative of key characteristics and differences.

Another way of examining the response, and importantly the reliability of any estimates made of the basis of the survey, is to compare the reported numbers of RSEs with the known population data. Table A1.5 does this in terms of countries and FTE RSEs, additionally the table gives the standard errors of the

Table A1.5 Population and respondents FTE RSEs and reliability of survey estimates by country

	FTE RSE Population	Respondents giving FTE RSE data	FTE RSEs in survey	FTE RSEs in survey as a % of Population	Standard error assuming SRS	95% confidence level of estimate + or -
Belgium	22,919	7	131	0.57	0.0013	28.96
Denmark	16,361	13	156	0.95	0.0014	22.53
Germany	231,128	24	1650	0.71	0.0041	943.54
Greece	8,031	3	394	4.91	0.0022	17.34
Spain	47,344	15	386	0.82	0.0021	101.21
France	151,249	11	1758	1.16	0.0042	632.63
Ireland	8,514	6	211	2.48	0.0016	13.59
Italy	75,536	9	99	0.13	0.0011	83.13
The Netherlands	34,038	15	144	0.42	0.0013	45.06
Austria	12,821	7	117	0.91	0.0012	15.32
Portugal	11,599	6	1684	14.52	0.0041	47.73
Finland	16,863	11	78	0.46	0.0010	16.49
Sweden	33,665	12	1460	4.34	0.0039	130.94
United Kingdom	148,000	29	723	0.49	0.0029	424.44
EU	**818,068**	**168**	**8,991***	**1.10**	**—**	**—**

** 15,000 headcount*

Source: IES R&D establishments survey and Eurostat (1999) R&D Statistics 1998

survey estimates and the 95 per cent confidence levels for these estimates. The standard error has been calculated on the basis of reported RSE numbers and this assumes that the respondents are based on a random sample and are typical the R&D establishments in that country.

It should be realised that the stratification of the sample means that in practice the standard errors and the 95 per cent confidence limits are much smaller. However, as already mentioned without detailed information about the population of the sampling units (R&D establishments) it is impossible to calculate these design effects. Similar surveys, with the same sort of stratification adopted here, generate relatively large design effects and would in practice halve the standard errors and 95 per cent confidence limits. The impact of the stratification can be seen in the higher proportions of Portuguese and Greek RSEs covered by the survey. However, the low response rate in Italy worked against the stratification and therefore the Italian estimates are particularly suspect.

Table A1.6 undertakes a similar analysis for the sectoral breakdown. This shows that at the sectoral level the results are more reliable.

Table A1.6 Population and respondents FTE RSEs and reliability of survey estimates by sector

	FTE RSE Population	Respondents giving FTE RSE data	FTE RSEs in survey	FTE RSEs in survey as a % of Population	Standard error assuming SRS	95% confidence level of estimate + or -
Business Enterprise	384,030	77	3,643	0.95	0.0052	91.24
Higher Education	293,219	26	3,973	1.36	0.0052	92.30
Government	124,574	65	1,376	1.10	0.0038	66.91
EU	**818,068**	**168**	**8,991***	**1.10**	**—**	**—**

** 15,000 headcount*

Source: IES R&D establishments survey and Eurostat (1999) R&D Statistics 1998

Again, the standard errors and 95 per cent confidence limits are over estimates since the stratified sample design would in practice have greatly reduced the sampling errors.

Annex 2: Pilot Modelling of the Supply and Demand of RSEs

A2.1 Introduction

In the 'White Paper' on growth, competitiveness and employment, the European Commission states that the European Union (EU) should catch up in the technological race if it wishes to increase employment levels (Commission of the European Communities, 1993). Rapid technological change offers great opportunities for increasing employment in the EU, and the diffusion of new technologies is crucial for the EU's international competitive position. However, this requires a highly skilled labour force that gives competitive advantages in the growth sectors of the world economy.

Economic growth and rising employment usually correspond with productivity increases, mainly caused by technological progress (OECD, 1994). Productivity gains in the economy as a whole depend to a large extent on developments in the high-technology segment of the manufacturing sector. The employment in many other sectors of the economy will suffer in a situation where there is scarcity of skilled labour (Reich, 1991).

Knowledge-intensive sectors, both in manufacturing and in services, have been expanding their employment more rapidly than the rest of the economy. The importance of high-technology products has increased continuously in international trade. In particular, industries related to information technologies are the fastest growing categories in world trade and production. Information technologies increase the potential for economic growth and productivity gains, but due to their characteristics also broaden the mismatches between labour demand and supply in terms of skills and qualifications. Efficient implementation requires considerable changes in work organisation and skills requirements (OECD, 1994).

In a knowledge-driven global economy, it is essential that the education systems in the Member States of the EU produce sufficient science and technology (S&T) graduates both in quantitative and qualitative terms. The hard core of personnel in the R&D departments comprises the research scientists and engineers (RSEs). Any shortage in qualified RSEs will lead to unrealised output of knowledge and consequently a loss in product quality and variety. This in turn will hurt the international competitiveness of European firms and will result in lower market shares in technology-intensive products and services. The opportunities for economic growth and economy-wide employment will not be fully exploited. The loss in market share decreases the employment possibilities for other workers in the sectors that could be the growth sectors of the economy, such as technicians and supporting staff. Moreover, there will probably be large negative spillover effects to other sectors of the economy.

From a policy perspective, the availability of reliable forecasts on the adequacy of the education systems in the Member States of the EU to meet the future demand for RSEs, is therefore very important. Such forecasts could be an essential tool for policy-makers, as they serve as an 'early warning system' indicating possible bottlenecks in the labour markets for RSEs. It will give policy-makers the opportunity to initiate anticipating policies.

This pilot study explores the possibilities of developing a forecasting system for the European labour markets for RSEs. It is a pilot study that tries to establish what analyses are possible with the currently available data on R&D personnel and to identify the obstacles that stand in the way of a more reliable forecasting system. For this purpose, the pilot study produces forecasts for future demand and supply of RSEs for 14 Member States of the EU in the period 1997-2002, based on available data up to 1997. It offers an exploratory assessment of the expected quantitative adequacy of the education systems in the Member States of the EU in the period 1997-2002 in relation to the demand for RSEs, based on information up to 1997. It is important to emphasise that these forecasts are not yet suitable for policy purposes. The main purpose is to show the potential features of an early warning system for bottlenecks in the labour markets for RSEs, which play a crucial role in the European knowledge economy.

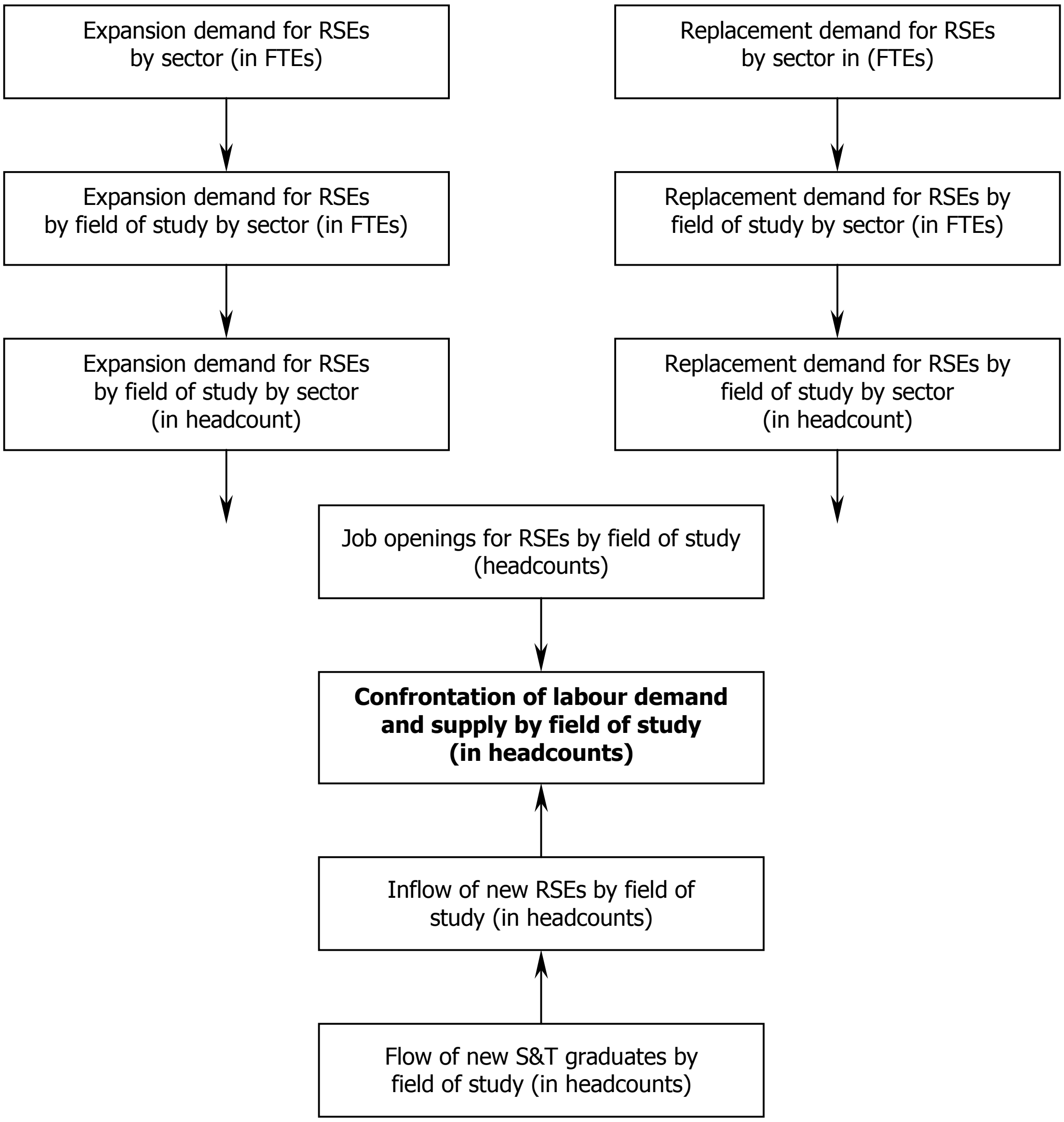
The remainder of this Annex is organised as follows. Section A2.2 describes the general structure of the labour market forecasting model. Section A2.3 discusses the scenarios that are based on two dimensions: the exogenous dimension (real GDP growth) and the policy dimension (expenditure on R&D and higher education). The four scenarios are quantified in Section A2.4. Section A2.5 describes the implementation of the scenarios in terms of the forecasting model. The forecasts for demand and supply under the four scenarios are discussed in Section A2.6 and compiled in the appendix. Section A2.7 concludes.

A2.2 The model

In order to assess the quantitative adequacy of the education systems in 14 Member States of the EU in the period 1997-2002 in relation to the demand for RSEs, we developed a model to track the relevant flows on the labour markets for RSEs. Under this approach, forecasts are made of the flows entering and leaving the labour market in the period 1997-2002. This approach enables us to make a confrontation between labour demand (the expected job openings for RSEs) and labour supply (the expected inflow of new RSEs). The general structure of the labour market forecasting model for each of the 14 Member States is visualised in Figure A2.1.

The *demand for RSEs* consists of two components. In the first place, job openings may occur due to growth of R&D employment. This is called *expansion demand*. In the second place, there are job openings because of the outflow of workers due to retirement and the mobility of RSEs to commercial and management jobs. This is called *replacement demand*. Expansion demand and replacement demand are considered in three sectors of R&D work: the business

Figure A2.1: General structure of the labour market forecasting model



Source: ROA

enterprise sector, the government sector and the higher education sector. The forecasting results for the demand side are summarised in terms of the total number of *job openings* between 1997 and 2002.

From the *supply side*, the job openings for RSEs will in general be filled by the *flow of new S&T graduates* from the educational systems of the Member States of the EU. The flow of S&T graduates is also largely determined by demographic developments. A country with a relatively young population will generate a relatively larger supply of graduates than a country with a 'greying' population. However, there may also be differences across Member States of the EU in the fields of study that are chosen by prospective students. In the first place, there may be differences in the relative enrolments of students in the S&T-related fields of study. In the second place, there may be differences in the enrolments in the various fields of study within the S&T-related fields. In practice, only a modest fraction of new S&T graduates has the qualifications and ambitions to pursue a career as an RSE. Therefore, it is important for the confrontation between demand and supply to distinguish between the flow of new S&T graduates and the considerably smaller labour market *inflow of new RSEs*.

