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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

This study was undertaken under the auspices of the OECD Group on the Science System. It is partly based on country notes provided by delegates to the Group, which will be disseminated as a general distribution document. The report was discussed by the OECD Committee for Scientific and Technological Policy in October 1997 and declassified on the responsibility of the Secretary-General of the OECD.

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SUMMARY

Universities and other higher education institutions are key elements in the science system in all OECD countries. They perform research and train researchers and other skilled personnel. In recent years, significant changes in the university environment have affected the research-related missions of these institutions. In particular, universities are becoming more diverse in structure and more oriented towards economic and industrial needs, while coping with higher student enrolments, particularly in continental Europe. These trends raise serious questions about how to ensure that universities can continue to make their unique contribution to long-term basic research and maintain an appropriate balance among research, training and knowledge transfer.

On balance, universities are adapting to changes in their environment in largely positive ways. They appear to be evolving towards new roles and configurations for the 21st century. This report discusses these trends, as well as some of their longer-term implications:

- ◊ *Declining government R&D finance* – Government research and development (R&D) budgets are being reduced in a number of OECD countries, often leading to a levelling off, or even a decline, in university research support. Traditionally, 80 per cent or more of university research was financed by governments as a *"public good"* but the share has been declining, with the result that universities are seeking new sources of support and a new basis for that support.
- ◊ *Changing nature of government finance* – Government funding for academic research is increasingly mission-oriented and contract-based and more dependent on output and performance criteria. This can lead universities to perform more short-term and market-oriented research.
- ◊ *Increasing industry R&D finance* – Private industry is funding an increasing share of research in universities. This support, in the form of joint projects, contract research, and financing of researchers, is also leading universities to perform research more directed to potential commercial applications.

◊ *Growing demand for economic relevance* – Universities are under pressure to contribute more directly to the innovation systems of their national economies. However, they are often constrained by rigidities arising from the traditional disciplinary organisation of research. This causes considerable tensions in the university research environment.

◊ *Increasing systemic linkages* – The institutional context of research is changing as universities are encouraged to enter into joint ventures and co-operative research with industry, government facilities, and other research institutions as a means of improving the effectiveness of networks and feedback loops in national innovation systems.

◊ *Growing research personnel concerns* – An ageing scientific workforce, coupled with declining interest in some fields of science on the part of youth in some countries, raises concerns about the future availability of adequate numbers of well-trained researchers, at a time when the training of researchers is changing.

◊ *Internationalisation of university research* – Globalisation, stemming partly from advances in information and communications technologies, is affecting the climate for research and the conduct of R&D. It is also making research more competitive and leading to specialisation.

◊ *A changing role* – Universities are recognised as essential to the knowledge-based economy, and no country will willingly permit a serious, permanent decline in the research, training or knowledge-transfer capabilities of their national systems. In the early part of the 21st century, however, university research and its relation to society are likely to be very different from what they are today. OECD countries need to ensure that universities can continue to perform their functions to the benefit of society at local, national, and global levels.

INTRODUCTION

With the increasing emphasis in recent years on national economic well-being and international competitiveness in OECD countries, the production, application and use of new knowledge have taken on major importance. As key sites both for research into new fields and for the training of future researchers and skilled personnel, universities and other higher education institutions have found themselves inevitably drawn into the modern national policy arena. Universities are, however, only one of several research-oriented actors. They are important, and in many ways strategic. Nevertheless the role of universities in the overall national research endeavour is both distinctive and constrained by other aspects of their missions, most notably their education and training functions. The functioning, orientation, and capacities of universities in OECD countries are all under scrutiny, as new directions are being sought for the new century. Given the many demands on universities and increasing expectations, as well as the major changes they have undergone in the past two decades, it is timely to inquire about effects on their research role and implications for its future.

The report begins with a general presentation of the research mission of the higher education sector in a long-term perspective (Chapter I), and examines how research has evolved with the transformation of the university itself. There follows a discussion of the evolution of university research as an aspect of national R&D efforts (Chapter II). University research represents between 15 and 35 per cent of the overall R&D effort in the OECD economies. The position of university research, measured as a proportion of total R&D effort, has been relatively stable over the last decade. However, stagnation or a slight decline is evident in the 1990s in most OECD countries, principally owing to a continuous reduction of government-financed R&D in relative, and sometimes in absolute terms. Nonetheless, support to university and basic research has been relatively protected, as compared to other items in a context of increasing budget stringency.

The financing of university research is changing significantly (Chapter III). Reductions in government support have been partly compensated by business funding. However, in a number of OECD countries, further budget reductions are foreseen. Moreover, an increasing share of government support tends to be short-term, mission-oriented, and contract-based rather than more stable, long-term institutional funding. Government support is also increasingly dependent on output and performance criteria.

Governments, as well as private interests, are also pressing universities to be more relevant contributors to innovation in a context of increasing global economic competition. In many countries, however, universities find it difficult to satisfy this demand, owing to long-standing structural rigidities, notably related to the disciplinary organisation of research. These rigidities may also threaten creativity in the long term. As one response to this problem, governments are encouraging the establishment of centres of excellence where universities are encouraged to focus on perceived research priorities linked to technological priorities. Governments also attempt to promote co-operation with the public sector institutions and with industry. Finally, evaluation of university research is being stimulated and sometimes imposed by governments concerned with more effective budget allocation as well as research productivity. As a result, important changes are occurring in the institutional context of research (Chapter IV).

Other pressures to adapt arise from the increasing internationalisation of university research (Chapter V), and are boosted by the globalisation process and progress in electronic communications and related information technologies, which multiply opportunities for co-operation but also intensify the competitive climate at world level. Co-operative trends are also influenced by the process of regional integration in major trade areas. In Europe, these trends have been affected by the opening and transformation of the former socialist countries. Other important issues are human resource development and renewal (Chapter VI), notably in view of an ageing scientific workforce and the moderate interest in research careers among the youth of many countries. The conditions for training the scientific workforce and advanced researchers are also changing significantly because of the new demands being made on them, while new structures, such as research schools, are being established.

Selected policy considerations of particular importance for the future of university research, particularly in the sciences, conclude the report (Chapter VII). These are framed in terms of the issues considered in detail in the first six chapters. Although the resolution of many of these issues exceed the authority of national governments, governments have an essential role in ensuring that the short-term difficulties experienced by individual institutions and researchers are minimised, and in monitoring longer-term trends to ensure that university research retains its unique place, even as the character and structure of universities evolve into forms better suited to the global, knowledge-based economy of the 21st century.

The report draws principally upon country notes prepared by delegates to the Group on the Science System and published separately. Country-specific information is used to illustrate general trends and issues discussed in the report, but no attempt has been made to compare countries systematically. Statistical data on the place and evolution of university research in national R&D efforts are extracted from the OECD science and technology (S&T) indicators database. Supporting figures and tables are presented in Annex 1. The report has also benefited from information provided at a series of conferences recently held under the auspices of the OECD Group on the Science System (GSS): the conference on the Global Research Village (Denmark, June 1996); the symposium on Public Understanding of Science and Technology (Japan, November 1996); and the workshop on the Evaluation of Basic Research (OECD, April 1997). The document is based on an initial draft prepared by Ms. Helen Connell (consultant), under the guidance of the Secretariat and the GSS Chair.

I. HIGHER EDUCATION AND THE RESEARCH MISSION

Universities have been a part of our heritage for some thousand years: the earliest European universities, including Bologna, Paris and Oxford, date from the high Middle Ages, as do universities in the Arab world. European universities evolved from schools for scholars from many countries who wished to be educated beyond the standards of the cathedral or monastic schools. For centuries, the principal disciplines were the liberal arts, jurisprudence and theology, While the Scientific Revolution did not originate in the universities, it eventually transformed them. During the Enlightenment, the curriculum was gradually broadened, and the university as we know it today gradually emerged. Over time, the specific fields of knowledge have evolved and have not infrequently been contested, but from the beginning, universities have been characterised by a balance between scholarship and teaching, an international perspective, and the preparation of graduates for employment.

The classical university

The classical European university embodying the concept of research-based teaching and a comprehensive humanistic education was given institutional form with the founding, by Wilhelm von Humboldt in 1810, of the University of Berlin, a model which continues to be influential today. The American graduate school, with its focus on research and higher learning, grew out of the training of large numbers of American scholars in European, particularly German, universities, from the second half of the 19th century to the 1930s.

The role of the university as a leader in research took on a new dimension when universities added scientific and technological knowledge to their curricula. The problematic relationship between research and the productive sectors of the economy emerged with the parallel development of the Scientific Revolution and the Industrial Revolution. Distinctions were made between basic, applied and developmental research; actors in different parts of the economy engaged in research activities, and university researchers focused on basic research, with some commitment to applied research, but little to developmental research.

The mission and fundamental values of the classical university were only moderately tied to the economy and to employment of graduates. Rather, knowledge was sought without consideration for its practical applications and consequences. Subjects for teaching and research were defined in terms of disciplines rather than solutions to practical problems or industrial and societal needs. Academics claimed the right to define both the content of studies and the overall purposes of their institutions. Students were selected on the basis of academic achievement, often through highly competitive processes. Innovation and fundamental reform have frequently been viewed with deep suspicion, and the freedom of academics to pursue their inquiries and to disseminate their findings has been central to the idea of the autonomy of the institution.

In the 20th century, however, with the demands made on scientific research for reasons of national defence and the growing needs of industry and other branches of the economy for advanced knowledge, the university has faced new challenges. Consequently, attempts have been made to reform existing institutions, and to create new ones, such as the technical universities (those entirely devoted to the technical sciences and their applications) in continental Europe. Even so, the classical university retains its power, both as a public image and within the university itself.

The modern university

During the 20th century, and particularly the past 30 years, a different model, which might be termed the "modern" university, has emerged. While it shares many features with the classical model, such as the right to select students, academic freedom, and a commitment to the pursuit of knowledge, it has a number of distinctive differences. It takes a less absolute view of institutional autonomy and is more ready to serve the community. It is more prepared to carry out research and to teach in ways that apply knowledge to the solution of social, economic, political, industrial and other problems and to concern itself with the employment of graduates. The modern university is less aloof from society, and is more willing to engage in dialogue with the wider community about the ends and the means of university education. The American land-grant university, which dates in fact from the 19th century, is a good example of this trend.

A “market” approach has strongly influenced the development of the modern university. Students are consumers or customers with wants (such as marketable skills – competencies or skills certified through degrees or diplomas), and service providers (*e.g.* universities) compete in order satisfy them. This approach also affects the research function of universities and accompanies the trend to contract-based research funding and closer links with industry. Government and industry are customers with wants (particular research projects, at a competitive price, within a specified time frame), and service providers (universities among others) compete in order to satisfy them. Universities stand to gain recognition and prestige, increased influence in the community, and continuing support from government or funding agencies, with opportunities for further expansion and growth. Institutional competition is a marked feature of this approach; to function effectively, a tertiary education market needs to have a range of providers, and consumers must be able to make well-informed choices and to switch “suppliers”. Customer satisfaction – efficient and cost-effective delivery of graduates and research “services” – is a primary value of this system.

To some extent, the classical liberal and the market-oriented models currently co-exist even within individual institutions, where their supporters – generally from different parts of the university community – are not infrequently in conflict because they see the two models as mutually exclusive. The reality of the modern university, however, is a gradual accommodation of the two models in a complex institutional setting.

To the long-standing tandem of teaching and research, many universities have added a third mission: service to the community. In our increasingly knowledge-intensive societies, this mission focuses attention on universities as centres for lifelong education (and further professional studies), as well as centres for scientific services in the form of technology transfer to the business sector in the pursuit of national economic advantage. In a number of countries, universities are seen as important elements in regional development strategies.

Institutional diversity in higher education systems

One of the most significant developments in higher education over the last 30 years has been the development of new kinds of institutions parallel to, but different in mission and character from, the established universities. These include the *Fachhochschulen* in Germany and Austria, the *hogescholen* in the Netherlands and Flanders, the community colleges in the United States and Canada, the polytechnics in Portugal, New Zealand and formerly in the United

Kingdom, and the former colleges of advanced education in Australia. Overall, tertiary education institutions have become much more diversified, whether they are formally organised as a binary system, favoured in much of continental Europe, or as the more or less unitary system now favoured in the United Kingdom and Australia, or as an "intermediate" system, such as that of Sweden, which has a unitary system, but with different types of institutions, not all at the highest university level. In France, which has long had a dual system of universities and *grandes écoles,* including specialised engineering schools, efforts have been made to close the gap between the two types of institutions; in particular, research is being undertaken in engineering schools. All higher education teaching staff have research and teaching functions, and there are some 45 000 university-based *enseignants-chercheurs.*

In the United States, with a higher education sector of over 3 600 institutions, only slightly over 200 qualify as research universities under the widely accepted Carnegie classification, which defines research universities as those offering the PhD degree in several fields and receiving over $15.5 million annually in research support. These approximately 200 universities award over 90 per cent of US PhDs in science and engineering, and receive over 90 per cent of the research support provided to colleges and universities by the federal government.

In several countries, the defining characteristics of the technical institutions have been an explicit link to employment and to the economy, short-cycle higher education mainly in technical and economic subjects, no doctoral programmes, and an applied orientation to research (when engaged in). Yet over time, the division has proved very difficult to maintain, and the boundaries between the classical and the technical institutions have blurred. A more "academic" approach is currently evident in the binary Norwegian system, for example, and was one of the reasons behind the recent amalgamation of the polytechnic and the university sector in the United Kingdom and of the college of advanced education and the university sector in Australia. In both these countries, all universities now have a research mandate, and the universities have responsibilities that in other countries are divided among different institutions. In Sweden, all colleges are likely to receive permanent resources for research (if current legislation passes parliament), and some may be called universities before the year 2000.