On the supply side we distinguish between four fields of study: natural sciences, technology and engineering, medical sciences and agricultural sciences. Consequently, for a *confrontation between demand and supply* we have to express the sectoral expansion demand and the sectoral replacement demand in terms of these four fields of study. Since the supply side forecasts refer to 'head-counts', we also transfer the demand for RSEs from full-time equivalents (FTEs) to head-counts. As a result, the confrontation between demand and supply takes place for 14 Member States of the European Union for the period 1997-2002 in four fields of study in terms of the number of people. An alternative for these so-called 'head-counts' is to express both labour demand and supply in full-time equivalents (FTEs).

The implementation of this general framework is hampered by the lack of adequate data. As a result, we have had to fill the gaps by assumptions and approximations. It is therefore important to distinguish which parts of the forecasting model are firmly grounded in statistical data and which parts are based on hypotheses. In fact, each model component contains a blend of statistical data and *ad hoc* assumptions. This implies that the forecasts generated by the forecasting model should be interpreted with care. Alternative assumptions will lead to alternative forecasting results. Therefore, the forecasts are primarily an illustration of the type of information that can be provided by a forecasting system for the European labour markets for RSEs. The empirical foundation of the pilot model is not yet firm enough for reliable policy conclusions.

Table A2.1: Main data sources and crucial assumptions for the model components

Model component	Data source	Assumptions
Expansion demand	R&D statistics (Eurostat)	Cointegration of R&D expenditure and RSE employment by sector (stable long-run relationship)
Replacement demand	IES Survey of R&D establishments	Country-specific age structure Country-specific outflow coefficients by age cohort
Inflow	S&T graduate output data (IES/Eurostat)	Constant growth rates

Source: ROA

We will now discuss the implementation of the three model components in turn. First the expansion demand model is described, then the replacement demand model and finally the inflow model. The central data sources and crucial assumptions for the three components of the model are summarised in Table A2.1.

In order to get the most accurate forecasts of *expansion demand*, we developed econometric models for each sector of each Member State of the EU. These models use the sectoral expenditure on R&D to explain sectoral expansion demand. The use of expenditure data instead of GDP (or Gross Fixed Capital Formation) allows us to capture effects that are specific for the R&D sector as opposed to the economy as a whole. By distinguishing between three sectors (business enterprise, government and higher education), sector-specific effects can be tracked. Finally, the heterogeneity among the different Member States of the EU can be reflected by the use of specific models for each country. Therefore, the forecasting results for expansion demand are based on 42 models (14 countries × 3 sectors). The models all belong to the class of error correction mechanisms, which are appropriate in the case of non-stationary variables. They also have the advantage of distinguishing between short-run and long-run dynamics. For each sector and for each country the following error correction mechanism is estimated:

$$\Delta FTE_t = \alpha\, \Delta ERD_t + \Theta\, (FTE_{t-1} - \beta\, ERD_{t-1}) + \varepsilon_t$$

where FTE denotes the sectoral RSE employment in full-time equivalents and ERD denotes the sectoral expenditure on R&D in 1990 national currency prices.

The long-run dynamics represents co-integration of FTE and ERD, which means that there is a stable long-run relationship between these two variables, expressed in parameter β. The short-run dynamics consists of direct effects of increases of ERD on FTE (parameter α) and corrections for the deviations from the long-run relationship between FTE and ERD (parameter Θ), the latter short-run component explains the term ‘error correction mechanism’.

The model was estimated by the two-step estimation procedure proposed by Engle and Granger (1987). In the first step, FTE is regressed on ERD which yields a super-consistent estimate of β. In order to deal with breaks in the data, we added dummy-variables to this regression. In the second step, the estimate of β is inserted in the error correction mechanism, which therefore reduces to a linear model that can be estimated by OLS. In addition to the t-statistics for statistical significance of the estimates of α and Θ and the R^2 for the goodness-of-fit, we show the Breusch-Godfrey Lagrange-Multiplier (LM) test for first order serial correlation to measure the adequacy of the dynamic specification. (The Durbin-Watson statistic is inappropriate in the presence of lagged endogenous variables). For each of the 42 models, we inspected the statistical significance of the parameter estimates, the plausibility of the signs of α (should be positive) and Θ (should be negative), the presence of serial correlation and the R^2 to select either the general error correction model or one of its two nested simplifications ($\alpha = 0$ or $\Theta = 0$). The results of the model selection and estimation are shown in Tables A2.2-A2.4. An empty cell indicates that one of the two simple versions of the general error correction mechanism was selected.

The uniform approach that we have taken by estimating error correction mechanisms of identical functional form for all countries and sectors avoids *ad hocery* and data mining. However, the regression statistics show that a uniform approach has its drawbacks, since for some sectors in some countries there are poor statistical fits as evidenced by the low R^2. In certain cases this may

Table A2.2: Expansion demand model by Member State, business enterprise sector

Country	α	Θ	β	t(α)	t(Θ)	LM
Belgium	0.113			4.40		0.5
Denmark	0.384			15.33		0.8
Germany	1.995	-0.379	2.282	4.48	-2.16	2.7
Greece	0.026			6.53		0.8
Spain	0.009			2.23		7.1
France	0.447	-0.538	0.476	3.10	-2.24	0.8
Ireland	4.398			5.12		0.0
Italy	0.001			4.00		3.2
Netherlands	1.906	-0.470	1.353	3.32	-2.13	0.1
Austria	0.327	-0.275	0.353	7.19	-2.15	6.1
Portugal		-1.403	0.028		-5.18	1.6
Finland	0.215			3.37		0.3
Sweden	0.198	-0.042	0.483	5.93	-1.24	2.4
UK	10.177	-0.252	9.723	1.59	-1.08	1.1

Source: ROA

Table A2.3: Expansion demand model by Member State, government sector

Country	α	Θ	β	**t(α)**	**t(Θ)**	**LM**	**R^2**
Belgium	0.176	-0.803	0.172	4.94	-2.66	1.7	0.68
Denmark	0.662			4.78		2.4	0.64
Germany	3.003	-0.451	2.787	3.04	-1.86	3.5	0.47
Greece	0.009			0.70		0.6	0.04
Spain	0.021			2.02		0.0	0.24
France	0.385	-0.370	0.545	2.00	-1.67	0.8	0.31
Ireland	2.049	-0.060	11.295	0.78	-1.33	9.8	0.15
Italy	0.001			1.30		0.1	0.11
Netherlands	1.370	-0.094	3.399	0.85	-0.61	8.8	0.07
Austria	0.230	-0.192	0.325	9.27	-3.82	0.2	0.89
Portugal	0.184			3.35		0.1	0.46
Finland	0.326			3.22		1.7	0.44
Sweden	0.624	-0.087	1.154	4.04	-1.84	2.2	0.59
UK	5.898	-0.784	6.438	2.01	-2.72	4.2	0.46

Source: ROA

Table A2.4: Expansion demand model by Member State, higher education sector

Country	α	Θ	β	**t(α)**	**t(Θ)**	**LM**	**R^2**
Belgium	0.309	-0.693	0.244	6.02	-2.90	3.6	0.79
Denmark	0.616			9.62		1.2	0.88
Germany	4.688	-0.421	4.290	5.57	-2.09	3.2	0.78
Greece	0.081			4.79		0.1	0.64
Spain	0.025			2.30		1.4	0.29
France	0.641			4.72		0.0	0.63
Ireland	33.744	-0.278	37.846	6.71	-1.79	2.8	0.79
Italy	0.001			0.75		0.1	0.04
Netherlands	3.995	-0.609	3.093	5.08	-1.90	1.6	0.69
Austria	0.190			10.02		0.0	0.89
Portugal	0.084			6.89		2.5	0.78
Finland	0.937	-0.065	2.161	4.45	-1.98	2.6	0.62
Sweden	0.318			2.59		0.1	0.34
UK	10.927	-0.117	15.808	4.16	-2.15	0.4	0.62

Source: ROA

be caused by the data themselves, for example because the dummies for breaks may not have filtered out all noise. In other cases, it might be the case that different functional forms apply for different sectors of different countries. Estimations in terms of natural logarithms in a uniform way did not yield better results than the current functional form. Another problem might be that the error correction mechanism with one explanatory variable is too simple, introducing omitted variable bias. One extension might be the incorporation of other explanatory variables. Another extension might be the dynamic specification. For example, the LM-statistic for the Austrian business-sector-model points to first order serial correlation. In any case, it should be kept in mind that the length of the time series is close to the minimum as far as the applicability of error correction mechanism modelling is concerned. In this light, the regression results are quite satisfactory. A final remark can be made on the assumption of a stable long-run relationship between R&D expenditure and RSE employment. Structural breaks may occur in the composition of R&D expenditure, as factor prices and relative factor inputs evolve over time. In addition, changes in science funding policies may contribute to changing shares of R&D expenditure.

Replacement demand is the second source of job openings. While expansion demand is closely related to the growth of the R&D sector, replacement demand is largely a matter of the demographics of the R&D sector. It depends on the distribution of the RSEs over the various age cohorts and the probability that an RSE from a specific age cohort will leave. We used RSE stock data from the IES Survey of R&D Establishments to infer the age structure of the RSE stocks of the Member States of the EU. However, for a number of countries there was a low response rate of the survey in certain sectors, therefore we had to pool the data either over sectors or over countries. Since demographics are country-specific to a large extent, we decided to pool over the sectors and thus obtain *country-specific age structures* that are uniform across sectors. The probability that a person will flow out of the RSE stock depends on several factors. The most obvious departures result from retirement. Therefore, a country with a relatively old labour force will usually have higher replacement demand. Another source of replacement demand is the mobility of RSEs to non-RSE jobs within or outside the firm. Often people start their career as an RSE, but then move on to commercial, managerial or other jobs. Since data on the outflow of RSEs were not available from existing sources, relevant questions were included in the *IES Survey of R&D Establishments*. The survey data allow us to derive the RSE age structure by country and by sector and also the outflow-coefficients for each cohort by country and by sector. However, because of the low response in certain sectors for a number of countries, we impose uniform outflow-coefficients across sectors for each cohort in each country. This implies we have *country-specific outflow-coefficients*. Analogously, we do not use the available data on the age structure in the various sectors in a particular country. Instead, we use the more reliable aggregate data on the average age structure in each country, *ie* a *country-specific age structure*.

In order to confront the number of job openings arising from expansion demand and replacement demand with the inflow of RSEs on the supply side, we have to express the sectoral expansion demand and the sectoral replacement demand in terms of these four fields of study. This is achieved by assuming that the current distribution by field of study remains the same. Since the supply side forecasts refer to 'head-counts', we also transfer the demand for RSEs from full-time equivalents (FTEs) to head-counts. We assume that the ratio between head-counts and FTEs remains constant.

From the *supply side*, the job openings for RSEs will in general be filled by the *flow of new S&T graduates* from the European educational systems. The data on S&T-graduates in the various Member States of the EU contain information on the enrolments in the various fields of study within the S&T-related fields. We assume that the growth rates of S&T-graduates in the various fields of study are constant. The fraction of S&T-graduates who will pursue a career in R&D can in principle be derived from First Destination data of S&T-graduates. Unfortunately, the quality of the available First Destination data is very poor. Therefore, we use the available data on changes in RSE employment — in combination with the data on S&T graduates — as a starting point for the derivation of inflow-coefficients.

A2.3 Scenario analysis

A2.3.1 Scenarios for the RSE labour market

Forecasting the European labour markets for research scientists and engineers with our model requires forecasts of expenditure on R&D. A straightforward approach would be to use extrapolations of available time series. However, there are serious drawbacks to this approach. Expenditures on R&D depend both on the general economic situation and on the policies that are implemented with respect to human capital development. In a prosperous economy, there will in general be more funds available for R&D expenditure. Analogously, in a stagnating economy it may be difficult to raise more funds for R&D expenditure. However, there still remains an important policy choice as in both situations it is possible to follow either a high human capital growth policy or a low human capital growth policy.

Since both future developments in GDP and human capital policies are uncertain, we follow a scenario approach — instead of extrapolations — to obtain time paths for R&D expenditure. We developed 4 scenarios that are based on the combination of 2 dimensions (see Table A2.5): an *exogenous dimension* and a *policy* *dimension*. The exogenous dimension refers to the overall developments in the global economy, which can only be influenced to a limited extent by policy-makers in the EU, since these developments have their causes for a large part in international economic developments. The policy dimension reflects the choices that policy-makers in the EU face with respect to R&D — and education policies. In order to separate the exogenous effects from the policy effects, human capital policies will be indicated by the R&D expenditure in a country relative to GDP. The interaction of the two dimensions can be represented by the following deconstruction of R&D expenditure:

ERD = GDP x ERD/GDP

The exogenous dimension is reflected by the time path of GDP, while the human capital policy is indicated by the evolution of the ratio of R&D expenditure to GDP. In other words, we assume that human capital policy is formulated on terms of R&D expenditure as a percentage of GDP.

If we consider 2 different outcomes for each dimension, we get 4 possible RSE labour market scenarios (see Table A2.6). The combination of an exogenous dimension and a policy dimension offers a consistent way of building scenarios, instead of making *ad hoc* assumptions on the various components of the model. Moreover, the interaction of the policy dimension and the exogenous dimension, enables us to get an idea of the effects of human capital policies in the EU in case of both high and low growth paths of the world economy. In this way, the scenarios provide a 'policy-rich' analysis of the labour markets for RSEs in the various EU Member States up to 2002. The scenarios developed are translated into different time paths for R&D expenditure and different labour market inflow — and outflow-coefficients, capturing the dynamics of the labour market. In turn, the model translates these time paths into forecasts of the supply and demand for RSEs to 2002.

Table A2.6: The four scenarios

	High human capital growth policy	**Low human capital growth policy**
High GDP growth	GDP growth: OECD-forecast + 0.5% Growth of ERD/GDP: Average of last 5 years	GDP growth: OECD-forecast + 0.5% Growth of ERD/GDP: Zero growth
Low GDP growth	GDP growth: OECD-forecast - 0.5% Growth of ERD/GDP: Average of last 5 years	GDP growth: OECD-forecast - 0.5% Growth of ERD/GDP: Zero growth

Source: ROA

A2.3.2 The exogenous dimension: economic growth

According to the *OECD Employment Outlook June 1998* (OECD, 1998a) the average economic growth rate for the EU in the period 1985-1995 was 2.0 per cent. In 1996, it was even lower at 1.7 per cent, but it picked up in 1997 to 2.6 per cent. The OECD projections for 1998 and 1999 were 2.7 per cent at time of publication. However, the turmoil on the international financial markets has led to a revision of the OECD economic growth projections. The *OECD Economic Outlook December 1998* (OECD, 1998b) still has the 1998 growth rate at 2.8 per cent, but the 1999 growth rate is reduced to 2.2 per cent, with a slight recovery in 2000 to 2.5 per cent. This volatility of growth expectations shows that it may be prudent to use scenarios with respect to economic growth. Depending on the effects of, for example, the financial crises in emerging countries around the world, the situation in Japan and the state of the US economy, but also economic developments within the EU, the EU may face different possible growth rates to 2002.

In the forecasting model, sectoral *expansion demand* is explained by sectoral R&D expenditure. In case of higher economic growth, more funds will be available for expenditure on R&D. In the business enterprise sector, sales and profits rise, which in turn enables firms to invest in their knowledge base. Hence business enterprise expenditure on R&D (BERD) will increase. In the government sector, the higher economic growth increases government tax receipts. If policy on human capital development is formulated in terms of R&D expenditure as a fixed percentage of GDP, the larger public budget leads to higher government sector expenditure on R&D (GOVERD). Since a major part of the higher education sector is funded by the public sector, an increase in economic growth will also benefit the higher education sector expenditure on R&D (HERD). In short, the cross-sector effect of increased (decreased) economic growth is increased (decreased) expansion demand.

If the high expansion demand resulting from high economic growth cannot be met by adequate supply, then efforts will be made to reduce replacement demand: fewer RSEs in the higher age cohorts will flow out of the labour market by early retirement. Firms engaged in R&D will try to keep their ageing RSEs employed as long as possible. Probably firms will also induce fewer RSEs to switch to non-RSE jobs. Consequently, the *outflow-coefficients* will be relatively small in case of high economic growth. Thus, replacement demand is assumed to partially compensate movements in expansion demand.

High economic growth means that job opportunities for recent S&T graduates will probably increase both in RSE jobs and in non-RSE jobs. The effect on the *inflow-coefficients* will depend on the relative employment growth of RSE jobs versus non-RSE jobs. We

Table A2.7: Assumptions on the effects of GDP growth on model components

Model component	High GDP growth	Low GDP growth
Expansion demand	high	Low
Replacement demand	low	High
Inflow	low	high

Source: ROA

assume that economic growth increases the job opportunities in the manufacturing sector more than in the research sector, hence increased economic growth will lead to lower inflow-coefficients.

The assumptions on the effects of economic growth on expansion demand, replacement demand and inflow are summarised in Table A2.7.

A2.3.3 The policy dimension: policies on R&D and education

There are two types of public 'human capital' policies that are relevant for our forecasts. In the first place, there are policies on R&D expenditure, which primarily affect the demand side of the labour market for RSEs. In the second place, there are policies on higher education spending, which affect both the demand and the supply side of the labour market for RSEs. Other policies aimed at the development of human capital, such as tax and levy exemptions on work and aid for recruitment and training, fall outside the scope of this study.

Spending on R&D is subject to budgetary pressures: '*… the fact that there is close interdependence between the macro economic policies of the European Union and the research and technological innovation policy, means that public financing of R&D cannot escape the constraints of budgetary reform, which characterise the current economic policy in the Member States of the Union.*' (European Commission, 1997, p. 311)

Educational expenditure is also under pressure*: 'In almost all OECD countries, total education expenditure accounts for between five and eight per cent of GDP. The public portion of this represents between ten and 15 per cent of public spending. This is a substantial proportion of national income by any standard. Under current conditions of tight public constraints, such a large spending item is subject to close scrutiny by governments looking for ways to trim or limit the growth of expenditure . . .* ' (OECD, 1997, p. 10).

How do budgetary pressures translate into spending on R&D and education? In the first place, we assume that R&D expenditure and public expenditure on higher education will go hand in hand, reflecting a coherent human capital policy. In the second place, budgetary pressures may have different consequences for human capital budgets, depending on the emphasis of the policy-makers. Insights from endogenous growth theory (*eg* Romer, 1990) stress the importance of accumulation of knowledge (through R&D) and human capital (through education) for sustained long-term growth. If these insights are reflected in government policies, expenditure on R&D and education will be less affected than other parts of the public sector. In an international context, the situation is even more complicated, since certain countries are still trying to catch up: *'Other Members, despite budgetary problems and restrictions, are seeking to increase public expenditure on R&D. These include both countries with a 'catching up' policy like Spain, Portugal, Greece and Ireland, and more developed countries that want to increase or keep emphasis on R&D.'* (European Commission, 1997, p. 314)

Therefore, we will distinguish between 2 outcomes of the human capital policy dimension.

If the public sector allocates more funds to R&D and education, then there will be an increase in BERD, GOVERD as well as HERD. This will increase *expansion demand* for RSEs in all three sectors. At the same time, it means that there will be more funds available to keep older RSEs employed, hence *replacement demand* will be lower in case of high human capital expenditure. The increase in R&D funds will, ceteris paribus, lead to an increase in the relative wage of RSEs to all S&T graduates. Hence, the *inflow* of RSEs will increase. In addition, there is also a long-term effect from the increase in education spending, since it will probably further increase the future supply of S&T graduates. Since this pilot study has a five-year horizon, this effect may be ignored. However, the general structure of the model developed in this study is capable of incorporating such long-term effects, in particular via the inflow-component. In other words, although the short horizon of the study implies that human capital policy is predominantly expressed in terms of R&D-policy, the forecasting system is also equipped to deal with education policy.

The assumptions on the effects of human capital policy on the various model components are compiled in Table A2.8.

Table A2.8: Assumptions on the effects of human capital policy on model components

Model component	High human capital growth	Low human capital growth
Expansion demand	High	Low
Replacement demand	Low	High
Inflow	High	Low

Source: ROA

Table: A2.9: Exogenous dimension: real GDP growth rates per cent

Country	1998		1999		2000		2001		2002	
	High	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Belgium	3.4	2.4	2.8	1.8	2.8	1.8	2.7	1.7	2.6	1.6
Denmark	2.9	1.9	2.5	1.5	2.4	1.4	2.9	1.9	3.0	2.0
Germany	3.2	2.2	2.7	1.7	3.0	2.0	3.1	2.1	3.2	2.2
Greece	3.5	2.5	3.7	2.7	3.9	2.9	3.6	2.6	3.4	2.4
Spain	4.3	3.3	3.9	2.9	3.9	2.9	3.9	2.9	4.0	3.0
France	3.6	2.6	2.9	1.9	3.1	2.1	2.9	1.9	2.8	1.8
Ireland	9.6	8.6	7.2	6.2	7.0	6.0	7.2	6.2	7.2	6.2
Italy	2.0	1.0	2.6	1.6	3.1	2.1	3.2	2.2	3.1	2.1
Netherlands	4.3	3.3	3.2	2.2	3.0	2.0	3.3	2.3	3.3	2.3
Austria	3.6	2.6	2.9	1.9	3.1	2.1	3.1	2.1	3.0	2.0
Portugal	4.5	3.5	3.8	2.8	3.7	2.7	3.6	2.6	3.5	2.5
Finland	5.5	4.5	3.7	2.7	3.5	2.5	3.9	2.9	3.9	2.9
Sweden	3.3	2.3	2.7	1.7	2.9	1.9	3.1	2.1	3.1	2.1
United Kingdom	3.2	2.2	1.3	0.3	2.0	1.0	2.7	1.7	3.0	2.0

Source: OECD/ROA

A2.4 Quantification of scenarios

A2.4.1 Growth rates of real GDP

The first question to be addressed when we quantify the scenarios, is to assign specific numerical values to 'high growth' and 'low growth' in the various Member States of the European Union. For this purpose we will use the most recent OECD forecasts (OECD, 1998b), as a baseline growth figure. The high and low growth rates were chosen at equal distances above respectively below the OECD projections. A bandwidth of 1.0 per cent (*ie* 0.5 per cent above and below the OECD projections), yields the high and low growth figures presented in Table A2.9. This bandwidth is in line with, *eg* the expected impact of the crisis in emerging Asia on real GDP growth in the EU which is put at –0.4 per cent for 1998 and –0.2 for 1999 in OECD (1998a). It is also in line with the adjustment between May 1998 and December 1998 of the OECD projection for real GDP growth for the EU. (Made because of the effects of the international financial turmoil, and which was changed from 2.7 per cent to 2.2 per cent, an adjustment of 0.5 per cent.)

A2.4.2 Growth rates of the ratio of R&D expenditure to GDP

The second issue to be addressed in quantifying the scenarios is to assign numerical values to 'high human capital growth policy' and 'low human capital growth policy'. On this point, it is important to make a distinction between R&D expenditure in the public sector (GOVERD and HERD) and R&D expenditure in the private sector (BERD), as data on the financing of R&D expenditure show that GOVERD and HERD are government-financed, while BERD is only for a minor part financed by the government sector.

We will use constant growth rates of the GOVERD/GDP-ratio and the HERD/GDP-ratio during the entire forecasting period to focus straightforward on two different human capital policies: a low human capital growth policy and a high human capital growth policy. The low human capital growth policy freezes these ERD-to-GDP ratios at the last observed level, *ie* a zero growth policy with respect to the share of public sector R&D expenditure in GDP. The high human capital growth policy focuses on the RSE labour market impact of a knowledge-intensive growth path, by setting the growth rate of the GOVERD/GDP-ratio and the HERD/GDP-ratio at their respective averages of the last five observed years. We have made an exception for the HERD/GDP-ratios of Greece and Spain, which we set at a half of the average growth rate of the last five years. At the very high average growth rate of the last few years, these countries would get implausibly high values for the level of HERD/GDP by the year 2002. In other words, we assume that the R&D 'catching up' policies of Greece and Spain in the higher education sector will be sustained in the next few years, albeit at a slower rate such that the R&D expenditure as a percentage of GDP will reach levels comparable to other European countries in 2002.

The scenario growth rates of R&D expenditure (as a percentage of GDP) in the government sector and the higher education sector are summarised in Table A2.10 and described in more detail in Table A2.12 (government sector) and Table A2.13 (higher education sector).