The unitary systems continue to manifest considerable diversity (not least in terms of status), which is in fact encouraged, but boundary issues (function, funding, and staffing), which were characteristic of binary systems, have dropped from the agenda. In the Netherlands, however, government policy is to increase selectivity for the academic university sector, and thereby eventually to shift the balance of higher education enrolments into a clearly demarcated higher vocational education sector.

When considering financing, university systems appear even more diverse. In centralised countries, the central government generally provides support, while in federal states, the provincial or regional authorities are the primary source of support. Moreover, while most countries have public universities, the United States, Japan and Portugal have significant numbers of private universities.

The growth of student demand and enrolments in higher education

The dramatic growth, over the last generation, of demand for access to higher education has considerably transformed higher-education systems in most OECD countries, and has a number of implications for the research function of universities. Countries now have, or are moving towards, mass higher education systems, with first degrees achieved by some 16 per cent of an age group in those countries with short first degree courses, and 10 per cent in those countries offering long first degree courses. In the United States, Australia and Canada, more than 30 per cent of the relevant age cohort graduates with a short first degree (OECD/CERI, 1996, p. 179). A recent UK estimate indicates that 60 per cent of the population will, at some stage in their lives, graduate from universities. The Finnish government has set comparable targets for the early 21st century. France has a target of 80 per cent of an age group qualifying for higher education, although there is still some way to go to reach it.

A striking feature of university graduate degrees in OECD countries is their concentration in the humanities and social sciences (38 per cent), and law and business (23 per cent). Sciences (apart from the social sciences, which in OECD statistics are included among humanities) for 39 per cent of graduates: medical science (11 per cent), natural science (10 per cent), mathematics and computer science (4 per cent), engineering and architecture (14 per cent) (OECD/CERI, 1996, Table 14.1). It is frequently noted that science and engineering students complete higher degrees more "efficiently", *i.e.* they complete more rapidly and have lower drop-out rates than students in other fields.

University graduates continue to show characteristic patterns of gender imbalance. With notable exceptions, slightly more women than men graduate at first degree level (both short and long). For second degrees, slightly more men than women graduate in most countries, and almost twice as many men as women graduate with a PhD or equivalent (OECD/CERI, 1996, Table R12.1). Women are far less likely than men to graduate in the sciences (30 per cent and 49 per cent, respectively). Women predominate, however, in the medical sciences and are well represented in the natural sciences. Mathematics and computer science, engineering and architecture essentially remain male bastions in OECD countries.

While many governments have programmes specifically aimed at boosting science enrolments, results to date have generally been somewhat unsatisfactory. In some systems, there is an alleged "flight from science" (and various reasons are identified), yet in others, courses that are judged interesting and relevant are well subscribed. These points are discussed below.

The growth of student demand for higher education in recent decades is due not only to school leavers seeking initial degrees, but also to adults seeking either second-chance education or the opportunity to upgrade, renew or develop new qualifications for a labour market in flux. However, much of the demand is social, the result of growing affluence and a pervasive belief in development and growth, with parents seeking better opportunities for their children. Moreover, in a period of high unemployment, particularly among young people (youth unemployment as a percentage of youth labour force stands at 14.1 per cent in North America, 4.4 per cent in Japan, 18.9 per cent in the European Union, 9.6 per cent in EFTA countries, 19.3 per cent in Oceania: OECD, 1994), employers seek tertiary rather than secondary level qualifications.

Institutions and systems have responded differently to the increase in student demand, which has presented a strong challenge to higher education institutions, especially the traditional universities. In Germany, some have tripled or quadrupled in size in recent times. Some universities have maintained open access to all qualified students, with the result that there is shortage of staff and overcrowding (Italy, Germany). Others have set quotas, thereby creating queues of unsuccessful individuals waiting to apply for the following year or later and perhaps continuing their studies in an attempt to improve scores in the entry examinations or taking other courses. The consequent delays and inefficiencies are being recognised. In many OECD countries, the issues of adequate provision and maintaining quality as the system expands to meet demand, are increasingly crucial.

Predicting future patterns of demand is difficult, especially in countries where, as is common, access is open to all those with appropriate certification or work experience or even, as in some countries, to all those beyond a certain age. While numbers of young people will continue to decline for a number of years in most (but not all) OECD countries, increasing participation rates have expanded overall enrolments. Some commentators believe that higher education enrolments have peaked, but others, including the authors of a recent ten-country OECD study of tertiary education, believe that tertiary education will eventually become universal (OECD/DEELSA, 1998, forthcoming).

The balance between research and teaching

Within individual universities, the balance between research and teaching often remains delicate. Where research is rewarded disproportionately, the staff is strongly tempted to favour it. Recent initiatives to reward excellence in university teaching, both at individual and institutional level, in the United States, Germany and Australia, among others, are interesting, but relatively isolated, developments.

The debate on the balance between teaching and research can be engaged at several levels. First, there may be an institutional separation of research and teaching. The former Soviet and Eastern European pattern, for example, was characterised by the concentration of basic research in publicly supported institutions (the academies), while universities concentrated on teaching (with some research around individual professors). With the move to market economies in these countries in the 1990s, this system has undergone major changes, with a marked weakening of the academies, and a strengthening of university-based research.

Second, certain institutions in the higher education system may have various levels of engagement in research, or different research intensities, in addition to the teaching performed by all. The US research-intensive universities provide the clearest example of this differentiation within a so-called unitary system. Several commentators see contemporary developments in the UK and Australian university systems eventually leading some universities to become more research-intensive, while others become dominantly teaching-oriented as a result of tightened financing. While from the national perspective this may foster research excellence, if taken to the extreme, it discounts the other important social and regional functions of universities and the importance of fostering excellence through the balanced development of the system as a whole.

Third, at the institutional level, the debate concerns the distribution of teaching and research roles among staff members. A recent survey showed that faculty members in US research-intensive universities spend about 44 per cent of their weekly working time on teaching, and about 32 per cent on research (National Science Board, 1996, Chapter 5). It is widely thought that all academic staff should engage in both teaching and research, on the assumption that the two activities are mutually reinforcing. In many systems, however, particularly those of continental Europe, the senior staff has long tended to teach graduate students (largely as supervisors in a mentor-apprentice relationship) and to depend on teaching assistants or junior staff for undergraduate courses. Here again, changing financial conditions may affect the balance between research and teaching (see below). In recent years, the debate has broadened to include the personal characteristics of staff, with the recognition that there are some good scholars and university-level teachers who are not (and need not be) good researchers, and it may suffice that their teaching is informed by current research; moreover, not all researchers are good teachers. Thus, while the dual function of the institution is supported in the main by staff with dual engagements, exceptions can and should be tolerated.

In a recent study of universities as “places of inquiry”, Clark (1995) maps two dominant countervailing forces that tend either to fragment or to integrate, noting that an increasing share of research activities is located in specialised units outside traditional teaching departments and that the response to mass enrolments has been to concentrate teaching efforts. At the same time, however, a variety of forces act to integrate research, teaching, and study. They include the organisational patterns that prevail in national systems and in the university-wide and departmental or basic units where staff and students are located.

II. UNIVERSITY RESEARCH IN NATIONAL R&D EFFORTS

University research in science systems

In quantitative terms, university research plays a moderate role in OECD science systems. In the five largest scientific powers (the United States, Japan, Germany, France and the United Kingdom), it represents about 15 per cent of the total R&D effort, and in other countries it ranges between 25 and 30 per cent (Figure 1).

However, universities fulfil an essential function as the principal performers of basic research. For the major scientific powers, universities undertake 60 per cent or more of basic research. In general, basic research amounts to half of university research, although its share is tending to diminish. As their relations with the business sector intensify, universities are increasingly involved in applied and technical tasks. At the same time, it should be noted that modern technologies (*e.g.* biotechnologies) are blurring more and more the boundary between basic and applied research (and, to a certain extent, technical development).

It is important to underline important differences among OECD countries as regards the position of university research in science systems and more particularly in relation to research in other publicly supported research institutions. Several profiles can be drawn on the basis of cultural background and economic structures:

◊ In Anglo-Saxon countries, universities are the major source of basic research, but they co-exist with public research institutions devoted to sectors of national interest, such as defence, energy, agriculture, medicine, etc. The latter may undertake basic research where needed, although they are generally involved in applied and technical research activities.

◊ In large continental European countries, university research co-exists (and co-operates) with a large public sector engaged in basic research in its own laboratories [Germany's Max-Planck Society, France's Centre National de la Recherche Scientifique (CNRS), Italy's Consiglio Nazionale delle

Ricerche (CNR)], which are also involved in technical and applied activities, to provide either R&D infrastructures (as in Germany) or mission-oriented activities (as in France and Italy).

◊ In smaller continental European economies, public research tends to be mainly oriented towards technical and industrial research activities, while universities perform most basic research. There are, however, important differences among countries: some have a large public sector (*e.g.* Norway, Iceland and Portugal), while others do not (*e.g.* Sweden or Switzerland).

◊ Finally, in East Asian countries, which were formerly strongly oriented towards technical applications and the assimilation of foreign technology, university research has remained modest, owing to lack of financial support, over-regulation and the burden of teaching tasks. The situation is changing rapidly, however, as these countries, and notably Japan, are boosting their basic research efforts.

Along the same lines, there are important differences in the functioning of university research and the behaviour of teacher-researchers in the various university systems (see Clark, 1995, for a comparison of the United States, the United Kingdom, Germany, France and Japan). In the Anglo-Saxon world, where academic research is to some degree subject to the values that apply throughout society and the market principles that regulate the overall economy, it develops in an extremely competitive environment. Researchers are concerned with publication and constantly under the eye of their peers. They are very mobile and move easily from one university to another according to the offers they receive. They are constantly in search of contracts with industry, government agencies, and local authorities in order to finance their research. They often spend some time in the private sector and even create their own firms. This model is very different from others, where researchers are under less pressure, more protected, less pushed to publish and less mobile. They also have fewer opportunities for diversification in their research fields and their careers.

University research, including basic research, contributes significantly to innovation and technical change, but largely indirectly. Firms, the key actors in innovation, rely little on university (and public) laboratories as a source of information or stimulus for their innovative efforts, as a number of surveys, including recent empirical analyses of national innovation systems, have demonstrated. Even in science-based sectors, interaction with competitors, suppliers and customers is more important for firms' innovative efforts than information from university and public sector research (OECD/DSTI Brochure: *National Innovation Systems*, 1997).

However, university research efforts play a crucial role in many other ways (SPRU, 1996). Academic research adds to the overall stock of the pioneering knowledge on which industrial research draws, notably for major breakthroughs, and individual academics act as problem solvers on specific requests by industry. Academic laboratories are also a source of advanced instrumentation that can be transferred to industry. University researchers are important members of the scientific networks that innovators need to develop their ideas, and they become a reservoir of talents able to migrate to, and nurture, research teams in industries. Sometimes, academics become innovators and create their own firms, but this phenomenon is largely restricted to the United States.

University research, which provides most basic research, cannot fulfil its function in the entire innovation process if it depends too heavily on market-led demand. Besides, when asked about what they mainly expect from universities, industrialists emphasize the provision of good basic research and well-trained and creative scientists and engineers. Therefore, government support has to be maintained at a reasonable level.

Government support: general policy orientations

Governments in OECD countries are the main source of support for university R&D and basic research, as they finance 80 per cent or more. This has not always been the case; indeed, public funding of R&D has grown notably since World War II.

The United States provides a striking example of this change, as it has built by far the world's largest university research system. In the United States, publicly supported universities are the responsibility of state and, to a lesser extent, local governments. There are no federally funded universities, since there is a virtual constitutional ban on federal involvement in organisation, management and policy setting for education at all levels, a prohibition that extends to university education. Pre-war research was funded by private philanthropic organisations, state government appropriations, and to a small extent by private industry. Following the significant wartime contributions of university scientists, however, the argument that federal support for academic research in science and engineering, especially basic research, was in the national interest prevailed. Vannevar Bush's essentially "laissez faire" economic argument that: "The most important ways in which the government can promote industrial research are to increase the flow of new scientific knowledge through support of basic research, and to aid in the development of scientific talent" set the stage for significant and sustained project-based funding to universities across a wide range of scientific and technological fields, including a sizeable defence component. Public funding for basic research achieved and retained strong bipartisan support in the United States. In the 1970s, this "minimalist" policy was seen as insufficient to maintain national pre-eminence in an increasingly competitive economic environment. More interventionist policy directions evolved which have (to date) involved no significant reduction in public support for university research, but rather a reshaping of the context of that support, by encouraging and facilitating closer co-operation between academic and industrial research.

In recent years, there has been an overwhelming government policy interest in fostering national economic growth. As we have seen, this has emerged in an era of intensifying international competition and the globalisation of industrial activities, accompanied by at times severe budget crises, structural adjustment and persistent unemployment.

Against this background, the high-technology sector and science-based industries are considered to be of strategic importance, and support for them is central to many national R&D policies. This knowledge-intensive sector has shown consistently stronger productivity growth, comparatively stronger employment growth, and more resilience in economic downturns than other parts of manufacturing. Despite its relatively small size (only 20 per cent of manufacturing employment), its perceived strategic national importance derives from the new technologies it generates, and their subsequent use throughout the economy and for export.