The effect of human capital policy on the growth rate of the ratio of BERD to GDP depends on the relative role of public financing

Table A2.10: Scenario growth rates of the ratios of government and higher education R&D expenditure to GDP

Component of public R&D expenditure	High human capital growth policy	Low human capital growth policy
GOVERD	Average growth rate of total GOVERD in last 5 years	Zero growth
HERD	Average growth rate of total HERD in last 5 years	Zero growth

Source: ROA

Table A2.11: Scenario growth rates of the ratio of BERD to GDP

Component of BERD	High human capital growth policy	Low human capital growth policy
Publicly-financed BERD	Average growth rate of total BERD in last 5 years	Zero growth
Privately-financed BERD in the context of stimulation measures	Average growth rate of total BERD in last 5 years	Zero growth
Autonomous BERD	Average growth rate of total BERD in last 5 years	Average growth rate of total BERD in last 5 years
Total BERD	*Average growth rate of total BERD in last 5 years*	*Below the average growth rate of total BERD in last 5 years*

Source: ROA

versus private financing of business enterprise sector expenditure on R&D. In all Member States of the EU, the size of public financing of R&D expenditure in the business sector is modest. However, an aspect of stimulation measures often entails co-financing of R&D expenditure by the public and the private sector. Therefore, we assume that the amount of public financing of BERD is accompanied by an equal amount of private financing.

Consequently, we can distinguish between private financing of BERD, which is independent of public financing (which we simply call 'autonomous BERD'), and private financing of BERD which takes place in the context of stimulation measures by the

Table A2.12: Policy dimension: annual growth rates of government sector expenditure on R&D as percentages of GDP, 1998-2002

Country	Per cent	
	High	Low
Belgium	0.0	- 7.8
Denmark	6.7	0.0
Germany	4.6	0.0
Greece	11.4	0.0
Spain	12.6	0.0
France	4.3	0.0
Ireland	1.2	0.0
Italy	0.0	- 0.7
Netherlands	6.5	0.0
Austria	6.2	0.0
Portugal	13.8	0.0
Finland	8.5	0.0
Sweden	8.1	0.0
United Kingdom	4.3	0.0

Source: ROA

Table A2.13: Policy dimension: annual growth rates of higher education sector expenditure on R&D as percentages of GDP, 1998-2002

Country	Per cent	
	High	Low
Belgium	5.1	0.0
Denmark	10.0	0.0
Germany	4.7	0.0
Greece	16.8	0.0
Spain	13.7	0.0
France	9.1	0.0
Ireland	9.1	0.0
Italy	5.6	0.0
Netherlands	6.0	0.0
Austria	6.2	0.0
Portugal	5.3	0.0
Finland	9.5	0.0
Sweden	4.3	0.0
United Kingdom	8.0	0.0

Source: ROA

public sector. Therefore we can deconsctruct R&D expenditure in the business enterprise sector in three parts, as indicated in table A.2.12: publicly-financed BERD, privately financed BERD in the context of stimulation measures and autonomous BERD.

Both in case of 'high human capital growth policy' and 'low human capital growth policy' we assume that the growth rate of the ratio of autonomous BERD to GDP remains constant at the average of the last five observed years in the EU Member State. However, the effect of human capital policy on the business sector works via privately financed BERD/GDP in the context of stimulation measures and publicly financed BERD/GDP.

In case of a low human capital growth policy we assume, as in the case of the public sector (GOVERD/GDP and HERD/GDP), that publicly-financed BERD/GDP is frozen at the current level. Consequently, also privately financed BERD/GDP which takes place in the context of stimulation measures will be frozen at the current level. As a result, the growth rate of total R&D expenditure in the business enterprise sector as a percentage of GDP is below the average growth rate in the last five years. In fact, the growth of this percentage exclusively originates from autonomous R&D expenditure in the business enterprise sector.

As in the case of the public sector (GOVERD/GDP and HERD/GDP), we assume that a high human capital growth policy leads to a growth rate of publicly-financed BERD/GDP that is identical to the average of the last five years. The same holds for the growth rate of privately financed BERD/GDP which takes place in the context of stimulation measures. Therefore, in this case the growth rate of BERD/GDP (as a whole) is identical to the average of the last five years. We made an exception for the BERD/GDP-ratios of Greece and Spain, which we set at a half of the average growth rate of the last five years. At the current rate, these countries would get implausibly high values for the level of BERD/GDP by the year 2002. A similar assumption was already made for R&D expenditure as a percentage of GDP in the public sector in Greece and Spain. In future work on this issue, it may be interesting to further investigate the nature of 'catching up' policies, allowing us to formulate scenarios which address this phenomenon more clearly.

An overview of the resulting growth rates for BERD/GDP during the forecasting period in the various EU Member States, both in case of 'high' and 'low' human capital growth policy, is presented in Table A2.14. Two interesting features emerge from Table A2.14. Firstly, countries with business sectors which depend more on public financing of R&D expenditure show larger differences between high and low BERD/GDP growth rates (*eg* Greece, France and the United Kingdom). Secondly, in case of the 'low' human capital growth policy, BERD/GDP growth rates increase over time. This is due to the fact that the share of privately funded BERD increases, as the level of publicly financed BERD is being frozen. Therefore, the BERD/GDP growth rate will in the course

Table A2.14: Policy dimension: annual growth rates of business sector expenditure on R&D as percentages of GDP, 1998-2002

Country	1998		1999		2000		2001		2002	
	High	Low	High	Low	High	Low	High	Low	High	Low
Belgium	5.1	4.9	5.1	4.9	5.1	4.9	5.1	4.9	5.1	4.9
Denmark	10.0	7.4	10.0	7.5	10.0	7.7	10.0	7.9	10.0	8.0
Germany	4.7	4.0	4.7	4.0	4.7	4.0	4.7	4.1	4.7	4.1
Greece	16.8	9.2	16.8	9.9	16.8	10.5	16.8	11.1	16.8	11.7
Spain	13.7	10.3	13.7	10.6	13.7	10.9	13.7	11.2	13.7	11.4
France	9.1	5.3	9.1	5.5	9.1	5.7	9.1	5.9	9.1	6.1
Ireland	9.1	8.4	9.1	8.4	9.1	8.5	9.1	8.5	9.1	8.6
Italy	5.6	5.5	5.6	5.5	5.6	5.5	5.6	5.5	5.6	5.5
Netherlands	6.0	3.9	6.0	4.0	6.0	4.1	6.0	4.1	6.0	4.2
Austria	6.2	4.7	6.2	4.8	6.2	4.9	6.2	4.9	6.2	5.0
Portugal	5.3	4.8	5.3	4.8	5.3	4.8	5.3	4.8	5.3	4.9
Finland	9.5	8.0	9.5	8.1	9.5	8.2	9.5	8.3	9.5	8.4
Sweden	4.3	3.4	4.3	3.4	4.3	3.4	4.3	3.4	4.3	3.5
United Kingdom	8.0	3.9	8.0	4.0	8.0	4.2	8.0	4.3	8.0	4.5

Source: ROA

of years move towards the growth rate of the ratio of autonomous BERD to GDP.

A2.5 Implementation of scenarios

A2.5.1 Model components

In Section A2.3, we formulated four scenarios for the labour markets for RSEs in the Member States of the EU. The scenarios were quantified in Section A2.4, by assigning specific values for the growth rates of real GDP (the exogenous dimension) and the growth rates of the ratio of sectoral R&D expenditure to real GDP (the policy dimension). In this section, the impact of high and low GDP growth and high and low human capital growth policy is translated in terms of the three modules of the forecasting model: expansion demand, replacement demand and labour market inflow of new RSEs. The scenarios affect expansion demand in a straightforward manner, as the expansion demand model explains sectoral RSE employment as a function of sectoral R&D expenditures. The impact of the scenarios on replacement demand takes place in terms of the outflow-coefficients. The scenarios influence the RSE labour market inflow via the inflow-coefficients. The effects of the scenarios on the three components of the model are summarised in Table A2.15.

A2.5.2 Expansion demand

The growth rate of sectoral expenditure on R&D can be deconstructed into the exogenous GDP growth factor and the human capital policy factor, *ie* the ratio of sectoral expenditure on R&D to GDP. For example, denote the growth rate of GDP by g and the growth rate of the ERD/GDP-ratio by h. Since:

$$ERD_t = GDP_t \times (ERD/GDP)_t,$$

it follows that:

$$ERD_t/ERD_{t-1} = GDP_t/GDP_{t-1} \times (ERD/GDP)_t/(ERD/GDP)_{t-1}.$$

Table A2.15: Effects of scenarios on variables of the model components

Model component	Variable affected by scenario	Method of calculation
Expansion demand	Sectoral R&D expenditure	Follows directly from scenario growth paths of GDP and ERD/GDP
Replacement demand	Outflow-coefficients	Calibration on the basis of the effective age of retirement, which is conditional on the scenario growth paths of GDP and ERD/GDP
Inflow	Inflow-coefficients	Maximum of historical inflow, adjusted for scenario growth paths of GDP and ERD/GDP

Source: ROA

Hence, the growth rate of ERD, say f, is given by

$1+f = (1+g)(1+h)$

In other words, the growth rate of sectoral expenditure on R&D can be deconstructed into the exogenous GDP growth factor and the human capital policy factor, the ratio of sectoral expenditure on R&D to GDP. The deconstruction shows how the possible outcomes of the two scenario dimensions affect the growth rates of sectoral expenditure on R&D. Notice that the effect of the growth of GDP on RSE employment is only indirect: it is the combination of GDP growth and human capital policy which determines the growth of R&D expenditure. Human capital policy is defined as R&D expenditure as a percentage of GDP, which is a matter of definition: it is not a causal relationship. Although it is possible to consider scenarios where the exogenous dimension plays no role and R&D expenditure is completely unrelated to the economic situation of the country, it is more plausible to assume that in a prosperous economy there will be more funds available for R&D expenditure. Analogously, in a stagnating economy it may be difficult to raise more funds for R&D expenditure. Therefore we use the deconstruction of the two scenario dimensions to study the interaction of the human capital policy (R&D expenditure relative to the economic situation) and the exogenous dimension (the economic situation). The advantage of this approach is that R&D expenditure is placed in the context of the economic prosperity of each Member State.

The expansion demand forecasting model directly translates these growth rates of R&D expenditure into forecasts of RSE employment. From these forecasts, we can infer the expansion demand for RSEs in each of the three sectors in the 14 Member States. The growth rates of sectoral R&D expenditure under the four scenarios follow from Table A2.9 and Tables A2.12-14 via the deconstruction.

A2.5.3 Replacement demand

The four scenario paths for sectoral R&D expenditure affect replacement demand via the outflow-coefficients. Time series data on outflow-coefficients for RSEs in the 14 Member States are not available. The available data, the IES Survey of R&D Establishments, refer to a single moment in time. This means that we do not have insight into the time series variation of the outflow-coefficients. In order to capture the order of magnitude of the temporal variation of outflow-coefficients, we use the effective age of retirement. Even without scenarios (*ie* in case of extrapolation of current trends), we already would have to use the oldest cohort of RSEs to correct for the under-reporting of outflow in the IES Survey, based on the effective age of retirement. In addition, the oldest cohort of RSEs provides an easily interpretable measure of high and low outflow. We will assume that high outflow corresponds with an effective retirement age of 62 years, while low outflow will be associated with an effective retirement age of 65 years. This gives a straightforward interpretation for the low GDP growth — low human capital growth — scenario (high outflow = 62 years) and for the high GDP growth — high human capital growth — scenario (low outflow = 65 years). A natural interpretation of the two other scenarios can then be based on the sectoral R&D expenditure. The effective retirement age for the high GDP growth — low human capital growth — scenario is:

$$62 years + \frac{(1+g_H)(1+h_L)-(1+g_L)(1+h_L)}{(1+g_H)(1+h_H)-(1+g_L)(1+h_L)} 3 years$$

where g_H (g_L) denotes the high (low) GDP growth rate and h_H (h_L) denotes the high (low) growth rate of the ratio of sectoral R&D expenditure to GDP. We use the average growth rates of GDP and R&D expenditure, since the replacement demand model is (due to data limitations) based on replacement in a period of five years. Analogously, the effective retirement age for the low GDP growth — high human capital growth policy scenario is:

$$62 years + \frac{(1+g_L)(1+h_H)-(1+g_L)(1+h_L)}{(1+g_H)(1+h_H)-(1+g_L)(1+h_L)} 3 years$$

Notice that similar formulas for the high-high and the low-low scenarios yield 65 years and 62 years respectively. From the effective retirement age, we calculate the scenario-outflow-coefficients for the oldest age cohort. The multiplication factor, which is needed to scale up the original survey-outflow-coefficient of the oldest age cohort to the scenario-outflow-coefficient of the oldest age cohort, is then used to scale up the survey-outflow-coefficients of the other age cohorts. Notice that the multiplication factor reflects both the correction for the under-reporting of outflow and the impact of the scenario.

It is obvious that the availability of data on the R&D labour force should improve. The IES Survey of R&D Establishments is a step in the right direction, but such surveys should be held at a regular basis. There also remain issues of low response and under-reporting. In this pilot study, we dealt with the low response by making plausible assumptions on the country-specificity of the age structure. In addition, we have tried to correct for under-reporting by easily interpretable assumptions on the effective age of retirement, which at the same time can be used to translate the scenario's into outflow-coefficients.