Support for universities as an element of national science systems is justified by the perceived economic importance of university-based basic research (in the context of good transfer structures to industry), their virtual monopoly on research training, and the political practicability of providing such support (as certain more direct forms of industry assistance are seen as too partisan and not politically feasible, if indeed desirable). Government policies favour technology transfer in the form of increased partnerships between university and industry, as well as closer ties between universities and public sector research laboratories. Many OECD countries have developed centres of excellence (often on a collaborative basis) as a means of concentrating resources in areas of comparative research advantage. Government policies also favour higher enrolments in science and technology at school and university level as a means of maintaining a good supply of graduates for the economy, and school and university level education as a means of raising the overall level of public understanding of science.

However, governments have also been increasingly preoccupied with funding, owing to their overall financial situation, with repercussions on all policy areas. Ever since the oil crisis of the 1970s shattered the boom mentality of the 1960s, there has been a sense of financial unease, if not outright crisis, in OECD governments. In recent years, the reduction of budget deficits has become a widespread preoccupation, and annual budget cuts have become commonplace.

It is in this context that most governments have sought to reduce their expenditures as far as possible, while actively seeking new sources of wealth creation. Overall Canadian R&D policy, which exemplifies broader trends in OECD countries, has taken a three-pronged approach. First, it has scaled back its own direct R&D investments and activities and increasingly become a manager and co-ordinator rather than a funder or performer of R&D. Second, it emphasizes new instruments and mechanisms to promote knowledge transfer, while seeking private sector partners to help share R&D costs. Third, it is emphasizing measurement of output rather than input in the search to maximise returns on R&D investments; as a result, R&D is increasingly seen in terms of its measurable contributions to social and economic productivity and less in terms of traditional input indicators such as amounts invested in R&D (AUCC, 1996*a*).

To some extent, university budgets have been protected when compared to government cuts in other sectors, because of increasing student enrolments and the generally positive view governments have taken of the teaching, research and service roles of higher education. How long this situation will continue is not clear. Moreover, as will be seen below, the support provided has been insufficient to prevent a relative decline of university research in a number of R&D systems.

University research in the overall R&D effort

During the 1980s, the percentage of GDP spent on R&D in OECD countries grew steadily to reach an average figure of 2.4 per cent for the various elements of national science systems: universities, public sector laboratories and institutes, private non-profit laboratories, and industry. The 1990s have seen a flattening out or a slight decline in the share of R&D

expenditures in each of the major zones (North America, European Union, Asia-Pacific), with an average of 2.2 per cent in 1995.

For most countries, this was due to lower government spending, particularly for defence, and recurring budgetary pressures. While business R&D continued to rise, it rose at a lower rate than during the 1980s. In 1993, close to two-thirds of R&D was funded and carried out by industry and was mostly concentrated in high-technology industries. Since the late 1980s, government-funded R&D has shifted towards intramural government projects and the higher education sector, and away from the business sector (OECD/DSTI, 1996*b*).

R&D trends in the higher education sector in OECD countries are presented in the figures and tables included in Annex 1. It should be noted, however, that university R&D statistics are notoriously difficult to compile and may be seriously flawed. They are generally based on studies of how time is spent or estimates and face problems of defining activities in terms of “education” or “research”.

Figure 1 shows that the percentage of gross expenditure on R&D (GERD) performed by the higher education sector over the past decade or so increased steadily, notably in the largest economies, up to the early 1990s, and then began to stagnate, while several countries show a limited but observable decrease since 1993-94 and the economic recession.

R&D expenditure in higher education (HERD) as a percentage of GDP (Figure 2) gives a somewhat more detailed and differentiated picture for three groups of countries. In the G7 countries, after increasing steadily up to the early 1990s, it has declined to the level of the early 1980s. For smaller advanced economies, the steady upward trend continued longer, and for the less developed European countries, growth has been strong since the late 1980s.

Figures 3 and 4 show the ratio of R&D expenditure in higher education to gross R&D expenditure and to business R&D expenditure, respectively. These have evolved relatively favourably for the higher education sector in most countries. On the other hand, the growth rate of R&D in the higher education sector has continuously declined in almost all countries over the last decade (Figure 5). In recent years, it has even become negative in some (Canada, Italy). Data on R&D expenditure in the higher education sector (in PPP $) paint a more precise picture of the relative stagnation, and sometimes the decline, of overall efforts.

These trends seem to be due mainly to changes in government R&D funding, which is channelled either directly (general university funds) or through research councils. In most economies, notably the largest ones, government-financed R&D, as a percentage of GDP, has decreased regularly for a decade, and this overall trend has had a negative impact on R&D in the higher education sector. Certain countries, notably Japan, are exceptions to this trend.

It should be emphasized, however, that, within overall government R&D budgets, the higher education sector has been relatively protected and that it has performed an increasing share of government-funded R&D in most countries (Figure 6). Moreover, "General University Funds" (Figure 7) have maintained their share among government objectives. Support for basic research, particularly in universities, has also been maintained. The relative decline of government support has been partly compensated by support from the business sector, which nonetheless remains relatively modest at less than 5 per cent in the vast majority of countries. Moreover, overall business R&D efforts have also been severely affected by the economic recession.

These trends are relatively worrying, in that university research will continue to depend largely on government funding, even if funding from other sources will necessarily grow. In fact, support for university research will likely be determined by the importance given to the R&D budget in overall government budgets. In this respect, OECD countries reveal striking contrasts (Figure 8). Moreover, as discussed in Chapter III, government support itself takes an increasingly "precarious", mission-oriented form, which taken to the extreme, could lead to unforeseen and unfortunate consequences for scientific research.

Before examining the situation of various countries in more detail, it is worthwhile considering briefly the trends in human resources (Figure 9). Percentages of higher education researchers in national totals present important differences. They are smaller in the United States (13 per cent), moderate in the United Kingdom and Germany (almost 30 per cent) and highest in southern European countries (50 per cent or more). In most OECD countries, the share of university researchers in national totals has been relatively stable, or slightly increasing, over the last decade. Therefore, these trends do not parallel budget trends, and university researchers have experienced a relative drop in allocations per head as compared to their colleagues in other sectors of the research system.

Country-specific trends and features

Within the general trends discussed above there are some important differences and exceptions among countries that deserve to be described briefly through a rapid overview of the main OECD areas.

In the United States, reductions in federal R&D budgets have so far mainly affected the defence, space and energy programmes. To date, direct support to basic and university research has been maintained, but the future is worrying. Funding by the National Science Foundation (NSF) and the National Institutes of Health (NIH) is being reduced or is stagnating in constant terms, and the R&D budgets of mission-oriented agencies are being cut further over five years. Diminishing support to basic research and increasing industry involvement are seen by some observers as inducing a shorter time horizon for the research effort as a whole. In Canada, where the decline in university research began in the late 1980s, there was a reduction in nominal terms in 1995. The situation is likely to improve, as can be seen from budget trends and related policy decisions to provide increased funding to university research investments.

The Japanese government, unlike that of most OECD countries, has boosted its R&D efforts, particularly in the area of basic and university research. This trend has been maintained throughout the economic recession and projections for the future are relatively favourable. At the same time, in order to stimulate the scientific creativity of academics, measures have been taken to increase the autonomy of universities, augment project funding, and establish centres of excellence. The impact of those measures, some of which have been in place for a decade, is clear. Japan's share in world "mainstream publications" has risen from 6.1 to 9.2 per cent over the period 1981-94. Korea's university research suffered, to a certain extent, from the same problems as Japan's, and the government has begun to take measures to boost basic research capacities, including the creation of centres of excellence. Efforts to deregulate the university system, increase project funds, and introduce a peer review process appear necessary for further progress (OECD/DSTI, 1996*a*).

In the southern Pacific, New Zealand has undertaken a radical reform of government and the budget, in order to reduce drastically the government's role in the economy. In this context, it has, over the past decade, considerably changed the financing of its R&D system and of university research in particular by applying market principles for support to this sector, as to much of the public sector. This seems to have resulted in a certain “short-termism” in the research effort. Recent upward trends in the R&D budget may reduce this tendency. In Australia, overall support to university research is being maintained, both through the education and the science budget, but with a marked increase in contract-based funding and development of output criteria. More funds are being provided for industry-university co-operative schemes such as Strategic Partnerships with Industry Research and Training (SPIRT). While the Co-operative Research Centres Programme remains the major scheme facilitating research linkages between sectors, the Programme is currently being reassessed by government on the basis of the need to become more self-funding.

In Europe, there are notable differences, especially between the countries with the largest scientific effort. In the United Kingdom, university research has maintained and even increased its relative importance in the overall R&D effort. As early as the mid-1980s core funding has been allocated on the basis of quality ratings, weighted in favour of international excellence in individual subjects. This has concentrated funding in those universities achieving the top ratings in the four-yearly assessment of research. Around 30 universities currently receive some 70 per cent of the funds. The German R&D system, for its part, has had to absorb the shock of reunification and the integration and downsizing of the former DDR academy institutes. The economic recession has increased the pressures on university and basic research, and there was a net drop in the research effort in the higher education sector in 1995. Budget projections are not encouraging. France has so far been able to maintain the overall university research budget, in a context generally marked by little change. The most significant efforts concern doctoral training, with the increase of research allocations (from 3 600 to 3 800), the strengthening of reading and research attaché posts, and the recruitment of young holders of diplomas (linked to the fight to reduce youth unemployment). Italy has seen a regular decline in government support, and the overall university R&D effort was reduced in nominal terms in 1996.

In other advanced European economies, university research has generally benefited from relatively good support, as has the R&D system as a whole, especially in the Nordic countries, and notably in Finland, where the effort in favour of R&D has been maintained despite the severe recession that the country has experienced since the early 1990s. Scandinavian countries have also made impressive efforts, although, as elsewhere, the importance of contract-based funding has increased. This may have particularly detrimental effects in contexts with a tendency towards egalitarian allocation of support and small research units, as in Denmark (OECD, 1995). In Iceland, the university system has been expanding, both in its teaching and research mission, in a context where resources for R&D have been expanding relatively rapidly, at an average of 10 per cent per annum in real terms since the mid-1980s. A deliberate effort is now underway to link the universities more closely to national needs through research training linked to and supported by public research institutes and industrial companies. New posts of time-limited research professorship have been established to encourage the return of outstanding Icelandic scientists from abroad and the renewal of the scientific staff. In the Netherlands, an entrepreneurial university system has been able to attract increased business support and obtain contracts from various public agencies. In Belgium (Flanders) and Austria, budget support has been maintained but has become more precarious and short-term in nature. In Switzerland, support to university research has stagnated since the late 1980s and the policy-making community is discussing the need for "research-oriented universities".

In southern European countries and in Ireland, the overall R&D systems, and university research in particular, appear to be evolving favourably. This is largely due to support from the European Union's Cohesion Programme and related structural funds, which have provided between 30 and 50 per cent of the financing for the R&D infrastructure. This has given a considerable boost to the scientific communities of these countries, and other European R&D programmes supporting specific R&D projects or teams have facilitated their integration into European research. The usual bibliometric indicators show that these countries have made significant progress.

The European Union's R&D budget, which amounts to 4 per cent of the total R&D expenditure of EU members, has significantly helped the integration of related scientific communities (see Chapter V). The new framework programme now in preparation should benefit from a slight increase in budget. It is not known precisely how much will directly support university research; this may depend on actual demand. An adequate balance will also have to be found between programmes that fund academic research on the condition that there is an industrial partnership (a model favoured in the recent past) and those more oriented towards support of basic innovative research, which also cover international mobility of researchers and their access to large-scale instruments.

In central and eastern European countries R&D systems were generally influenced by the Soviet pattern, with the universities focusing on teaching, while basic research was performed by science academies and industrial research by branch institutes. These countries have experienced a considerable reduction in their R&D systems, particularly as regards the branch institutes. Most had to face significant reductions in the science academies' research capabilities and to (re)build those of the universities. The outcome was uneven. In Hungary, the Higher Education Law (1993) declared the importance of university research, gave back to the universities the right to award the doctoral (PhD) degree, and appropriated new resources for university research, while another law (1994) reconstituted the Academy of Sciences foreseeing a decisive reorganisation of the retained research institutes' network. In the Czech Republic, for example, the Academy of Science has become a learned society and its institutes have been moved to universities. In Poland, university research, contrary to other countries, used to be largely developed, and the status and budget of the universities have undergone significant overhauling, but the Academy and its network of institutions continue to play a role in the research effort. In Russia, university research has progressed very little; the Academy has maintained the place and importance it had in the communist period, although the nation's R&D effort has been reduced to a quarter of what it once was.

III. THE CHANGING FINANCE OF UNIVERSITY RESEARCH

Changing sources of research funds for universities

A feature of all universities is that, although they draw extensively on their own resources for research, resources in addition to regular university budgets are increasingly sought and are considered essential for carrying out research activities. Overall, university research budgets have held their own or increased in most OECD countries. This is evidence of resilience, resourcefulness, and the ability and willingness to adapt to new circumstances, although there are those who feel that the system suffers from sclerosis.

The research funding received by a university depends increasingly on the entrepreneurial talents of individual researchers and their teams and of the university administration, often in combination. Universities are casting their nets increasingly wide, and, in addition to their own sources, they obtain funds from a variety of private providers (enterprises, foundations, wealthy benefactors) as well as from a considerable range of public bodies (government and their agencies at central, regional and local level, intergovernmental bodies, and a wide range of substantive departments across these bodies). The overwhelming bulk of funds come from the public sector, although industry funding has grown steadily.

Although the situation varies from country to country, the example of Norway is not atypical. In 1993, the bulk of funds for university R&D were public (90 per cent), the largest element being "floor funding" covering salaries and university overheads (56 per cent), followed by research council funds (18 per cent), other government departments (15 per cent), and other public sources (1 per cent). Only 5 per cent came from industry (a typical figure for universities within the OECD area), 4 per cent from other sources, and 1 per cent from abroad. Overseas funds are more significant for some other countries.

External resources to universities vary considerably from field to field. For example, in Finland, 74 per cent of engineering research was externally sponsored in 1993, while in medicine, the social sciences and the humanities, university budget allocations exceeded external funding, although the latter was still significant. Over half of the research done by Finnish universities (59 per cent) is financed from state budget allocations, with external funding increasing by some 5 per cent since 1989, of which two-thirds from various public sources, notably the Academy of Finland and the Technology Development Centre. In 1993, just over one-tenth came from Finnish firms, although the share is growing, and 81 per cent went to engineering and natural sciences projects. The 1994 breakdown for Finnish universities was: direct budget financing, 69 per cent; chargeable services, 15 per cent; and other outside financing, 16 per cent. As no tuition fees are charged, private funding accounts for only 3 per cent. Given the tightness of public financing, the aim is to widen the base by increasing private funding and other financing not channelled through the Ministry of Education.

Between 1980 and 1992, Dutch universities trebled their income from contract research, which now represents about a quarter of their research capacity. Companies, however, account for only about 20 per cent of total external income, *i.e.* they fund 4-5 per cent of university research. Government, social groups, medical charities and international organisations (such as the European Union) account for the other 80 per cent.

Flanders illustrates the changes that have occurred in a small system under severe constraints. Over the last 25 years, the importance of the Flemish universities' block grant has decreased, and universities now rely almost exclusively on external resources for their research activities. In 1996 there were fewer tenured academic staff on the block grant (2 345) than there were researchers that were not (2 647), and 38 per cent of technical staff were paid by external sources. Because most research grants are for short-term contracts of a few years duration at best, there are concerns about creating and maintaining a "critical mass" of researchers. In a few strategic areas (microelectronics, biotechnology), the government is funding inter-university research centres so as to ensure the stability of research groups that are international leaders. One result of a new legal framework for the university research fund is to enable universities to finance more long-term projects.

It should be noted that "real" research costs are often higher than those actually reported. Estimating input costs for academic research using an approach similar to those used in the private sector, Statistics Canada has shown that for 1986-87, all R&D expenditures in post-secondary institutions amounted to C$ 1.64 billion, considerably higher than the C$ 1.02 billion reported by the universities for the period as comprising the total of various research grants, contracts, and donations to universities.

Universities have begun to be much more involved in commercialising their R&D and obtaining income from it. Patenting and licensing have increased substantially in US universities over the past 20 years, as universities have increasingly negotiated royalty and licensing arrangements based on their patents. Typical licensees are small US pharmaceutical, biotechnology or medical businesses. Gross university revenues increased to $242 million in 1993 from $172 million in 1992. While this is modest in comparison with the overall volume of R&D funding, the strong upward trend appears to indicate a growing willingness on the part of universities to seek applications for their own research, and a comparable willingness among entrepreneurs and companies to look at and invest in the market potential of this research.

Quasi-commercial income-generating activities have become established in some parts of the university. Finland's experience shows that not all departments have the same potential for generating income, and considerable tensions can develop over how much departments or units are allowed to keep in view of payment of overheads to central administration, and, more controversially, redistribution of some income to departments less well placed for access to such income.

There is thus an important element of entrepreneurship at the individual academic and institutional level, which helps determine the research profile of individual institutions. The existing status and prestige of certain institutions is obviously important, in terms of their power to attract productive researchers and to offer them good facilities as well as to attract external grants and funding. There have, however, been a number of striking examples of entrepreneurship changing the established university landscape and carving out leading research roles, either at a departmental level, through the activities of key researchers and teams, or on a university-wide basis with the active participation of the university administration.

New directions in public funding for research

Many actors are involved in public funding of research, each with his own priorities, agenda, and areas of competence. The key trend of recent years has been for them to seek greater control, through a variety of mechanisms, over how their funds are spent. This frequently involves a shift from input-based to performance-based funding. In many systems, the long-standing pattern of research funding is one that allows researchers considerable autonomy over what they study and how they organise their research; decisions on the allocation of funds have largely been made by the profession, through a process of peer review of applications emanating from researchers. While this system remains in place, considerable inroads have been made in recent years.

Public funding for university research has three main strands: base funding, grant-based funds, and contract funding. The balance between them has been changing in recent years. For base funding, changes have recently been made both in the basis on which it is allocated and its proportionate importance in relation to overall public funding of universities. Base funding has not generally been specific to the research function of universities, as it covers staff salaries and general running expenses (in institutions where academic staff have both teaching and research functions, the common practice has been to have a single budget cover operating costs). In a number of countries, there is a move towards linking base funding with specific outcomes, most commonly enrolment numbers.

In the United Kingdom, a large-scale peer-based evaluation/appraisal of the research performance of each university department was undertaken in 1993/94 under the auspices of the Department for Education and Employment (DFEE). It is anticipated that such reviews will be repeated every five years or so. Based on the grading of each department, the DFEE uses a formula for establishing the base funding for each university. Universities receive this as a lump sum, however, and while they are not required to distribute it among departments on the basis of their research profile, it seems difficult to avoid a subtle (or not so subtle) set of expectations. While the DFEE seeks to distance itself from the inevitable consequences of making this sort of evaluation public and establishing rankings, the media have been quick to do so.

The operating costs of Finnish universities are covered by allocations consisting of base funding (90 per cent), performance-based funds (5 per cent) and project funding (5 per cent), the last of which is earmarked for new research and education projects of national importance. From 1996, base university funding will be established on the basis of agreed graduation and degree targets, with bonuses distributed on the basis of the results and quality of operations. Performance-based funding, which began cautiously in 1988, now emphasizes performance in basic, doctoral and adult education and in international co-operation, and also rewards “centres of excellence” in teaching, research and the arts.

In several systems, the relative importance of base funding has been diminishing over a period of some years. The Flemish block grant, which is linked, though not proportionally, to student numbers, has increased in real terms more slowly than enrolments, essentially reflecting a government policy to control education budget increases. While Australia is reducing overall university operating grants over the next three years by close to 5 per cent, it is increasing the funding for the targeted research programmes of the Australian Research Council, the principal supporter of university basic research.

Structures for research councils vary considerably, with some countries having consolidated bodies responsible for funding all (or a considerable range of) fields of science (*e.g.* Finland, Germany), while others have a plethora of bodies of different importance for funding. In the United States, for example, some six agencies account for over 90 per cent of all federal R&D expenditures, and a similar share of federal research funds, but the NSF, and to some extent the NIH, fulfil functions similar to those of research councils in other OECD countries. Some countries show a move to consolidate research grant bodies. The stated objective of merging five Norwegian councils (four mission-oriented, which largely supported applied research, and one traditional university-oriented council, which was part of a dual funding system for universities, with a strong focus on basic research) under a single ministry was to achieve a simpler, more rational and more efficient organisation of R&D, with better integration between basic and applied research. In 1994 Iceland merged its two research councils for applied and basic science into one council with responsibility for financing and co-ordinating research across all major disciplines and socio-economic goals. Skoie (1996) notes that during the late 1980s and early 1990s, there were two broad tendencies in government policies towards “university-type” research-funding councils: first, a general expansion of budgets, frequently by more than that of the general university funds from the appropriate ministry; and second, a growing tendency for authorities to earmark and specify budgets in increasing detail.

Many agencies have established priority setting processes for research, often as part of a review of institutional mission. The Japan Society for the Promotion of Science (JSPS), a quasi-governmental organisation which channels large sums to the university research community, began in 1996 to allocate over half its budget for domestic programmes to a new Research for the Future Programme which selects research fields of a “future-oriented nature that will form the knowledge assets and scientific bases for advancing Japan’s economic and social development in the years leading up to the 21st century” (JSPS, 1996). Instead of researchers submitting proposals for work in these fields, JSPS solicits identified leading researchers to conduct projects, each of which lasts five years. The Australian Research Council increases are targeted for research infrastructure, postgraduate awards and enhanced research collaboration between industry and universities.

In recent years, several OECD countries have moved to define priority areas through a process of research foresight, essentially seeking consensus on the most interesting options for future research. This approach has been used in the Netherlands to set government priorities in science policy development. The 1996 report of the independent Foresight Steering Committee has been used as the basis for establishing science and technology priorities in the 1997 Science Budget. In addition, other research institutions, including universities, are being encouraged by the Minister of Education, Culture and Science to develop strategies which take the Committee's priorities into account. In the United Kingdom, all departments now allocate a share of their research funds to specific priority fields identified through the technology foresight exercise as having potential for national wealth creation and strategic advantage.

In recent years, a number of countries have engaged in quality assurance activities, as a growing concern with the quality of research and research outcomes accompanies budget restrictions. These initiatives are examined in the context of research evaluation efforts, which are discussed in Chapter IV. Research quality is associated with the building up of centres of excellence within university systems and the development of different and distinctive research profiles in universities within national systems. In theory, a focus on quality can encourage all to improve, but, in practice, it as often acts to select and reward the strong.

The net effect of these changes in strategy has been to increase the dependence of university research activities on short- to medium-term non-core funding. There is, then, an important question of how to provide long-term stability in an environment where research depends increasingly on external funding.

Private sector funding

Private sector funding of research in public universities stands at around 5 per cent in OECD countries, a figure which a number of governments would like to boost. Indeed, the principle of matched funding from the private sector has become a criterion for a number of programmes.

There has been, over time, a slight increase in business-financed R&D in the higher education sector, although the trend varies in different countries and is reversed in years of recession (see Tables 2 and 4). The highest proportion of business-financed R&D in the higher education sector is in the Anglo-Saxon countries and in Germany. Canada leads the OECD countries, with some 11 per cent. Germany is next, with almost 8.7 per cent, followed by the United Kingdom (6.1 per cent) and the United States (5.7 per cent). Japan stands at a modest 2.3 per cent, while in France, funding peaked in 1990 and then dropped to 3.3 per cent in 1993.

It is useful to look at the same time at the share of enterprise-funded R&D performed in the higher education sector. In most countries, it stands at between 6 per cent (Canada) and 2 per cent. In a number of countries, the share diminished in 1994 and 1995, owing to the recession. It is also worthwhile noting the strong contrast furnished by several less developed and smaller countries where industries lack R&D structures and therefore need to make considerable use of higher education's R&D capabilities (30 per cent of business R&D goes to higher education in Turkey and 13 per cent in Mexico).

Academics are generally favourable to business funding, to the extent that it does not excessively affect their choice of research topics or their perceived freedom. As observed, this depends largely on the nature of the research field as well as publication/patent arrangements. Academics should not feel that publication is excessively delayed by secrecy obligations imposed by industrialists. It seems that, at least in most advanced countries experienced in business/university collaboration, such as the United States, appropriate balances have been found, which respect the interest of both parties.

Financing graduate students

While tuition fees are not allowed at public universities in many OECD countries, particularly in continental Europe, several countries do allow public institutions to recover all or part of tuition costs for graduate students (or for certain categories of graduate students), either through up-front fees, or through deferred payment schemes. In the United States, it is common to charge in-state or in-province students different tuition fees from those charged to students from other parts of the country. Recent substantial rises in tuition fees in the United States have led some commentators to feel that further rises would be unacceptable (Blanpied, 1997). In the United Kingdom, full tuition fees for overseas students have been in force for many years, and the government has just announced fees for home-based students. Australia provides the option of an up-front fee or a deferred payment whereby, through the taxation system, students repay a fixed proportion of tuition costs once they have graduated and are employed, with earnings above a threshold level. The collected funds are redistributed to the universities. Introduced in the late 1980s, this scheme has been modified several times to increase the refundable proportion of tuition; the question of differential repayments according to courses studied has now been raised. Iceland has long maintained a government-backed system of soft loans to finance its students who, until recently, all had to pursue graduate studies at foreign universities.

Whether or not they are directly liable for tuition fees, all graduate students need to have a source of income for living expenses. In the United States, 30 per cent of graduate science and engineering students were self-supporting in 1993, although the proportion varied considerably by field of study. Part-time study is relatively common at graduate level, and in the United States, part-time work to support higher education studies is extremely common. There is also a well-developed system of student loans in many countries, with a variety of repayment arrangements.

Significant numbers of graduate students and post-doctoral fellows in science and engineering at US universities are supported by government fellowships or research assistantships financed by federal research grants and contracts. Overall, the period 1983-93 saw a 4-5 per cent annual increase in federal and non-federal sources of support for graduate science and engineering students, with some tailing off of non-federal support for engineering students in the early 1990s. Such students are seen to play an indispensable role in academic research in science and engineering as assistants, or, more accurately, apprentices to research staff. Japan has recently launched a plan to increase the number of post-doctoral researchers to 10 000 by the year 2000 (Supporting Plan included in the Science and Technology Basic Plan approved by the Cabinet in 1996). The number actually increased from 6 028 in 1996 to 7 815 in 1997. A number of countries are paying greater attention to the importance of "post docs" in dynamising research in all disciplines. At the same time, government support, given on a temporary basis, also serves to compensate the lack of employment opportunities offered by the public and private sectors and saves a number of doctorate holders from unemployment. This trend is noticeable in several countries in continental Europe.