The type of assumptions that were made to deal with the low response and under-reporting, make it difficult to give reliability estimates of the outflow-coefficients and age structure that are used in the scenario forecasts. As a matter of fact, even the confidence intervals of the survey estimates are impossible to obtain (see Table A1.4 of Annex 1). The analysis in Annex 1 nevertheless indicates that the overall sample is fairly representative of the R&D establishments in each country and overall representative at the sectoral level. However, the survey estimates for Italy are suspect as the low response rate seemed to have worked against the stratification procedure.

A2.5.4 Inflow

Due to the poor quality of the available First Destination Data of S&T graduates in the European Union, we have to base the inflow-coefficients on RSE employment data. The inflow-coefficients are derived in two steps.

The first step we take in the inflow-analysis is to derive the maximum inflow coefficient based on past observations. New RSEs flow into job openings arise either from expansion demand or from replacement demand. The flow into expansion demand related ‘new jobs’ can be observed from relative changes in RSE employment (headcounts, by field of study). Since the observation period can be compared best with the low GDP growth/high human capital growth scenario, we can use forecasts of the demand side under this scenario to get an idea of the relative size of expansion demand and replacement demand during the observation period. The results indicate that replacement demand is about a third of all job openings. Hence, the maximum inflow coefficient during the observation period can roughly be approximated as 1.5 times the maximum expansion demand inflow coefficient.

The second step is to relate the inflow-coefficients for the different scenarios in the forecasting period to the maximum inflow-coefficient of the observation period. The lack of data on (relative) wages makes it difficult to estimate the relative magnitude of the inflow-coefficients in the four scenarios. As an approximation, we assume that the inflow-coefficient in period t evolves according to:

$I_t = (1 + h_t - g_t)\, I_{t-1}\ t = 1998, \ldots, 2002$

where I_{1997} is the maximum inflow-coefficient of the observation period and h_t and g_t are the growth rates of real ERD/GDP and real GDP under the specific scenario. Notice that the observations are the net results of demand and supply interactions. Hence, we use the maximum inflow coefficients of the observation period to approximate the potential RSE inflow.

Obviously, the availability and quality of First Destination Data on S&T graduates is a problem for modelling the inflow of RSEs. In this pilot study, we have made some strong assumptions in order to compensate for the lack of reliable data. In fact, it can be argued that the assumptions themselves require empirical study.

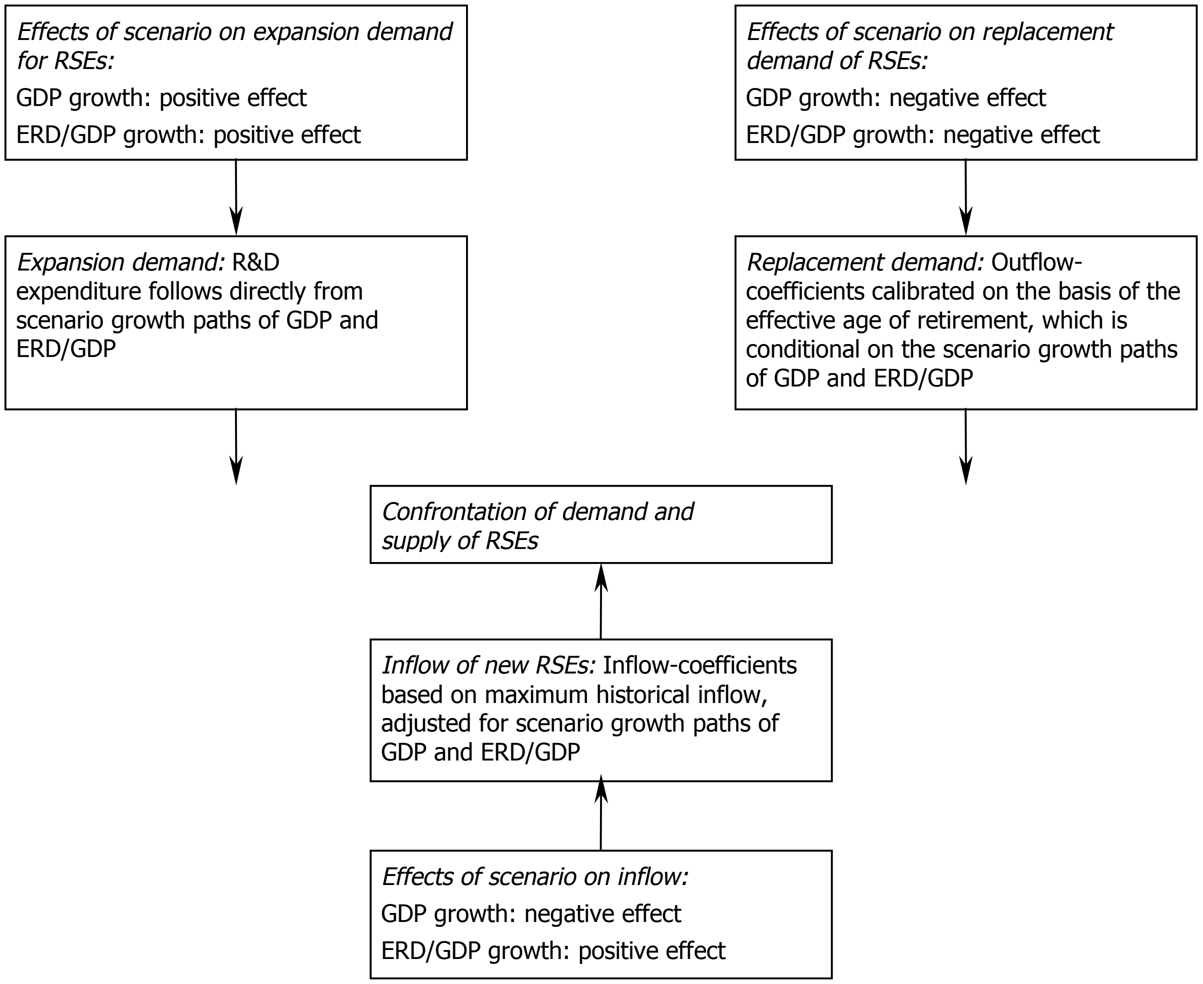
However, the appropriate way to deal with these problems is to improve the collection of data on this crucial segment of the labour market.

Figure A2.2 provides a summary of the forecasting system that has been developed in this pilot study, featuring the main assumptions that have been made to translate scenarios into demand and supply effects.

A2.6 Forecasts

The forecasts for the demand and supply side of the labour markets for new RSEs in the Member States of the European Union to 2002 are compiled in Tables A2.17-A2.76. Each table corresponds with the labour market for new RSEs in one of four fields of study in a specific Member State. Each row of the table corresponds with one of the four scenarios. In each row the three key numbers in assessing the quantitative adequacy of the education system of the Member State are given. The first column ('job openings for RSEs') is the number of job openings (head-

Figure A2.2: Summary of the forecasting system with its main assumptions



Source: ROA

counts, not full-time equivalents) for RSEs in this field of study between 1997 and 2002. The second column ('inflow of new RSEs') gives the forecast supply of new RSEs in this field of study. The third column ('flow of new S&T graduates') displays the number of new S&T graduates in this field of study.

The difference between the second and the third column can be explained as follows. The types of jobs that a S&T graduate can apply for can roughly be classified in two categories: RSE-jobs and non-RSE jobs. Not every S&T graduate has the abilities or ambitions to get an RSE-job. On this point, moreover, there are large differences between the fields of study distinguished. For an assessment of the quantitative adequacy of the education system to produce sufficient numbers of new RSEs, obviously only the fraction of new S&T graduates that will apply for RSE-jobs is relevant. This can be done by comparing the first column ('job openings for RSEs') and the second column ('inflow of new RSEs'). In fact, we have indicated forecast shortages of RSEs by adding asterisks to the second column. However, the third column ('flow of new S&T graduates') provides additional information on the **potential pool of graduates** that can be attracted to RSE jobs under different wages and other job characteristics. (If even this pool is smaller than the number of job openings, we have added asterisks to the third column.) Of course, there will always be considerable numbers of 'competitive' non-RSE-jobs for S&T-graduates outside the R&D-sector. Therefore, it is unrealistic to consider a large increase of the percentage of S&T graduates that applies for an RSE job as an easy option.

These forecasts should, however, be interpreted as ex-ante forecasts. In practice, labour markets will exhibit adjustment processes that will bring the difference between labour demand and supply down. This does not mean that there will be no ex-post shortages. It also does not mean that ex-ante shortages matter less: adjustment processes often require high costs. Adjustment processes may take place within the labour market for RSEs of a specific field of study, between labour markets for RSEs with different fields of study and between labour markets for RSEs in different countries. The main report discusses potential adjustment processes, several are considered again here.

An important adjustment process on the **demand side** of the labour market for RSEs with a specific field of study is the time spent by RSEs on non-R&D tasks. The ratio of headcount to full-time-equivalent indicates the scope for a reduction of the time spent on R&D. Such a reduction would require a reorganisation of R&D and non-R&D tasks, such that activities which specifically require for example natural scientists are performed by natural scientists. Workers with other qualifications (lower level of education or other field of study) can be recruited to perform the non-R&D tasks. This adjustment process is particularly relevant for the higher education sector where a considerable part of the working time is spent on teaching. Another example of this adjustment process can be found in the IT sector, where academically trained IT-graduates focus on tasks which require a thorough academic background in information technology, while workers which have other educational backgrounds perform activities which require less formal training. When the ex-ante shortage is not too large, this adjustment process may reduce the number of job openings in the ex-post situation to match the level of RSE inflow. A closely related adjustment process is an increase in total working hours, by stimulating overtime of qualified RSEs. Other adjustment strategies that employers may follow to reduce shortages include improved management, substituting physical capital for human capital and even reducing R&D-activities (see *eg* Borghans, De Grip and Van Smoorenburg, 1998).

Adjustment processes may also take place on the **supply side** of the labour market for RSEs with a specific field of study. When the ratio of RSE inflow to total flow of S&T graduates is relatively small, there may be a hidden potential of S&T graduates who do not yet apply for RSE jobs in the ex-ante situation, but who may decide to do so in the ex-post situation. Motives may be the good employment opportunities as an RSE or changing job preferences induced by for example promotional campaigns. Of course, higher wages may also be used to attract more RSEs. However, one might wonder if the productivity of these workers in RSE jobs is at the same level as the productivity of the S&T graduates with a higher preference for RSE jobs. An additional pool of S&T graduates from which new RSEs may be recruited is the unemployed. Since the supply forecasts refer to the total flow of S&T graduates from 1997 to 2002, the relevant figure is the number of unemployed S&T graduates in 1997. However, according to the labour queue theory (Thurow, 1975), a longer duration of unemployment, on average implies a lower quality of the unemployed S&T graduate. In addition, there may be a loss of skills. Hence, both supply side adjustments may be accompanied by a loss in quality and productivity.

An additional adjustment process may take place **between labour markets for RSEs with different fields of study**. An important opportunity is the similarity between certain natural science curricula and technology and engineering curricula. For example, a shortage of chemistry RSEs (natural scientists) may be alleviated by an excess supply of chemical engineering RSEs (technology and engineering). From the demand side, this would probably entail a reorganisation of the R&D tasks of natural scientists and on the supply side, it implies that graduates are willing to work outside their field of study.

Another adjustment process that may take place is **international labour mobility**. A shortage of natural scientists in one Member State may be reduced by an excess supply of natural scientists from another. Of course, this requires a fully integrated European labour market with a geographically mobile labour force. However, in practice there often are various barriers to mobility such as mutual recognition of educational qualifications, geographical distance, differences in language and culture and fiscal differences. On the other hand, within-company mobility may facilitate international mobility. Incentives for international migration are differences in wages and benefits. After the full introduction of the Euro the lack of transparency of the real wage differentials will decrease, which will probably further facilitate international mobility.

In many instances, international labour mobility may be a considerably less costly adjustment mechanism than the intra-national adjustment mechanisms. According to human capital theory (Mincer, 1958, Schultz, 1961, Becker, 1962), it is an adjustment mechanism that is especially suited for young S&T graduates. Young people have a longer period to write off the costs of moving to another country, while S&T graduates have a large knowledge potential which can generate a high income path (Hansen, Heinrich and Nielsen, 1992). In addition, international mobility within a multinational firm often relates to higher educated staff.