IV. THE CHANGING INSTITUTIONAL CONTEXT OF RESEARCH

Institutional organisation of research: excellence and interdisciplinarity

The organisation of research at institutional level has undergone – and is undergoing – considerable change in OECD countries. Several of the factors at work help explain the new emerging patterns of internal university organisation.

One is the need for governments to focus their support, at a time of increased budget constraints and competition. One policy initiative in many countries has been the establishment of centres of excellence (Canada, the Netherlands, Japan, Australia, Flanders, the United States, Finland). These centres act to concentrate resources on key strengths within the university (and within the system as a whole). Selection criteria for Finland's 17 centres (in 1995) included scientific merit and the future prospects of the research units, their significance for researcher training and the larger research community, and their involvement in high-level international scientific co-operation.

In many countries, this approach has helped establish institutional research priorities. In Japan, centres of excellence are a new and major policy thrust; they are to be given priority resource allocation and the latitude to develop innovative initiatives in the most advanced fields of science. Because they build on existing joint university centres that "possess COE characteristics" in specific fields, they will strengthen the concentration of effort. Centres of excellence are discussed further below in relation to collaboration with the public sector and industry.

A second major factor, to which the development of centres of excellence is partially linked, is the development of interdisciplinary groups and problem-focused institutes. Disciplines have furnished the traditional framework for research in universities and indeed have been the basis of the internal structuring of most universities into departments and faculties. In discipline-based research, the discipline provides a structure which helps define the important problems, how they should be addressed, by whom, and what knowledge should be regarded as a contribution to the field.

Alongside this so-called Mode 1 research, Gibbons (1995) has identified a new and emerging research mode whose structures and participation map very different terrain. For Gibbons, Mode 2 is trans-disciplinary and heterogeneous, in terms of the skills and experience of participants. Problem-solving teams change over time as requirements evolve, and knowledge is created not only in universities and colleges, but also in virtually any other part of the science system, with sites linked electronically, organisationally, socially and informally through the functioning of a communication network. Mode 2 research has been stimulated by growing public concern about such issues as environment, health, communications, privacy and procreation where, in addition to technical questions, solutions involve issues of social organisation and values which often have ethical aspects.

While Mode 2 is by no means about to replace Mode 1 research, universities increasingly need to accommodate both. Organisationally, this means that universities are becoming more porous and building partnerships with other knowledge-producing institutions. The two modes are rather different in terms of research careers and research training, particularly as Mode 2 knowledge tends not to be codified and presented in peer reviewed publications or exchanged through such activities as conferences, as is common for Mode 1 knowledge. It is significant, in that it highlights the breadth of disciplinary participation in many current research questions, the loosening and reshaping of many structures within the research environment, and the growing permeability of institutional boundaries.

Collaboration and partnerships with the public sector

In many OECD countries, government policy fosters increased collaboration between university and public laboratory researchers. This appears especially the case in those countries where the institute sector is important and where governments are seeking to get the most mileage from public expenditures on basic and applied research. A variety of patterns characterise the relationships which have been established between the two sectors. The examples given below illustrate typical approaches used to strengthen partnerships between the two sectors.

Government laboratories are frequently based at universities, with a variety of joint management arrangements. In France, 85 per cent of researchers in public laboratories and 50 per cent of university research staff work in laboratories jointly run by the two sectors. The most important public research organisations are the CNRS (which covers all disciplines and employs 12 000 researchers) and the Institut national de la santé et de la recherche médicale (INSERM) (which covers medical sciences and employs 2 000 researchers). Both are the responsibility, along with universities, of the Ministry of Education, Research and Technology. While both CNRS and INSERM maintain some independent laboratories, a considerable number are co-managed with universities. These organisations have seen their budgets increase by 3.1 per cent. In Italy, besides funding research grants and scholarships for research training, and advising government, the CNR itself undertakes scientific work directly in 289 research bodies. Of these, 115 study centres and 17 research groups involve collaboration with universities and other agencies.

An important goal in Germany of both federal and *länder* (state) research policy is improving co-operation between universities and non-university research organisations. University research is supplemented by research activities in non-university institutions funded jointly by the federal and *länd* governments. One of the most effective links has been found to be professors holding joint appointments in universities and non-university institutes: they teach and supervise doctoral research at the university and also direct the extra-university institute or department. Joint appointments are steadily increasing, and are particularly numerous in the recently founded institutes in eastern Germany (many of which are located on or near a campus). For many of the Blue List institutions (a group of independent research institutions and facilities which receive government funding) and national research centres, joint appointments are already standard practice throughout Germany; they also exist with some institutes of the Fraunhofer Society (applied research) and the Max-Planck Society (basic research). Joint research projects, mostly supported by research grants, have also been found useful for connecting universities and extra-university institutes.

Japan’s universities and their affiliated research institutions play a major role in scientific research, which includes university faculties and graduate schools, research institutes and centres attached to faculties, inter-faculty and inter-university joint-use facilities, research institutes attached to universities (including those for joint use) and inter-university research institutes. There is a strong emphasis on co-operation and on access by researchers to facilities based at other institutions.

In the case of Hungary, the relationship between public laboratories and universities has changed significantly since 1989. Hungarian R&D staff decreased by 34 per cent (0.5 per cent in higher education) in 1989-94. In 1994, the Hungarian Academy of Science (HAS) lost the "ministerial level" administrative role it enjoyed under the previous government, but it continues to play an important role in supporting basic research. The HAS and the newly established Bay Zoltán institutes run an organised network of research institutes. The latter (modelled after the Fraunhofer institutes) are located close to universities and are independent of HAS and the universities. HAS employs research groups associated with higher education departments, and there is strong interaction between research and education.

The former Portuguese National Institute for Scientific Research, until its demise in 1993, was responsible for a large network of research centres located at universities. Since 1993, these centres have been integrated into the universities, and their research activities are supported by projects and contracts from the National Scientific and Technological Research Agency. Several non-profit private institutions have been created in partnerships among public universities and laboratories, corporations, business and industrial associations and act as a bridge between universities and the productive sector.

Inter-university research collaboration is also intensifying, with the spread of formalised inter-university research groups. The two Flemish public research centres are both inter-university bodies. Large central facilities exist for the microelectronics centre (IMEC), although part of the R&D remains university-based. The biotechnology centre (VIB) is an "institute without walls", which finances university research groups. Canada's centres of excellence are similarly inter-university groupings of researchers in specific fields. Since the early 1990s, the Netherlands has established a policy of "research schools" which aim to bring together the best research programmes and researchers in various research schools into "centres of excellence" and provide training for doctoral students as well. The selectivity that had initially inspired this initiative has, however, been considerably reduced over the years, since, in 1997, more than 90 per cent of university researchers are included in "research schools". Recently a new scheme was started up in which "top research schools" are selected by the research council NWO to receive preferential support of Gld 100 million within the "first flow of funds" (institutional funding) from 1999 onwards. An equivalent sum is also set aside within the "first flow of funds" to give an added stimulus to the quality of work in other research schools.

Collaboration and partnerships with industry

The dominant patterns of collaboration between industry and universities relate to technology transfer, with the universities seen as a source of knowledge to be exploited for commercial purposes. A variety of links exist between universities and business enterprises. They are fostered by government policy throughout the OECD area, and many are supported or facilitated in certain respects by governmental and inter-governmental programmes. Schemes which have proven effective are described below.

Germany has encouraged university-industry partnerships as a means of speeding up technology transfer. German policy towards knowledge transfer is to support pre-competitive approaches across industries. Between 1991 and 1996, some 350 projects were funded in the areas of medicine/pharmacy, the food industry, plant breeding, and environmental biotechnology in order to transfer research results rapidly to industry and to increase the R&D activities of small and medium-sized enterprises (SMEs). This support programme was shown to have contributed substantially to speeding up the commercialisation of biotechnology in Germany. Collaborative research between different business enterprises and research institutions on a single project has been found to contribute to the better exploitation of limited research capacities by pooling resources, the speeding up of technology transfer between science and industry, the generation of synergy, and large-scale instead of selective promotion. As government support is available only at the pre-competitive stage, projects tend to involve basic industrial research. Subsequent company-specific solutions are developed without government support.

Since the late 1970s, the US NSF has had a number of different programmes to facilitate co-operation between university and industrial research laboratories and to promote knowledge transfer. The two most ambitious of these, initiated in the late 1980s, involve the Engineering Research Centers and the Science and Technology Centers (STC), which provide substantial support for up to ten years for research in areas of interest to industry; these are frequently multidisciplinary in character and conducive to a team approach. Both require that undergraduate and graduate students be centrally involved in the research activities. A recent and highly positive evaluation of the STCs affirmed the value of long-term stable funding, found them to have produced research of high scientific quality which could only have been addressed through such centre-based research, and concluded that dissemination of both their basic and applied research had been highly successful. The active co-operation and participation of industry was seen to lead to better research, new ideas, leveraged funding, staff appreciation of the industrial sector, and better preparation of students for entering the workforce.

Australian policy makers believe that the best mechanism for knowledge transfer is the mobility of persons who have both transferable skills (including research problem-solving abilities) and a good informal network of professional contacts. The Co-operative Research Centres (CRC) Programme has supported long-term collaborative ventures linking research and research users from universities, Commonwealth and state-funded research organisations and business enterprises as well as improving Australia's research culture. Australia has complex research and research training links among individual universities, the various public sector agencies, and industries, which are facilitated by major programmes such as the CRC. The new SPIRT Programme, operational from 1998, provides greater flexibility for institutions in their negotiations with industry on collaborative research and training activities. The proposals under the new combined scheme can encompass collaborative research projects, collaborative research training or a combination of both projects and training. For a number of years, industry has been able to benefit from an R&D tax concession of 150 per cent (now reduced to 125 per cent) through which universities can benefit as partners in university-industry collaborative research.

Since the early 1970s, Sweden has seen the growth of institutionalised interaction between higher education and the private sector, including science parks, liaison offices, technology bridge foundations to support patenting, facilitate industry's access to sources of information within universities, develop co-operative industry-university research, and encourage interaction among SMEs in common projects. Technical consortia and competence centres are structures for industry-relevant interdisciplinary research, with active industry involvement. The lack of good evaluative data makes assessment of the different approaches difficult. Many suffer from lack of funds, and some forms of interaction are too recent to be evaluated. In general, temporary concentration (for five to ten years) of financial and human resources in a university environment, with a focus on a particular area of industrial relevance and with strong industry involvement (50 per cent), seems promising. Another interesting model is interdisciplinary graduate schools with industrial relevance and involvement. It is of decisive importance that both models facilitate movement of students and researchers between university and industry and vice versa.

Japanese universities are increasingly requested to co-operate with industry in order to respond to society's needs. Co-operative research projects with industry have increased thirty-fold since their launching in 1973. University-industry collaboration schemes include the programmes for joint research (¥ 5.5 billion for FY 1997), commissioned research (¥ 41.9 billion), commissioned researchers (531 researchers), grants and endowments (¥ 52.8 billion) and endowed chairs and funded research departments (47 chairs and nine departments as of 1 March 1996). Centres for co-operative research have been established in 49 universities to promote university-industry collaboration at the local level. In order to further promote collaboration, the Japanese government relaxed regulation on R&D activities of university professors at private corporations in 1996, and, in 1997, amended a law to eliminate disadvantages in calculating retirement allowances for university researchers who took a leave of absence for co-operative research activities with the business sector.

Several countries have targeted SMEs, which play a major role in technological innovation but have undertaken little R&D. The "research co-operation" programme of the German Ministry for Education, Science, Research and Technology (BMBF) focuses specifically on increasing the innovative power of SMEs, supports application-oriented co-operation between SMEs and universities, *Fachhochschulen* and other tertiary institutions through work as subcontractors in joint research projects of enterprises, R&D contract work for enterprises, temporary exchange of research personnel between business enterprises and higher-education institutions. The German *länder* also have some co-operation programmes. The Dutch PROMOTIE programme to stimulate research in SMEs allows companies to take on research assistants in the context of doctoral research (four years) or technological design (two years) to work on a problem selected by the company and under the academic responsibility of the university. Half of the overall costs of hiring the research assistant are reimbursed.

In 1993, the Austrian Industrial Research Promotion Funds introduced a new promotion scheme for young scientists (undergraduates, graduates, doctoral students) wishing to gain academic credit by participating in practical research projects of SMEs. The programme, which has been extended, met its goals, and increased firms' awareness of the advantages of employing academics. "Scientists for the Economy" is another Austrian scheme which allows a university assistant to take one or two years' leave from university to work in an firm's research department and have a university post to return to. Enterprises receive a tax-free government subsidy for R&D personnel costs.

After a five-year pilot phase, the scheme was made permanent in 1987. A second government scheme, "Scientists Found Their Own Firm", offers a non-repayable grant plus additional subsidies for investments in special equipment for scientists who have left the university to start their own firms; 81 per cent of these have been in the service sector (software and consultancy). In a recent study of the "Austrian Science Cluster", the Austrian Economic Research Institute found that 152 of 220 university institutes mentioned their co-operation with enterprises. A large majority of respondents emphasized the importance of personal contacts for co-operation with enterprises. Professional intermediary agencies and information exchange or liaison offices played only a marginal role in promoting contacts between enterprises and universities. This finding suggests the need for a reappraisal of the role of such bodies.

An important development in many countries has been the science parks built alongside universities, which provide opportunities for close collaboration between industry and academia. Their aim is to promote technology transfer from universities and public research organisations to the private enterprise sector and to encourage the establishment of science and research-based firms. There have been few substantial assessments of the success of the science park strategy, but anecdotal evidence suggests that success rates vary.

In Finland, science parks are private firms owned by a consortium of local and regional authorities, firms, regional universities, and research institutes. A survey of the ten Finnish science parks notes that the number of firms located in science parks has increased steadily since the 1980s and presently stands at about 800. The number of employees has grown by an average annual rate of 20-30 per cent during the last five years and stood at about 8 000 in 1995. There are between 20 and 250 firms in the parks, and the most successful sites have between 100 and 1 500-2 000 employees. It is interesting to note that the adjoining city populations are in the range of 100 000-200 000 persons. This may provide some indication of how much science parks can be expected to grow.

The legal and ethical dimensions of research

The pressures of economic imperatives on the university system are being felt in the effect of all types of patent systems on the academic freedom of university researchers (Schmidt-Szalewski, 1996). In "first to file" patent systems – found mostly in continental Europe – inventions of university researchers are increasingly assimilated to inventions by employees, a regime under which the interests of the employer (*i.e.* the university) are protected.

Similar trends are evident in “first to invent” systems, notably in the United States. This system was formerly very much attached to the protection of the inventor, but the rights of the university tend increasingly to prevail over those of individuals. At the same time, it should be noted that a change in the US patent law in 1980, which enabled academic institutions and small businesses to retain title for inventions resulting from federally supported R&D, appears to be an important factor in explaining the sevenfold increase in university patents over the last 20 years, a much steeper increase than the doubling of patents for the country as a whole.

Pioneering research in fields such as genetic engineering, fertility treatment, nuclear energy and waste disposal raise fundamental ethical and social issues which have not infrequently brought researchers to the forefront of public controversy. This illustrates the tension between the wish to take research to its technical limits (*i.e.* unfettered scientific freedom), on the one hand, and, on the other, the restraining hand of a society (or sections thereof) which believes that limits should be imposed on scientific investigation, both on ethical and on social grounds.

The question of who defines the limits to research is resolved differently by different countries. In some, public debate is channelled through public inquiries (*e.g.* the Warnock Commission on human fertility in the United Kingdom). In others, committees on research ethics have been established. How agreed limits are implemented also varies. Some limits to scientific research have emerged through conventions among scientists (*e.g.* medical ethics) and in most countries they are the object of regulation and legislation, as well as agreements among countries (*e.g.* the nuclear non-proliferation pact). There are always, however, groups that do not abide by such agreements (particularly in the military sphere, *e.g.* for biological weapons). The public role in defining limits is important, and the educated public is becoming more critical and less supportive of ethically controversial research. At the same time, a number of countries – notably in northern Europe – have established institutional settings that facilitate open and mature debate. Such structures (*e.g.* in the form of technology assessment organisations) help further public involvement in R&D and discussions of its positive as well as its negative aspects.

Evaluation of university research

In most OECD countries, there is increasing emphasis on accountability, as well as on the effectiveness and efficiency of government-supported research, as is also the case for many government expenditures. Governments need such evaluations for different purposes: optimising their research allocations at a time of budget constraint, re-orienting their research support, rationalising or downsizing research organisations, augmenting research productivity, etc. To this end, governments have developed or stimulated research evaluation activities, in an attempt to get "more value for the money" they spend on research support. This trend is evident for university research, and several examples of evaluation were mentioned in the context of government initiatives to rationalise the financing of university research in Chapter III. Here, the different ways in which evaluation practices are being diffused and implemented are discussed in more detail.

First, there is the development of self-evaluation by the universities themselves. In the Netherlands, under the auspices of the Association of Universities (VSNU), research in all disciplines is being evaluated by review committees constituted mostly of foreign peers appointed by the Royal Academy (KNAW). In German-speaking countries, including Switzerland and Austria, individual universities undertake evaluations. In countries such as Japan, government guidelines strongly encourage self-evaluation efforts, while Italy has introduced assessment groups in each university and an observatory at national level through legislation.

Second, agencies that directly support research teams and projects perform evaluations which have been developed for making appropriate selections of grantees and monitoring the results of their research activities. The UK experience in allocating support among universities on the basis of performance reviews has already been mentioned. In a similar vein, there is the Portuguese experience, launched by the JNICT (the national scientific and technological research agency): research contracts are allocated to university units within a five-year framework which covers an initial evaluation for grant decision and interim and final evaluations for monitoring progress and assessing results. Mexico undertakes a systematic review of all scientists, including university researchers, every three years in order to determine promotions and salary increases. Similarly, certain countries with public research organisations of an academic nature have established formal evaluation systems for managing personnel and institutes. The French CNRS, for instance, has a national committee with over 40 sections covering all disciplines; its evaluation activities involve large segments of the higher education system, as many CNRS units are jointly established with universities.

Third, there are *ex post* evaluations of programmes that support university research and/or scientific disciplines that entail university research. The Australian Research Council has extensive programme evaluation experience; the results and outcomes of grants are systematically surveyed and analysed by means of questionnaires, interviews, publication records, etc. Evaluations of disciplines have been developed in Nordic countries, and notably in Sweden, under the auspices of the Natural Science Research Council, which undertakes systematic multi-annual reviews of all disciplines; in which teams including at least three foreign experts analyse selected laboratories and scientists, provide comments on their performance, and incidentally, on the appropriateness of government support.

In the OECD workshop held in April 1997, several important conclusions were drawn from the examination of various countries' experience (OECD, 1997). The need for balance and complementarity between quantitative criteria (*e.g.* publication records) and qualitative judgements (*e.g.* peer reviews) was emphasized, as was the need to take into consideration not only the direct output of research (articles, discoveries, etc.) but also more indirect outcomes, such as contribution to technical developments, improvement of instrumentation, diffusion of knowledge, etc. A key general conclusion of the workshop was that evaluation of research at institutional level must be conducted with full cognisance of the impact of research on related functions of that institution. For universities, these include teaching and training, knowledge transfer to other social and economic sectors, international links, and effect on national and international culture.

V. INTERNATIONALISATION OF UNIVERSITY RESEARCH

A long-standing tradition

The end of the 20th century has seen important shifts towards globalisation of business and financial affairs and towards the grouping of countries into competitive supra-national regional blocs based essentially on regional economic co-operation and integration, but also, increasingly, on political considerations. In terms of scientific and technological research, three poles dominate – Europe, Japan and North America – with Russia, Eastern Europe, East and South-East Asia, Australasia and parts of Latin America representing dynamic nodes. Evidence of continued and growing internationalisation of research is provided by bibliometric studies of scientific publishing. There is steady growth in the number of scientific papers involving international co-authorship (NSB, 1996).

World-wide linkages among universities are complex and increasingly affected by the latters' growing identification with national economic strategies. Inasmuch as the pursuit of knowledge is universally valued, the mission of universities has always had an international dimension, and a commitment to the free exchange of knowledge has always been part of the university tradition, particularly at the graduate level. However, the growth of mass enrolments in higher education presents new challenges in this respect. A variety of international links have been forged, ranging from bilateral ties between individuals in related departments to complex multidisciplinary networks, twinning arrangements and institutional consortia (Neave, 1992). Co-operation at institutional level has become more marked in recent years, and the move to establish "branch" campuses of national institutions in other countries is spreading (Wagner and Schnitzer, 1991).

Science, and to some extent technology, are international bodies of knowledge which do not naturally recognise national or regional boundaries. The free flow of basic scientific knowledge, through publication and peer review, are long-standing traditions. In considering contemporary developments in the internationalisation of research, particularly in view of advances in information technologies, it is necessary to reappraise the fundamental concept of mobility. It has traditionally been thought of in physical terms – the movement of staff and students. With recent technological developments, particularly in information technology, it is necessary to think more in terms of the mobility of ideas, information, learning opportunities, institutions and programmes.

Impact of regional groupings

The OECD area shows a strong trend towards supra-national regional groupings, particularly in the European Union and, to a much lesser extent, in the North American Free Trade Agreement (NAFTA) zone. Within such groupings, international co-operation tends to be encouraged and, at least in the case of the European Union, is supported by well-funded programmes.

Since the early 1980s, European higher education institutions have co-operated in international R&D projects on a far greater scale and more intensively. Partly on their own initiative, partly pushed by government policies, they have established direct inter-university and university-industry links, as well as co-operative relationships funded on a competitive basis by the EU framework programmes. Over the years 1984-94, universities became the most active participants (32 per cent), ahead of public and private research centres (30 per cent), SMEs (18 per cent), big companies (17 per cent) and others (3 per cent). The EU funding, which has more than tripled over the period, is designed, among other things, to increase scientific and technological cohesion and harmonization among European countries in the interest of establishing a single internal European market.

The number of linkages between higher education institutions and research centres grew over this period. They accounted for the greatest share of collaboration, although in 1994 29 per cent of higher education linkages were still with big companies, SMEs or other industrial partners. Some 86 per cent of universities in EU countries participated in the first three framework programmes, but only a small number did so repeatedly. Geuna (1996) argues that their participation patterns represent an achieved balance between institutional research quality (as indicated by bibliometric measures) and positive discrimination in favour of institutions from smaller peripheral countries (in line with the EU's cohesion policy), with certain advantages accruing to older and larger universities, as well as to those that were among the first to participate.

The long-term impact on research of participation in these regional projects has yet to be established, however, as many are quite recent. In the case of the European Union, Contzen (1991) notes that the funding from major EU programmes in science and technology [*e.g.* ESPRIT (information technology), BRITE/EURAM (industrial and materials technologies), SCIENCE] have intensified these patterns of collaboration and also shifted collaboration away from the United States and towards partners in other European countries. Although funded much less lavishly, the impact of the long-standing Commonwealth (formerly British Commonwealth) programmes, particularly travel grants and fellowships, has been to foster research contacts and networks among member countries, thanks in part to a common language and cultural heritage, despite the vast distances that separate them.

Unlike the European Union, which is based on treaties and directives in many areas, NAFTA, which involves Canada, Mexico and the United States and which entered force in 1994, is entirely concerned with trade. It is an agreement to lower and ultimately remove existing barriers to trade among the three countries. However, as scientists and policy makers in the three countries have recognised, many of NAFTA's objectives can only be achieved by increasing Mexico's scientific capabilities. To this end, a number of trilateral scientific programmes have been initiated, on a pilot basis, and others are being considered. They include exchange fellowships, which are available to scientists in all three countries and enable recipients to spend a year or more at a research facility in one of the other two countries, and a materials science network initiative, which facilitates co-operation and exchanges among research institutions involved in the same specific areas of materials research in the three countries. As time goes on, specific science- and technology-related elements might well be incorporated into an expanded formal agreement. In addition, it is likely that the NAFTA agreement will eventually be extended to countries in South America, with Chile likely to be admitted first.

Opening of former socialist countries

The opening and transformation of the Former Soviet Union has considerably modified the world's scientific landscape. Scientific schools in the former Soviet Union, particularly in Russia which represented 70 per cent of its scientific potential, were among world leaders in a number of disciplines. With the drastic reduction of the R&D effort, there has been a considerable reduction of personnel. It is estimated that the number of scientists and engineers working in Russia's R&D system has decreased from 0.9 million in

1990 to 520 000 in 1996, while R&D expenditures as a share of GDP have declined from 2.1 to 0.5. The internal brain drain has been much greater than the external one. Conservative estimates situate the latter at an annual average since 1991 of about 2 100 scientists and engineers working in the R&D system. The actual figure may well be twice that, given the difficulties involved in identifying emigrant flows.

In any case, it is clear that emigrant scientists have largely been the "cream" of their disciplines. Many have gone to the United States, which, according to official statistics, has received about 800 a year. Most of the others have gone to Europe, China and India. For the OECD countries, one consequence of this massive arrival, on a definitive or long-term contract basis, has been the development of serious competitive pressures in the recruitment of university professors and assistants. In more than one country, "domestic" applicants have been passed over in favour of the newcomers. At the same time, the presence of the latter in universities has been very stimulating.

The other form of linkage has been the development of co-operation with research teams remaining in Russia through co-operative projects, twinning of laboratories, etc., stimulated by both bilateral and multilateral schemes such as the International Association for the Promotion of Co-operation with Scientists from the New Independent States of the Former Soviet Union (INTAS), the International Science and Technology Center (ISTC), etc. In addition, OECD enterprises have mounted a considerable number of contract-based activities in order to benefit from the competencies, and sometimes the unique infrastructures, of Russian institutes. The total amount of foreign and international co-operative R&D funds flowing into Russia has been estimated at some $500 million in 1996, (*i.e.* some 15 per cent of the domestic R&D effort). This has resulted in a kind of "delocalisation" of research, a trend that is very likely to continue strongly in the years to come.

From a scientific viewpoint, China, the other major former socialist country that has evolved towards a market economy, offers a different profile. So far, the linkages created have mostly benefited the United States, and to a lesser extent, Japan. In the United States, a third of the postgraduates and PhDs are of Chinese origin (diaspora included) and are a major source of creativity and dynamism for American science. However, US academics, supported by the NSF and other agencies, have been developing large co-operative programmes with their Chinese counterparts in selected fields with recognised competencies, sometimes of a world level.

Mobility of students and staff

Foreign students are probably the most visible expression of mobility among universities, and numbers have increased dramatically over the past 30 years to reach, by the end of the 1980s, over 1 million students studying in foreign countries under a variety of arrangements. There is, however, a striking concentration of foreign students in relatively few countries, with Europe and North America accounting for approximately 80 per cent of all foreign students in 1990.