It is however important to recognise that there are costs both for the demand side and the supply side of the labour market associated with all these adjustment processes. If an ex-ante shortage does not materialise as an (equally large) ex-post shortage due to the adjustment processes described above, this does not mean that the manpower problems are overestimated by the ex-ante shortage. The reduction from the ex-ante shortage to the ex-post shortage has come at a cost, which in some cases can be considerable. So the ex-ante shortage provides a general indication of the problems associated with the lack of balance between labour demand and supply.

The aggregated results for the **European Union** are described in Tables A2.17-A2.20. These results are simply obtained by adding up the demand and supply in the 14 Member States. This means that we did not build an aggregate model for the European Union as a whole. In each of the four fields of study, the forecast inflow of new RSEs exceeds the number of job openings for RSEs, no matter which scenario will unfold between 1997 and 2002. In other words, under perfect labour mobility within the European Union, the higher education systems of the Member States produce adequate numbers of S&T graduates to meet the demand for new RSEs to 2002.

The results for the various Member States are described in Tables A2.21 onwards. We can distinguish between three groups of countries with respect to the capacity of the national education systems to produce adequate numbers of S&T-graduates to meet the demands for new RSEs.

The first group consists of the countries that are not expected to have any problems up to 2002: Belgium, Greece, Spain, Finland and the United Kingdom.

The second group, France and Portugal, are expected to face RSE shortages in case of the high GDP growth/high human capital growth scenario.

France is expected to face shortages of natural science RSEs in case of a high human capital growth policy. However, since the ratio of inflow to job openings is relatively large, 0.96 in case of low GDP growth and 0.88 in case of high GDP growth, adjustments on the demand side of the labour market which reduce the average time spent by natural science RSEs on non-R&D tasks by four per cent respectively by 12 per cent, would shrink the number of job openings to match the RSE inflow. An increase in total working hours could also be an instrument to reduce personnel shortages. In addition, on the supply side of the labour market for technology and engineering RSEs, a large excess inflow is forecast, which could also contribute to solving the shortages of natural science RSEs. Hence, the ex-ante shortages will probably not materialise in ex-post shortages, due to adjustment processes on the demand and the supply side.

Portugal is expected to face shortages of natural science RSEs in case of a high human capital growth policy. The ratio of inflow to job openings is 0.95 in case of low GDP growth and 0.89 in case of high GDP growth. This means that an average reduction of 5per cent respectively 11 per cent of non-R&D activities performed by natural science RSEs could bring the number of job openings down to the level of RSE inflow. An increase in overtime is probably also be an effective instrument to accomplish a balanced labour market. The excess inflow of technology and engineering RSEs may also contribute to alleviating the manpower problems with natural science RSEs. Therefore, the shortages of natural science RSEs in Portugal should be manageable. Under the high GDP growth — high human capital growth — scenario, Portugal is also expected to experience shortages of medical science RSEs. Given the ratio of inflow to job openings of 0.93, a seven per cent reduction of time spent by medical science RSEs on non-R&D tasks, would bring the labour market for new medical science RSEs in (ex-post) equilibrium. Alternatively, increased overtime could play a role in reducing the shortage.

The scenario results indicate that France and Portugal will not experience any shortages in the case of a low human capital growth policy. A policy of zero-growth of public expenditure on R&D will avoid the emergence of RSE shortages up to 2002 in France and Portugal. Finally, in none of the scenarios will France or Portugal face RSE shortages in the fields of technology and engineering, and agricultural sciences.

The third group of Member States, Denmark, Germany, Ireland, Italy, the Netherlands, Austria and Sweden, is expected to face shortages under all four scenarios.

Denmark is expected to experience shortages of natural scientists under all scenarios. Even if the public expenditure on R&D is frozen at the current fraction of GDP, the expected rate of GDP growth will drive up the absolute level of R&D expenditure at a rate that causes demand for natural scientists to rise too fast for the inflow of new RSEs from the education system to keep up. In fact, the number of job openings is even larger than the total flow of new S&T graduates, so job choice adjustments in favour of the RSE jobs will not be able to meet the excess demand. There is also only limited room for adjustment on the demand side, on average a mere seven per cent of the working hours of natural science RSEs are spent on non-R&D tasks. At the same time, considerable excess supplies of new RSEs in the field of technology and engineering are forecast for Denmark. The Danish forecasts for the high GDP growth/high human capital growth scenario yield the largest shortage for natural science RSEs: 3,800. However, the excess supply of technology and engineering RSEs under this scenario is 9,900. Consequently, if about 40 per cent of this excess inflow can be recruited to meet the demands for natural scientists, then the shortage of natural scientists would be eliminated. Probably, this entails a reorganisation of tasks between natural science RSEs with an educational background in natural sciences and natural science RSEs with a technology and engineering background. However, using more than a third of the excess supply of technology and engineering RSEs to fill natural science RSE jobs would also probably be very difficult. So for Denmark, the ex-ante shortages of natural science RSEs are expected to materialise in problematic ex-post shortages under all scenarios. An inflow of natural science RSEs from abroad may be a solution to this problem. International labour mobility will be discussed separately after we have discussed the forecasts for the individual Member States.

Germany is expected to face a shortage of natural science RSEs under all scenarios. Even if natural science RSEs would perform R&D-activities full-time, which is very unlikely, the number of job openings would still exceed the RSE inflow. Even under the high GDP growth/low human capital growth scenario, which is expected to yield the smallest discrepancy, such a reduction of non-R&D tasks would bring down the job openings to 121,400, which leaves a shortage of 9,900. At the same time, under this scenario, there is an excess supply of 30,500 technology and science RSEs forecast for Germany, which could also contribute to alleviating the manpower problems for natural science RSEs, although a full elimination of the shortage of natural science RSEs seems unlikely. In the two scenarios with a high human capital growth policy, the problems are even more severe. The number of job openings for natural science RSEs even exceeds the total flow of new S&T graduates. At the same time the excess supply of new technology and engineering RSEs is smaller and offers therefore fewer opportunities for substitution. In these two scenarios there is also expected to be a shortage of medical science RSEs. However, the ratio of inflow to job openings for medical science RSEs is rather high. In the high GDP growth — high human capital — scenario this ratio is 0.92, which means an eight per cent reduction of non-R&D activities would suffice to eliminate the ex-ante shortage. An increase in overtime may also contribute to reduce the ex-ante shortage. So for Germany the main problems are expected for natural sciences, while the shortages for medical science RSEs under the high human capital scenarios should be manageable. In order to avoid a rationing of R&D activities in Germany, an inflow of foreign natural science RSEs seems necessary.

The forecasts for **Ireland** indicate shortages of medical science RSEs. Under the two low human capital growth scenarios, the ratio of inflow to job openings are 0.74 in case of high GDP growth and 0.78 in case of low GDP growth. This means that an average reduction of 26 per cent respectively 22 per cent of non-R&D tasks by medical science RSEs would reduce the job openings enough to match inflow. Given the relatively high average head-counts to FTE ratio, there is room for a considerable reduction of hours spent on non-R&D tasks. In addition, an increase in total working hours may help to reduce the ex-ante shortage. A complete solution of ex-ante shortages may however not be feasible. Under the high human capital growth scenarios, the required adjustment processes on the demand side are not feasible, since it would require a full elimination of all non-R&D tasks of medical science RSEs. However, as far as shortages occur in biomedical R&D, the excess supply of technology and engineering RSEs could contribute to reduce the shortages of medical RSEs. To summarise, Ireland is expected to face shortages of medical science RSEs that are especially severe under the high human capital growth scenarios. It is therefore very likely that R&D activities will have to be rationed, unless an inflow of foreign medical science RSEs can take place. This issue will be discussed later.

Italy is also expected to experience shortages of medical science RSEs under all scenarios. The ratio of inflow to job openings is rather high and varies between 0.85 and 0.93 depending on the prevailing scenario. This means that reductions between seven per cent and 15 per cent of non-R&D activities by medical science RSEs would bring the labour market in equilibrium. Increasing overtime may also help to avoid shortages. Therefore, the expected shortages of medical science RSEs in Italy do not seem severe.

The forecasts for the **Netherlands** indicate RSE shortages for both natural sciences and medical sciences under all four scenarios. The recruitment problems for natural sciences are expected to be most serious, because the number of job openings even by far exceed the total number of S&T graduates. The ratio of inflow to job openings varies between 0.31 and 0.40, depending on the scenario. This means that a reduction of hours spent by natural science RSEs on non-R&D tasks will not be an effective instrument to achieve labour market equilibrium. The excess supplies of technology and engineering RSEs can also only make a modest contribution to alleviating the recruitment problems for natural science RSEs. The recruitment problems for medical science RSEs are less extreme, but considerable ex-post shortages are still likely. Under the low GDP growth — low human capital growth — scenario it would require a 38 per cent reduction of R&D-tasks performed by medical science RSEs to bring down the number of job openings to the level of inflow. Under the other three scenarios, the ratio of inflow to job openings is too low for this adjustment process — even in theory — to balance the labour market. Therefore, any feasible reduction of hours spent on non-R&D tasks will only contribute modestly to the expected recruitment problems for medical science RSEs in the Netherlands. Increasing overtime will also make no more than a modest contribution to reduce the shortage. The ratio of inflow into RSE jobs to the total supply of new S&T graduates in medical sciences which in the Netherlands varies between 0.15 and 0.18, suggests that it may be possible to attract more medical science graduates who in the ex-ante situation do not apply for RSE jobs, but it will not eliminate the shortages. In addition, the excess supply of technology and engineering graduates may contribute to reducing the recruitment problems as far as the shortages for medical science RSEs occur in biomedical research. So in the Netherlands, shortages of natural science RSEs and medical science RSEs are expected. Unless there is an inflow of natural science and medical science RSEs from abroad, a rationing of R&D-activities in the Netherlands seems unavoidable.

Austria is expected to have RSE shortages in the fields of natural sciences and medical sciences under all scenarios. The largest problem with natural science RSEs occurs under the high GDP growth — high human capital growth - scenario. The ratio of the inflow of new RSEs (8,100) to the job openings for RSEs (9,300) is 0.87, which means that a 13 per cent reduction of the time spent on non-R&D-activities by natural science RSEs would reduce labour demand enough to eliminate the shortages. In addition, there is an excess supply of technology and engineering RSEs, which could also be recruited to solve the shortages of natural science RSEs. Therefore, the manpower problems for natural science RSEs should be manageable. The shortages for medical science RSEs are expected to be more serious, even in case of the smallest discrepancy, which occurs under the low GDP growth — low human capital growth — scenario. The number of job openings could at most be reduced from 5,700 to 3,800 if all medical science RSEs would perform R&D activities full-time, which is still too much to be filled by the inflow of 2,100 new RSEs. Increasing overtime will also be of limited effect in reducing the shortage. Since the ratio of RSE inflow to the total flow of S&T graduates is already high, adjustments on the supply side do not offer much help either. Austria is therefore expected to face serious shortages of medical science RSEs that cannot be solved without an inflow of medical science RSEs from abroad.

For **Sweden,** shortages are expected in all fields of study under all scenarios. However, in Sweden there is considerable room for adjustment on both the demand and the supply sides to solve the expected recruitment problems. For natural sciences, technology and engineering, and medical sciences the ratios of inflow to job openings are relatively large. For example, under the high GDP growth — low human capital growth scenario, these ratios are 0.92, 0.95 and 0.81 respectively. This means a reduction of five per cent to 19 per cent of non-R&D activities by natural science RSEs, technology and engineering RSEs and medical science RSEs respectively, would bring down the numbers of job openings to match the inflow of RSEs. An increase in overtime may also be an effective instrument to solve the recruitment problems. For agricultural sciences adjustments on the demand side will not suffice since the ratio of inflow to job openings is low, for example 0.22 under the high GDP growth — low human capital growth — scenario. The supply side offers considerably more opportunities as the ratio of the RSE jobs inflow to the total number of new S&T graduates is low (0.19) under that same scenario. This means that it might be possible to divert more S&T graduates to RSE jobs if competitive job offers are made. Under the high GDP growth/low human capital growth scenario, it would be sufficient if 4,300 of the 62,200 S&T graduates who do not apply for RSE jobs in the ex-ante situation — this is only seven per cent — would apply for RSE jobs in the ex-post situation.