Patterns of movement have nonetheless changed considerably, as Neave notes (1992), with a greater number of privately than publicly financed students since 1982. This shift suggests that higher education has become less a public service and an investment in human capital and more a saleable commodity, with students serving as a source of institutional revenue or cost recovery. With families the main financial support for foreign students, there has been a significant increase in students from the newly industrialising Asia/Pacific Rim area; they now represent more than half the foreign students in the United States, the largest receiving country. Geographic proximity is important in determining student destinations, with more than 40 per cent of foreign students in 11 European countries coming from other European countries, and more than 75 per cent of foreign students in Australia and Japan coming from Asia (Okamoto, 1990). Language ability is also important. The fact that English is a mother tongue or second language in many parts of the world favours English-speaking countries as a destination.

Details of programmes studied are not easy to obtain. However, in the United States, foreign students enrol predominantly at postgraduate level, largely in sciences and engineering (some 100 000, or just over one out of two overseas graduate students, enrol in science and engineering masters or doctorates). A smaller number of US students study abroad for short periods in relatively inexpensive language, history and culture programmes. Foreign students in the United States are concentrated in the more advanced degrees; while they obtain only a small proportion of science and engineering bachelor’s degrees, they gain 25 per cent of the masters degrees, and 47 per cent of the doctorates. Very recently, the number of foreign postgraduate science students in the United States has begun to fall. Japan has taken an ambitious initiative to attract 100 000 foreign students, particularly for graduate study, including attractive financial support, with instruction provided in English and in Japanese.

Particular local conditions favour or hinder mobility. Norway, for example, has had noticeably high mobility, attributed to its traditionally rather weak research training coupled with relatively generous financial support from research councils for travel and (frequently lengthy) overseas stays. From a pre-World War II orientation towards other Nordic countries and Germany, a strong post-war Anglo-American link has emerged, strengthened by attractive PhD research training programmes. At the end of the 1960s, 20 per cent of doctorate holders had foreign degrees, although this proportion is now smaller. Iceland has had a deliberate policy of not establishing PhD programmes within the university system and instead systematically sending students for doctorates abroad. This policy appears to be an important and efficient means of keeping a very small science system abreast of advanced trends (OECD, 1993). Today, one-quarter of Icelandic university-level students studying abroad, and nearly one-half of all Icelandic doctoral students, are in the United States. Many fewer post-doctoral and junior scientists from the United States seek research positions of six months or more outside the country than many observers believe desirable; the latter believe that international experience should be an important component of advanced education in science. One reason is the size and general level of excellence of many US research institutions, where young scientists can gain valuable experience without leaving the country. Moreover, young scientists have genuine grounds for fearing that if they spend an appreciable period of time outside the country, they will be less able to compete for favourable research positions, which are particularly scarce in the academic sector.

Impact of information technologies

Advances in information technologies (IT) have dramatically lowered the barriers to international co-operation, making international interaction part of everyday research and instruction. Main trends and issues affecting the "Global Research Village" (which were explored in an OECD conference held in Denmark in June 1996, and will be further examined in Portugal in 1998) concern notably publication, communication between scientists, use of remote instrumentation and training of researchers.

The world of science is being revolutionised by information technologies, which make possible the widespread dissemination of research results at all stages of investigation, owing to the growing number of users of electronic communication networks, notably the Internet, as well as the increasing capacity of electronic networks to support huge file transfers. Electronic publishing makes possible the speedy dissemination of research results and scientific information through the publication of working papers, pre-prints and scientific documents. Novel types of peer review are therefore being developed, and electronic scientific journals are taking shape. New problems are also emerging in relation to intellectual property rights, archiving of electronic publications, etc.

Electronic mail, telescience, and networking have considerable impact on the interaction between scientists and on their behaviour. Preliminary studies of these questions (Walsh and Bayma, 1996) show that the impact varies significantly from one discipline to another (*e.g.* the impact is different and greater in mathematics than in chemistry). It also seems that while the effects on research productivity may be important, they have limits, and personal, face-to-face communication remains irreplaceable for research creativity.

Ongoing developments in IT have made it possible not only to improve the quality and accuracy of available instruments, but also to increase researchers' access to instruments and facilities. High-performance computers and improved communications allow virtual instruments to replace traditional ones and make possible the development of virtual laboratories. Disciplines such as oceanography and astronomy, which are highly internationalised and use huge and costly equipment, already benefit greatly.

Finally, information technology contributes to greater participation in research and distance learning, allows for new teaching methods, and may lead to the emergence of the virtual university. It also improves scientists' access to electronic databases and libraries, including virtual libraries.

The long-term effects of the development of the Global Information Infrastructure and its use by scientists will no doubt be considerable, although their nature is still unknown. It is certainly likely that the gradual establishment of virtual universities, laboratories, libraries, etc., will have a significant influence on the location of research throughout the world, by reducing the need for concentration and the related mobility of scientists.

VI. TRENDS IN RESEARCHER TRAINING

A "flight from science"?

For some years now, there has been a growing concern in science circles that young people are increasingly rejecting – or at best apathetic towards – science, as manifested by the fact that fewer are choosing scientific careers. Such concern, however, is not new and was already apparent in a previous study of university research by the OECD in 1981 (OECD/DSTI, 1982). The issue is a complex one, and available evidence is somewhat ambiguous.

US studies indicate that at world level overall science enrolments are strong and have increased at both undergraduate and graduate levels in recent years. This must be seen, however, in the context of the overall increase in university enrolments and the apparently slower increase in science and technology enrolments by comparison with increases in other fields of study (NSB, 1995). While reliable international trend data are lacking on this point (difficulties of maintaining comparable categories being a key problem), anecdotal evidence and individual country data suggest a rather complex pattern. In general, biological and life sciences have maintained their numbers, computing and social sciences have increased, and physics, chemistry and engineering have dropped in some places (Flanders, Germany, Norway). Some countries note a marked decline in interest in science during adolescence (Denmark, Sweden, Japan), while others note lower scores among those enrolling in university science courses (Australia). But these patterns are neither universal nor necessarily consistent across countries. In the United States, for example, declining student interest has been reversed at James Madison University, Virginia, where a new College of Integrated Science and Technology has been particularly effective in attracting highly qualified women to the sciences.

Studies of student motivation indicate interest as the key reason for course choice, at least in Anglo-Saxon countries, followed by career prospects for certain courses (physics, maths). The bulk of science teaching at schools and universities has long been criticised, and with good reason, for stressing factual over theoretical learning, for overloading courses, and for failing to engage students' interest, involve them in meaningful problem-solving and provide a basis for active learning. Efforts to reform science teaching, although numerous and relatively widespread in the OECD area, have yet to make major headway in the many and diverse locations where science is taught in our societies (Black and Atkin, 1996).

Student perceptions of career possibilities and of appropriate course choices feature in overall science enrolment levels. Given the changing fields (and sub-fields) of employment and the growth of insecure employment, study options and career choices are not straightforward. Employment forecasting is regarded as a notoriously uncertain art. The process of career choice has been shown to involve a series of choices over a considerable period of years, with certain crucial points at the end of learning cycles. The tendency has been for most students to try to keep their options open for as long as possible, a tendency which may be at odds with the demands science courses commonly make in terms of prerequisites. In many countries, moves to provide bridging courses for late deciders have been relatively well subscribed, particularly among women.

Anxieties over a "flight from science" thus involve a range of questions: Which sciences? In which countries? In which institutions? To what extent and under what conditions? The "flight", insofar as it exists, is neither wholesale nor unconditional. Certainly, traditional "hard" sciences and engineering have cause for concern, but there are increases in computing and the social science (and humanities). Many governments have had specific programmes to encourage greater interest in science among young people for a number of years, with activities ranging from financial support for higher education to improving public outreach programmes at science museums.

Two important questions must, however, underlie policies to encourage more engagement with science. First is the level of scientific expertise, particularly for the research capabilities which our evolving economies are likely to need, and determination of the fields where these will be needed. In this respect, it may be misleading to rely on past participation in scientific careers as a yardstick. Second is the general level of public understanding of and engagement in science, which is desirable and even necessary in our increasingly technologically oriented and knowledge-intensive societies.

The academic research career

In the past, university graduate study was essentially the basis for a future academic career. The often narrow association with a particular field, and with a particular professor or research team, was not inappropriate, particularly in countries where staff mobility was poorly developed. At the same time, of course, the narrow and specialised character of graduate study tended to prepare students solely for academic careers.

During the economically buoyant 1960s and early 1970s and the early phase of growth in student numbers and institutional diversification in higher education, academic staff increased significantly in many OECD countries. At the time, employment conditions favoured tenured appointments. As a result, a large number of academics will retire over the next 15 years. This bulge phenomenon has been exacerbated by the fact that from the mid-1970s, the conditions of academic employment have considerably altered. Despite continued student growth, there has been a tendency to freeze tenured appointments, or even reduce them, by a combination of natural attrition and encouraged early retirements and non-replacement. Those who have succeeded in gaining academic appointments have increasingly been employed on short-term and fixed-term appointments, and often on "soft" money, whether primarily for research or teaching functions.

France illustrates the massive problems facing a number of countries. Between 1998 and 2005, close to 50 per cent of the current academic staff in France are due to retire. French policy is to seek an average recruitment of 2.5 per cent a year in order to avoid major problems. Early retirements are being encouraged, alongside increased mobility of public laboratory staff to universities and industry. In the Netherlands, in order to ensure that there will be high-quality replacements for ageing professors, a temporary scheme has been put in place that makes it possible to appoint successors even before the positions are vacant. In the United States where the obligatory retirement age for university faculty has been abolished in most institutions, some faculty members tend to remain active well into their 70s, further reducing the number of available tenure positions for younger scientists.

In the United States, young researchers have increasingly found it necessary to move from one post-doctoral position to another, often spending up to six years in this way before finding a faculty appointment, which is usually an untenured one. The Flemish Science Foundation has recently increased its funding for such positions to enable more individuals to move to a second "post-doc". There are also more researchers paid out of external money than tenured staff paid for by the block grant. The effect of these changing employment conditions is that fewer tenured academic positions are available for a given age cohort and that an academic career is more unstable and insecure for the growing proportion on contracts which are not necessarily renewable. Some countries are trying to stabilise particular research teams by providing longer-term funding. Nonetheless, the prospect of frequent changes of institutional base has become a widespread feature of contemporary university employment.

Several countries are concerned about the long-term viability of university research groups, particularly because the core of national basic research capacity is increasingly concentrated in the higher education systems. They note that the lack of a clearly defined research policy at the central university level has major implications for the future of academic research careers. Continuity and scale of funding for research; selective support for particular fields of research (the institutional research profile); balance between curiosity-driven research and more application-oriented research; the framework for collaboration with external partners, both nationally and internationally; university involvement in the commercialisation of institutionally generated research; institutional distribution of research funding (proportion of research contract funds allocated to administrative overheads and/or made available to researchers in fields where external funding is less forthcoming); balance between research, teaching and service commitments of individual staff members – all these areas would benefit from clearly formulated, institution-wide policy, as they materially affect the conditions of the academic research career.

Meanwhile, the conditions for pursuing a research career in industry are far from favourable in a number of countries. Most R&D is carried out in industry, but industry does not employ a high proportion of those with research degrees. Blume (1995) points out that while policy makers increasingly argue society's need for a more highly qualified body of individuals for the knowledge-intensive economy, industry has been slow to employ those with advanced research training, particularly doctorates, because they feel that the training is too specialised. The United States, and to some extent, Canada, are among the few OECD countries with a non-academic labour market for PhDs, *i.e.* a tradition in which industry actively seeks out PhDs in science for employment.

In the United States, the nature of industrial research has changed over the past decade, with a drop in long-term basic research and an increase in short-term application-focused research. Also, a steady-state job market for PhD scientists has persisted, possibly limiting the number of Americans seeking advanced degrees in some fields. To what extent this reflects the changing modalities of research discussed above and a long-term blurring of the boundaries between basic and applied research activities is not known. Whatever the explanation, employment in industry offers the basis for a type of research career very different from that in universities; remuneration is better, but researchers generally have less autonomy than in universities. Industry is an area where R&D is still expanding, albeit at a somewhat lower rate than a decade ago, a matter of concern for the employment prospects for the increasing numbers of doctorates in the pipeline.

Reforms in research training

These changes in the context of the research career, along with prolonged national policy emphases on economic objectives, have had a major impact on research training. Major reforms have been undertaken in many OECD countries, largely in the direction of broadening research training, increasing the creativity and problem-solving capacities of graduates, and strengthening linkages between universities, public laboratories and industry. While research training remains predominantly the concern of graduate studies, institutions in a number of countries have begun addressing the question of research-based teaching for all levels of science and of introducing practical research activities during the undergraduate years.

Participation in advanced degrees has been rising in OECD countries (OECD/CERI, 1996), a result both of increased demand and of government encouragement. With the growing policy focus on science and technology research for national economic development, the issue of the training of future researchers and their capacity to participate in economically valuable research has become more important. In both Japan and Korea, the authorities perceive the need for graduate students to show more creativity, initiative and problem-solving ability than is fostered under the current approach. This concern is linked to changes in the economic situation of both countries: the success of their efforts to “catch up” to the West has placed them in a new leading – and somewhat exposed – position; they find themselves at the cutting edge and to maintain their position, their industry needs to be more innovative. In Japan, a strong emphasis on expanding graduate study has been accompanied by increasing flexibility in graduate schools and an increasing number of overseas students, especially at the graduate level.