The forecasts can be summarised as follows (see also Table A2.16, columns 2-3). There are no shortages of RSEs expected for Belgium, Finland, Greece, Spain and the United Kingdom. France and Portugal may face some shortages under a high human capital growth policy, but these problems are mild and should be manageable by adjustment processes on the demand and supply side. Italy is expected to experience manageable shortages of medical science RSEs under all scenarios. For Sweden shortages are expected in all fields in all scenarios, but they could be solved by adjustments on the demand side (natural sciences, technology and engineering, medical sciences) and the supply side (agricultural sciences). Ireland is expected to face serious shortages of medical science RSEs, especially under high human capital growth scenarios. For Austria, shortages of medical science RSEs are expected, while shortages of natural science RSEs are less severe due to adequate adjustment opportunities. The forecasts for Germany indicate serious shortages of natural science RSEs. Moreover, under the two high human capital growth scenarios, mild shortages of medical science RSEs are expected but these problems should be manageable. Denmark is expected to have serious shortages of natural science RSEs under all scenarios. For the Netherlands, considerable shortages of natural science RSEs and — to a lesser extent — medical science RSEs are expected.

In the discussion of the forecasts so far, we have focused on the ability of the labour markets of the Member States to reduce the expected shortages, if any, by adjustment processes on the demand side and the supply side within the national labour market. We have seen that not all countries may be able to deal with the RSE manpower problems themselves, specifically Ireland, Austria, Germany, Denmark and the Netherlands. This means that there are opportunities for international labour mobility, since we already saw that there are no shortages expected for the European Union as a whole. The forecasts therefore emphasise the importance of European labour market integration. The shortages of medical science RSEs in Ireland are relatively small compared with the excess supply of medical

Table A2.16: Overview of expected RSE shortages and effectiveness of adjustment processes

Country	Projected RSE shortages	Effectiveness of domestic adjustment processes	Possible sources of RSE inflow from other Member States
Belgium	None		
Denmark	Natural sciences	limited	Greece, Spain, Italy
Germany	Natural sciences medical sciences	limited sufficient	Greece, Spain, Italy
Greece	None		
Spain	None		
France	Natural sciences	sufficient	
Ireland	Medical sciences	limited	United Kingdom
Italy	Medical sciences	sufficient	
Netherlands	Natural sciences medical sciences	limited limited	Greece, Spain, Italy France
Austria	Natural sciences medical sciences	sufficient limited	 France
Portugal	Natural scineces	Sufficient	
Finland	None		
Sweden	Natural sciences technology & engineering medical sciences agricultural sciences	Sufficient sufficient sufficient sufficient	
United Kingdom	None		

Source: ROA

science RSEs in the United Kingdom in all scenarios, except the high GDP growth — high human capital growth — scenario. Given the short distance, cultural similarity and absence of language problems between Ireland and the United Kingdom, the mobility of medical science RSEs from the latter country to the first would solve the shortages in Ireland. The shortages of medical science RSEs in Austria and the Netherlands can also be solved by mobility from countries with excess supplies, especially France. The shortage of natural science RSEs in Germany are considerable, but countries like Greece, Spain and Italy have considerable excess supplies of graduates with the required educational backgrounds which could fill the job openings. These countries could also contribute to solving the shortages for natural science RSEs in Denmark and the Netherlands.

Table A2.16 provides an overview of the expected RSE shortages in the various Member States (second column), the effectiveness of intra-national adjustment processes (third column) and the suggested international RSE flows that could solve the most serious shortages (fourth column).

Of course, international labour mobility is not only important in case of the inability of certain Member States to solve their own RSE manpower problems. It may also be a cheaper alternative to costly intra-national adjustment processes in a Member State facing shortages of RSEs. For example, while Sweden is expected to face mild shortages in all fields of study distinguished, Finland has excess supplies in all fields. Since Sweden and Finland are neighbouring countries and many Finnish people have a good grasp of the Swedish language, the mobility of Finnish RSEs to Sweden would be an answer to the shortages in Sweden, without the costs associated with intra-national adjustment processes.

A2.7 Conclusion

This pilot study has explored the possibilities of developing a forecasting model for the RSE labour markets in the Member States of the European Union to provide an important tool in the assessment of the quantitative adequacy of the European education systems relative to S&T employment needs. As a pilot study, a forecasting model was developed which tracks the relevant flows entering and leaving the labour market for RSEs the period 1997-2002, based on the available data up to 1997. The main problems in the development of the forecasting model were the availability of relevant data on RSEs and the often poor quality of the data that were available. As a result, the empirical foundation of the model showed gaps. Some of the gaps were filled in by the *IES Survey of R&D Establishments*, while other gaps had to be closed on the basis of assumptions and approximations. It is therefore essential for any future modelling of the labour market for RSEs in the European Union, that the availability and quality of data on RSEs is improved.

The problems were particularly evident in the replacement demand component and the inflow component of the model. In order to obtain more reliable replacement demand forecasts, it would be very useful if **RSE labour force surveys** — such as the *IES Survey of R&D Establishments* — are performed on a regular basis. In particular, time series data on the composition of the RSE labour force by age and gender would provide a better insight in the outflows of RSEs. Ideally, we would like to have gross flow data indicating whether outflow is due to retirement, job-to-job mobility within the same country or out of the country. In order to get better forecasts of the labour market inflow of RSEs, it is important that the **First Destination Data on S&T graduates** improve. A particularly important item in a First Destination survey would be the question whether the respondent has considered applying for an RSE job. This would give a better estimation of the RSE inflow of S&T graduates than the number of S&T graduates who actually got RSE jobs.

The forecasting model was used to generate forecasts of the demand and supply side of the labour markets for RSEs in the Member States of the EU up to 2002, under four scenarios.

It is important to emphasise that these forecasts are not yet suitable for policy purposes. The main purpose is to show the potential features of an early warning system for bottlenecks in the labour markets for RSEs that play a crucial role in the European knowledge economy.

The scenarios were designed to capture both the policy options with respect to human capital development and the uncertainty with respect to economic growth. This interaction of a policy dimension and an exogenous dimension, enables us to get an idea of the effects of human capital policies in the EU in case of both high and low growth paths of the world economy. In this way, the scenarios provide a 'policy-rich' analysis of the labour markets for RSEs in the various EU Member States up to 2002. The combination of an exogenous dimension and a policy dimension also offers a consistent way of building scenarios, instead of making *ad hoc* assumptions on the various components of the model.

The forecasting results indicated shortages of RSEs in various Member States of the EU. The forecasts for Ireland indicate serious shortages of medical science RSEs, especially under high human capital growth scenarios. For Austria, shortages of medical science RSEs are expected. The forecasts for Germany indicate serious shortages of natural science RSEs. Denmark is expected to have serious shortages of natural science RSEs under all scenarios. For the Netherlands, considerable shortages of natural science RSEs and — to a lesser extent — medical science RSEs are expected.

The forecasting results show that for the European Union as a whole, the forecast inflow of new RSEs exceeds the number of job openings for RSEs, in each of the four fields of study distinguished, no matter which scenario will unfold between 1997 and 2002. In other words, under perfect labour mobility within the European Union, the higher education systems of the Member States produce adequate numbers of S&T graduates to meet the demand for new RSEs to 2002. This implies that as far as the adjustment processes of the national labour markets for RSEs are unable to eliminate the shortages, inflow of RSEs from other Member States of the EU could balance RSE demand and supply in the country which faces a shortage.

In particular, countries in which considerable excess supplies of natural science RSEs are expected are Greece, Spain and Italy, while the forecasts for France indicate a large excess supply of medical science RSEs. Inflow of RSEs from a country with an excess supply to a country with a severe shortage would reduce the discrepancy between demand and supply on the labour markets for RSEs in both countries. International labour mobility facilitates the balance between demand and supply on the labour market for RSEs in each Member State of the EU. In fact, this even holds for countries that could achieve equilibrium on the labour market for RSEs without inflow from other countries. Often international mobility is a less costly alternative to domestic adjustment mechanisms. For example, the mild shortages, which are expected for Sweden, could be solved by inflow of RSEs from Finland.

For future research it is essential that the availability and quality of data improve, especially the first destination data on S&T graduates and labour force surveys on R&D personnel. Important topics that should be studied are the flexibility of the labour markets for R&D personnel in the European Union and the international mobility of R&D workers. A possibly interesting data source on S&T graduates is the survey developed in the CHEERS project within the TSER program of DGXII. The CHEERS data give information on the destination of university graduates in various EU Member States: Germany, Spain, France, Italy, the Netherlands, Austria, Finland, Sweden and the United Kingdom.

Better insight into the flows of R&D workers between Member States of the European Union, but also flows into and out of the European Union is crucial, both from the perspective of technology policy and from the perspective of educational policies. Therefore, it is important to collect **data on the flows of R&D workers between countries** within and outside the European Union.

Moreover, a deeper understanding is needed of the interaction between the demand side and the supply side of the labour market, both in the short run when the supply of R&D workers is relatively inelastic, and in the long run when educational choices of students may lead to larger changes in the supply of R&D workers. For further study of the interaction between demand and supply, it is important to have **data on wages of R&D workers**. As a first approximation, establishing which part of R&D expenditure is allocated to gross wage expenditures is a step in the right direction. Such data are available for the Netherlands and have been used to investigate the dynamics of the Dutch labour market for R&D workers (Marey and Borghans, 2000). With these data, it is possible to distinguish between the demand effects and the supply effects of R&D expenditure on R&D activities, both in the short run and in the long run. A large accumulation of human capital is embodied in R&D workers, which takes many years of education and training. As a consequence, the supply of R&D workers may be very inelastic in the short run. From a policy perspective, it is therefore important to get insight in the reaction of the supply of R&D workers and their wages to an increase in R&D expenditure. These elasticities of supply determine the limits to public intervention in the R&D market. The results for the Netherlands can be summarised as follows. In the short run, the small short-term wage elasticity of supply in the Netherlands is compensated by relatively large wage increases. In the long run, the sensitivity of the supply side improves, hence the same increase in employment is achieved by relatively small wage increases.

This pilot study explored the possibilities of quantifying the labour markets for research scientists and engineers in the European Union, in particular with the aim of assessing the adequacy of the education systems relative to S&T employment needs. It revealed the limitations of the currently available data and where new data and improved data are needed. It also suggested topics for further research on the labour market for R&D workers, which is of crucial importance for the knowledge-based economy of the next century. As such the forecasts are not yet suitable for policy purposes. Their main value is to show the potential features of an early warning system for bottlenecks in the labour markets for RSEs that play a crucial role in the European knowledge economy.

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DETAILED TABLES, BY COUNTRY

European Union

Table A2.17: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	461,500	776,700	1,199,600
High GDP growth low human capital	481,700	752,700	1,199,600
Low GDP growth high human capital	608,500	870,100	1,199,600
High GDP growth high human capital	640,200	849,000	1,199,600

Source: ROA

Table A2.18: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	341,600	800,700	2,306,700
High GDP growth low human capital	356,600	776,000	2,306,700
Low GDP growth high human capital	449,800	915,900	2,306,700
High GDP growth high human capital	473,100	888,500	2,306,700

Source: ROA

Table A2.19: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	220,700	279,000	1,782,100
High GDP growth low human capital	229,700	270,400	1,782,100
Low GDP growth high human capital	288,800	317,500	1,782,100
High GDP growth high human capital	303,600	307,800	1,782,100

Source: ROA

Table A2.20: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	75,000	122,300	325,700
High GDP growth low human capital	78,100	118,600	325,700
Low GDP growth high human capital	97,300	140,400	325,700
High GDP growth high human capital	102,300	136,100	325,700

Source: ROA

Belgium

Table A2.21: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	11,900	19,900	24,500
High GDP growth low human capital	12,700	19,300	24,500
Low GDP growth high human capital	14,000	20,800	24,500
High GDP growth high human capital	15,000	20,200	24,500

Source: ROA

Table A2.22: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	9,100	29,000	75,600
High GDP growth low human capital	9,800	28,100	75,600
Low GDP growth high human capital	10,800	30,400	75,600
High GDP growth high human capital	11,500	29,400	75,600

Source: ROA

Table A2.23: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	5,000	9,300	56,100
High GDP growth low human capital	5,300	9,000	56,100
Low GDP growth high human capital	5,900	9,800	56,100
High GDP growth high human capital	6,300	9,500	56,100

Source: ROA

Table A2.24: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	1,700	4,700	11,500
High GDP growth low human capital	1,800	4,500	11,500
Low GDP growth high human capital	2,000	4,900	11,500
High GDP growth high human capital	2,100	4,800	11,500

Source: ROA

Denmark

Table A2.25: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	6,100	4,400*	5,000*
High GDP growth low human capital	6,300	4,300*	5,000*
Low GDP growth high human capital	7,700	4,400*	5,000*
High GDP growth high human capital	8,200	4,400*	5,000*

Source: ROA

Table A2.26: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	3,500	13,000	36,800
High GDP growth low human capital	3,600	12,600	36,800
Low GDP growth high human capital	4,400	15,000	36,800
High GDP growth high human capital	4,600	14,500	36,800

Source: ROA

Table A2.27: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	2,300	3,800	24,100
High GDP growth low human capital	2,300	3,700	24,100
Low GDP growth high human capital	2,900	4,400	24,100
High GDP growth high human capital	3,000	4,300	24,100

Source: ROA

Table A2.28: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	1,500	2,000	3,500
High GDP growth low human capital	1,500	2,000	3,500
Low GDP growth high human capital	1,900	2,300	3,500
High GDP growth high human capital	2,000	2,200	3,500

Source: ROA

Germany

Table A2.29: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	162,500	115,000*	182,200
High GDP growth low human capital	165,100	111,500*	182,200
Low GDP growth high human capital	190,900	122,600*	182,200*
High GDP growth high human capital	194,600	118,900*	182,200*

Source: ROA

Table A2.30: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	124,700	162,100	501,000
High GDP growth low human capital	126,700	157,200	501,000
Low GDP growth high human capital	146,500	172,800	501,000
High GDP growth high human capital	149,400	167,700	501,000

Source: ROA

Table A2.31: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	68,000	72,300	375,700
High GDP growth low human capital	69,100	70,100	375,700
Low GDP growth high human capital	79,900	77,000*	375,700
High GDP growth high human capital	81,500	74,700*	375,700

Source: ROA

Table A2.32: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	22,700	26,000	78,400
High GDP growth low human capital	23,000	25,200	78,400
Low GDP growth high human capital	26,600	28,000	78,400
High GDP growth high human capital	27,200	26,900*	78,400

Source: ROA

Greece

Table A2.33: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	6,000	25,500	35,800
High GDP growth low human capital	6,500	24,700	35,800
Low GDP growth high human capital	16,700	31,700	35,800
High GDP growth high human capital	17,600	31,600	35,800

Source: ROA

Table A2.34: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	4,000	28,700	56,100
High GDP growth low human capital	4,300	27,700	56,100
Low GDP growth high human capital	11,100	42,600	56,100
High GDP growth high human capital	11,800	41,700	56,100

Source: ROA

Table A2.35: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	4,200	9,200	67,000
High GDP growth low human capital	4,500	8,900	67,000
Low GDP growth high human capital	11,500	13,800	67,000
High GDP growth high human capital	12,200	13,300	67,000

Source: ROA

Table A2.36: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	1,200	6,600	15,600
High GDP growth low human capital	1,300	6,300	15,600
Low GDP growth high human capital	3,400	9,900	15,600
High GDP growth high human capital	3,600	9,500	15,600

Source: ROA

Spain

Table A2.37: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	18,700	79,700	104,000
High GDP growth low human capital	19,500	77,200	104,000
Low GDP growth high human capital	30,200	90,500	104,000
High GDP growth high human capital	31,900	90,100	104,000

Source: ROA

Table A2.38: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	12,500	64,500	117,000
High GDP growth low human capital	13,000	62,500	117,000
Low GDP growth high human capital	20,200	81,800	117,000
High GDP growth high human capital	21,300	79,300	117,000

Source: ROA

Table A2.39: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	12,900	19,000	128,500
High GDP growth low human capital	13,500	18,400	128,500
Low GDP growth high human capital	20,900	24,000	128,500
High GDP growth high human capital	22,100	23,300	128,500

Source: ROA

Table A2.40: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	3,800	5,600	12,300
High GDP growth low human capital	4,000	5,400	12,300
Low GDP growth high human capital	6,200	7,100	12,300
High GDP growth high human capital	6,500	6,900	12,300

Source: ROA

France

Table A2.41: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	47,000	64,600	80,200
High GDP growth low human capital	51,600	62,600	80,200
Low GDP growth high human capital	73,200	70,600*	80,200
High GDP growth high human capital	79,600	70,200*	80,200

Source: ROA

Table A2.42: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	36,100	144,300	379,300
High GDP growth low human capital	39,600	139,900	379,300
Low GDP growth high human capital	56,200	167,600	379,300
High GDP growth high human capital	61,100	162,500	379,300

Source: ROA

Table A2.43: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	19,700	43,300	262,600
High GDP growth low human capital	21,600	42,000	262,600
Low GDP growth high human capital	30,600	50,300	262,600
High GDP growth high human capital	33,300	48,800	262,600

Source: ROA

Table A2.44: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	6,600	11,800	29,200
High GDP growth low human capital	7,200	11,400	29,200
Low GDP growth high human capital	10,200	13,700	29,200
High GDP growth high human capital	11,100	13,200	29,200

Source: ROA

Ireland

Table A2.45: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	12,200	27,100	44,100
High GDP growth low human capital	12,700	26,300	44,100
Low GDP growth high human capital	17,500	29,200	44,100
High GDP growth high human capital	18,200	28,200	44,100

Source: ROA

Table A2.46: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	3,700	12,000	43,200
High GDP growth low human capital	3,800	11,600	43,200
Low GDP growth high human capital	5,200	12,900	43,200
High GDP growth high human capital	5,400	12,500	43,200

Source: ROA

Table A2.47: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	1,800	1,400*	9,500
High GDP growth low human capital	1,900	1,300*	9,500
Low GDP growth high human capital	2,600	1,500*	9,500
High GDP growth high human capital	2,700	1,400*	9,500

Source: ROA

Table A2.48: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	500	1,800	3,500
High GDP growth low human capital	600	1,800	3,500
Low GDP growth high human capital	800	2,000	3,500
High GDP growth high human capital	800	1,900	3,500

Source: ROA

Italy

Table A2.49: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	22,800	79,900	133,600
High GDP growth low human capital	23,400	77,500	133,600
Low GDP growth high human capital	23,100	83,500	133,600
High GDP growth high human capital	24,300	80,900	133,600

Source: ROA

Table A2.50: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	11,700	76,500	247,700
High GDP growth low human capital	12,000	74,200	247,700
Low GDP growth high human capital	11,900	79,900	247,700
High GDP growth high human capital	12,500	77,500	247,700

Source: ROA

Table A2.51: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	19,100	17,300*	136,900
High GDP growth low human capital	19,600	16,700*	136,900
Low GDP growth high human capital	19,400	18,000*	136,900
High GDP growth high human capital	20,400	17,500*	136,900

Source: ROA

Table A2.52: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	8,000	10,900	29,100
High GDP growth low human capital	8,200	10,600	29,100
Low GDP growth high human capital	8,100	11,400	29,100
High GDP growth high human capital	8,500	11,100	29,100

Source: ROA

Netherlands

Table A2.53: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	25,500	10,200*	13,400*
High GDP growth low human capital	27,000	9,900*	13,400*
Low GDP growth high human capital	34,000	11,500*	13,400*
High GDP growth high human capital	36,400	11,200*	13,400*

Source: ROA

Table A2.54: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	19,600	29,700	82,400
High GDP growth low human capital	20,800	28,800	82,400
Low GDP growth high human capital	26,100	33,700	82,400
High GDP growth high human capital	27,900	32,700	82,400

Source: ROA

Table A2.55: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	10,700	6,600*	42,300
High GDP growth low human capital	11,300	6,400*	42,300
Low GDP growth high human capital	14,200	7,500*	42,300
High GDP growth high human capital	15,200	7,300*	42,300

Source: ROA

Table A2.56: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	3,600	6,300	16,500
High GDP growth low human capital	3,800	6,100	16,500
Low GDP growth high human capital	4,700	7,100	16,500
High GDP growth high human capital	5,100	6,900	16,500

Source: ROA

Austria

Table A2.57: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	7,900	7,500*	10,300
High GDP growth low human capital	8,200	7,300*	10,300
Low GDP growth high human capital	8,800	8,300*	10,300
High GDP growth high human capital	9,300	8,100*	10,300

Source: ROA

Table A2.58: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	3,900	4,900	15,800
High GDP growth low human capital	4,000	4,700	15,800
Low GDP growth high human capital	4,300	5,400	15,800
High GDP growth high human capital	4,500	5,300	15,800

Source: ROA

Table A2.59: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	5,700	2,100*	10,900
High GDP growth low human capital	5,900	2,000*	10,900
Low GDP growth high human capital	6,400	2,300*	10,900
High GDP growth high human capital	6,700	2,300*	10,900

Source: ROA

Table A2.60: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	900	1,400	4,300
High GDP growth low human capital	1,000	1,400	4,300
Low GDP growth high human capital	1,000	1,600	4,300
High GDP growth high human capital	1,100	1,500	4,300

Source: ROA

Portugal

Table A2.61: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	6,900	12,400	16,800
High GDP growth low human capital	7,500	12,000	16,800
Low GDP growth high human capital	15,500	14,800*	16,800
High GDP growth high human capital	16,600	14,700*	16,800

Source: ROA

Table A2.62: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	5,300	17,500	50,500
High GDP growth low human capital	5,800	17,000	50,500
Low GDP growth high human capital	11,900	22,100	50,500
High GDP growth high human capital	12,700	21,400	50,500

Source: ROA

Table A2.63: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	2,900	5,200	34,800
High GDP growth low human capital	3,100	5,100	34,800
Low GDP growth high human capital	6,500	6,600	34,800
High GDP growth high human capital	6,900	6,400*	34,800

Source: ROA

Table A2.64: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	1,000	4,900	13,500
High GDP growth low human capital	1,000	4,800	13,500
Low GDP growth high human capital	2,200	6,200	13,500
High GDP growth high human capital	2,300	6,000	13,500

Source: ROA

Finland

Table A2.65: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	3,700	13,100	19,800
High GDP growth low human capital	3,900	12,700	19,800
Low GDP growth high human capital	5,100	14,800	19,800
High GDP growth high human capital	5,300	14,400	19,800

Source: ROA

Table A2.66: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	4,000	15,100	44,600
High GDP growth low human capital	4,200	14,700	44,600
Low GDP growth high human capital	5,400	17,100	44,600
High GDP growth high human capital	5,700	16,600	44,600

Source: ROA

Table A2.67: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	4,400	14,300	70,800
High GDP growth low human capital	4,600	13,900	70,800
Low GDP growth high human capital	6,000	16,100	70,800
High GDP growth high human capital	6,300	15,600	70,800

Source: ROA

Table A2.68: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	1,600	3,400	9,900
High GDP growth low human capital	1,700	3,300	9,900
Low GDP growth high human capital	2,300	3,900	9,900
High GDP growth high human capital	2,400	3,800	9,900

Source: ROA

Sweden

Table A2.69: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	12,400	11,600*	18,400
High GDP growth low human capital	12,300	11,300*	18,400
Low GDP growth high human capital	13,100	12,300*	18,400
High GDP growth high human capital	13,400	11,900*	18,400

Source: ROA

Table A2.70: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	13,400	12,900*	39,800
High GDP growth low human capital	13,200	12,500*	39,800
Low GDP growth high human capital	14,100	13,600*	39,800
High GDP growth high human capital	14,400	13,200*	39,800

Source: ROA

Table A2.71: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	14,700	12,200*	63,400
High GDP growth low human capital	14,600	11,800*	63,400
Low GDP growth high human capital	15,500	12,900*	63,400
High GDP growth high human capital	15,900	12,500*	63,400

Source: ROA

Table A2.72: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	5,500	1,200*	63,400
High GDP growth low human capital	5,500	1,200*	63,400
Low GDP growth high human capital	5,800	1,300*	63,400
High GDP growth high human capital	6,000	1,300*	63,400

Source: ROA

United Kingdom

Table A2.73: Natural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	117,700	305,800	511,600
High GDP growth low human capital	124,800	296,200	511,600
Low GDP growth high human capital	158,600	355,000	511,600
High GDP growth high human capital	169,700	344,100	511,600

Source: ROA

Table A2.74: Technology and engineering

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	90,300	190,400	617,000
High GDP growth low human capital	95,800	184,400	617,000
Low GDP growth high human capital	121,700	221,100	617,000
High GDP growth high human capital	130,200	214,300	617,000

Source: ROA

Table A2.75: Medical sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	49,300	63,000	499,600
High GDP growth low human capital	52,300	61,000	499,600
Low GDP growth high human capital	66,400	73,100	499,600
High GDP growth high human capital	71,000	70,900*	499,600

Source: ROA

Table A2.76: Agricultural sciences

Scenario	Job openings for RSEs	Inflow of new RSEs	Flow of new S&T graduates
Low GDP growth low human capital	16,400	35,600	94,800
High GDP growth low human capital	17,400	34,500	94,800
Low GDP growth high human capital	22,100	41,400	94,800
High GDP growth high human capital	23,700	40,100	94,800

Source: ROA