A number of European countries have also made changes in their research training, particularly by broadening the course of study for the research degree, often along the lines of the American graduate school. In this model, graduate-level study in all fields is co-ordinated through a single office, which ensures that all departments act comparably and that the interests of graduate-level study are safeguarded at the institutional level. US graduate studies also tend to involve both course work and a dissertation, so that the overall study programme has greater breadth than most doctoral degrees based solely on a dissertation, the common practice in Europe. With highly focused academic careers and low mobility no longer the automatic end-point of higher studies, the specialisation *vs.* breadth debate has picked up in Europe, and significant reforms in research training are under way (Finland, Norway, Iceland, Germany). The trend towards combining courses and original research work in graduate studies is a long-standing tradition in France; recently, this had led to the creation of doctoral schools, similar in some respects to US graduate schools. Moreover, new diplomas, such as the DESS and the master's degree, are given at the conclusion of a professional course of study more oriented towards industry needs.

In a previous report of the OECD Group on the Science System, Blume (1995) notes that policy makers and university administrators have only recently been explicitly concerned with the postgraduate training of researchers, and that in so doing, they are grappling with several dilemmas:

◊ First is the problem of making research training more relevant to a wider variety of careers than in the past. This means reassessing the disciplines in which scientists are trained, as well as the function of doctoral training. By breaking the close relationship between doctoral training and preparation for an academic career, different needs can be addressed, and trainee researchers can become familiar with how research is undertaken outside the university, for example by working in teams and with colleagues from other disciplines.

◊ Second is the location of research and a questioning of the central role of universities in national research systems. Today, only universities award the title of "doctor", but in light of the increasing research partnerships between universities, government laboratories and industry, they no longer have an effective monopoly on training leading to the PhD degree. In the United States, many private industrial firms have had their own programmes for advanced training in science and engineering for many years. Many also provide incentives for their research scientists to take advanced courses at nearby universities, and frequently negotiate the particular courses of study they wish their employees to pursue.

- ◊ Third is growing internationalisation, with its impact on student mobility, and, increasingly, moves to harmonize requirements for doctoral research, particularly in Europe.
- ◊ Fourth is a concern with improving the quality of research training, in a context of growing numbers of students and the need for efficient use of resources and time (length of training). While "quality" has traditionally been related to the significance and originality of research, as presented in a dissertation, the move to broaden the market for PhDs has placed new emphasis on the importance of the research training process. Several countries have sought to improve students' formal preparation for undertaking doctoral research by providing an initial year of training, possibly resulting in a diploma.

The rising numbers of graduate students raise questions about the relevance of their education both for themselves and for the economy (employment prospects). This is an extension of the challenge presented by rising participation at secondary and then at first degree level. As countries move beyond elite systems to mass (first degrees) and then universal (secondary schooling) education, it is necessary to rethink both what is taught and how it is taught, in all systems, and on a continuing basis.

VII. SELECTED POLICY CONSIDERATIONS

Several issues discussed above are contributing to a significant reshaping and restructuring of university research, even as university research is being recognised as essential to knowledge-based economies in OECD Member countries. Some of the factors involved are directly tied to changes in national research emphases and patterns of financial support. Others are the result of advances in scientific knowledge or changes in universities themselves, including in their training functions which are necessarily affected by the development of lifelong learning. Still others have to do with the globalisation of knowledge, aided and abetted by rapid developments in information technologies.

Many of the factors reshaping university research are beyond the direct control of national governments, particularly in countries without national university systems and/or in which there are significant numbers of private universities. Yet, government policies in all countries will continue to have decisive indirect as well as direct impact on the evolution of university research. Governments will need to stimulate, become involved, and take positions in national debates on the future of university research. These debates, as well as the nature of the positions they take, will necessarily be conditioned by specific national contexts, including factors such as cultural traditions and prevalent ideologies, as well as the size of research structures and the character of industry. At the same time, OECD Member countries have many similarities as regards issues associated with university research. Moreover, certain decisive trends, such as the sharing of major research facilities by scientists from many nations and the rapid deployment of information technologies are leading to noticeable and probably increasing convergence among national science systems. For these reasons, further and more extensive cross-national comparisons and analysis will be needed.

This chapter summarises a few of the major policy concerns that will need to be addressed not only by governments, but by all sectors of society with a stake in the future of university research, including individual researchers and universities themselves.

The significance of university research

There is little doubt that the trends underlying the restructuring of university research will persist well into the next century. Within one or two decades, both the character of university research and its relation to society are likely to be very different from what they are today. It is probably that the universities, and university research in particular, will be better linked to societal needs in a climate of stronger competition of a world-wide nature, with even more pressing demand from the economy and the public at large. In short, university research is currently in transition, but the details of its future form are not yet known. This may will be unsettling, both to individual university researchers and to national university systems as a whole. Yet, it would be difficult to identify any period of two decades in the past 50 years when universities did not regard themselves as moving towards a largely unknowable future. Indeed, transition may well have been a fact of university life since the time of Wilhelm von Humboldt.

However, the current situation is probably unique in two respects:

◊ first, the pace of change has accelerated;

◊ second, debates about the future of university research are taking place at national and international level, a sign of the growing appreciation of their importance to the knowledge-based economy.

University research is an essential part of the national science systems of OECD Member countries and represents up to 30 per cent or more of the national R&D effort in a number of them. In addition, the academic sector is the principal performer of basic research. While the linear model of a direct, simple, and causal passage from basic to applied research to development to application has now been largely discredited, basic research remains a principal underlying factor in technological innovation in the long term. More generally, economic analysis has demonstrated that basic research has had major long-term social and economic effects, many of which, such as research in fields underlying information technologies, have been profound, fundamental, and wholly unanticipated.

The fact that governments in most countries have attempted to maintain support for university research despite severe budgetary constraints indicates their recognition of its importance. Nonetheless, government financing has stagnated in the 1990s and, in some countries, has declined in absolute terms.

The demand from other national sectors, primarily the business sector, for the research competencies concentrated in the academic sector provides another measure of the importance of university research to the knowledge-based economy. As industrial research has come to focus increasingly on the solution to specific short-term problems, large firms that previously conducted basic research in their own laboratories are tending to "outsource" longer-term research to universities. Likewise, in many countries industry-university research partnerships are increasingly attractive. In short, knowledge transfer is now regarded as an important and legitimate function of universities, in addition to their more traditional roles of producing knowledge (research) and transmitting it (teaching and training).

As a result of these trends, many university researchers are finding that although they are still expected to undertake basic research at a level of excellence measured according to the international standards of their discipline, they are also required to engage in research of social and economic relevance. Many, but by no means all, university researchers may be stimulated by this challenge. However, the fact remains that, in most countries, incentives for them to engage in knowledge-transfer activities are far from optimal.

To a certain extent, this report has accorded more attention to trends and issues affecting research in the "hard" sciences and engineering than in the humanities and the social sciences. However, the policy concerns expressed below also apply to researchers in the social sciences and the humanities, who face the same pressures and opportunities, with the difference that their partners are more likely to be government departments responsible for public policy.

Government financing of university research

The stagnation and, in some cases reduction, of government support for university research in virtually all OECD Member countries is no doubt the principal factor that has led to a reshaping of university research, at least in the short term. This is only one component of a broader pattern of declining R&D funding that has been characteristic of the 1990s. In many countries, academic research has fared better than other parts of the overall national science and technology effort, particularly those related to national defence. Nevertheless, the prospects of continuing stagnation or decline is a source of considerable discomfort to universities, even in the best cases. Many are engaging in priority-setting exercises and have eliminated less productive lines of research and/or have combined two or more previously separate research units in the interest of greater efficiency. While such re-examination and reorganisation are no doubt healthy and even necessary for maintaining the vitality of academic research, they can also lead to unanticipated, long-term negative consequences when carried out in a crisis atmosphere. In a few OECD countries, reductions in government support and the prospects of more to come constitute genuine crisis, both for individual institutions and for the national academic research system as a whole.

Governments need to be aware of the importance of basic research as a reservoir of knowledge, which needs replenishing to ensure a constant stream of applications. A shortage of research grants means that young scientists beginning their careers start slowly and that the very best are held back owing to a lack of research support. While countries are investing large sums in education, they may be jeopardising the returns on that investment if there is insufficient support for research.

In addition to the changes brought about by the prospect of continued stagnation in absolute levels of financial support, universities are also confronting changes in the character of government financing. In many countries, a considerable share of government support is now provided on a contract, mission-oriented basis, conditional on demonstrable or measurable short-term performance. There is a clear tendency in these countries to reduce base funding for university research ("first money flow" as it is sometimes called) as compared with conditional, mission-oriented, "second-flow" funding. This policy may be consistent with the knowledge-transfer functions of universities in contexts where second-flow funding has traditionally been low (10 per cent or less of total government support). It becomes more problematic when less reliable conditional funding represents a large share of government support. Creative research is frequently a long-term process which requires some reasonable assurance of stable, long-term funding. In contrast, over-reliance on conditional or contract support can lead universities to prefer short-term research projects when they are not sure that contract support for specific projects will continue to be forthcoming.

Another source of stability – or instability as the case may be – has to do with the ways in which governments allocate base research funds. In many cases, total funds are allotted to universities on the basis of the number of students they enrol or graduate, with research funds a specific portion of total funds. Holding research support hostage to student enrolments could have serious negative consequences in the long term if, as some analysts predict, the total number of students declines as a result of demographic trends. In the shorter term, it can lead to instabilities tied to year-by-year variations in enrolments.

Government policies intended to link academic research more directly to other sectors of the economy, and to require that at least some of the research supported by public funds is performance-based, are consistent with the importance of academic research to the knowledge-based economy. However, if carried to extremes, they can distort and undermine that research by obliging universities to focus excessively on short-term research that could be carried out in other types of institution. This may be detrimental to the traditional mission of universities to conduct long-term, curiosity-driven research and to impart knowledge to new generations of students.

Industrial contracts and partnerships

Governments are encouraging universities to seek industrial research support by various means, *e.g.* by making support partially conditional on establishing industrial research partnerships. Industrial support, whether in the form of contracts or research partnerships, is a welcome and often necessary complement to stagnating government financing. In addition, it promotes the integration of universities into the knowledge-based economy.

Owing to opportunities for industrial contracts and partnerships, some academic institutions are gradually transforming themselves into partially or even largely self-financed “profit” centres. This trend is likely to be amplified, although it will not become the dominant pattern for academic research within national science systems. Concerns expressed in the past about the ownership of intellectual property resulting from university research linked to industry, or about possible limitations imposed on the publication of commercially relevant research results in the open literature, have most often been settled to the satisfaction of both university and industry partners. A more serious problem is that not all types of higher education institutions, nor all disciplines, can prosper equally in this way. Such a road is most easily taken by medical and engineering schools. For science-oriented institutions it is more difficult. For most of the social sciences and all of the humanities, it is virtually impossible.

Industrial partnerships can be of much benefit to university research. However, there are clear limits on the financial resources universities can obtain from private industry or other non-government sources. While industrial financing can complement government financing, it cannot replace it. While universities can certainly make direct, short-term contributions to national economies, substantial core funding unrelated to identifiable short-term objectives will continue to be required if universities are to conduct the basic research on which the long-term vitality of the knowledge-based economy depends.

Because governments are demanding closer links between research and industry, there is a strong tendency to decrease the share of curiosity-driven research. At the same time, large industrial groups are withdrawing from basic research, in the expectation that the universities will furnish them with the knowledge they need and SMEs do not generally undertake research, with the exception of a highly innovative few. Under these conditions, there is a need to maintain enough basic research in universities and government laboratories while ensuring appropriate science-industry links.

The concentration of university research

Financial constraints are associated with a trend, noticeable in several countries, towards concentrating research activities in fewer universities and dividing specialisations among them. For some countries, this represents the continuation of a longer-term trend; for others, it results from more recent decisions. The search for excellence in a context of increasing competitiveness and mounting research costs in many disciplines explains this policy of selectivity. It is also due to the need of scientists in an increasing number of disciplines to use large-scale research facilities which are beyond the resources of any single institution and, in some cases, any single country.

For a number of reasons, however, the trend towards concentration and specialisation is likely to be self limiting. In most countries, there is a need to maintain research activities in a number of higher education establishments in order to serve the needs of local communities and industries. Furthermore, the training of creative scientists generally requires an active research environment. Finally and significantly, the development of information technologies facilitates the establishment of "research schools" without walls and the networking of distant research teams within countries, within regions, and at the global level. This works against concentration of research activities and in favour of its dispersion.

In this context, the principal issue to be addressed involves the concentration and selectivity of research within individual higher education establishments themselves. Choices will have to be made regarding the disciplines for which research capabilities should be maintained and supported, for which investment in scientific equipment should be made, and for which special efforts to link research more closely to teaching will be fruitful.

Balancing research with other university functions

Although it is now broadly recognised that universities make important contributions to the knowledge-based economy through their research and knowledge-transfer functions, it is likely that a sizeable majority of citizens in OECD countries assign a higher value to the teaching and training functions of national systems of higher education. Given the almost certain persistence of the trend towards a globalised economy, with increased opportunities for both co-operation and competition, a high value will continue to be assigned to the role of higher education institutions in preparing not only future scientists but young people in non-scientific fields as well. In recent years, it has become increasingly important for workers to undergo continuing education at post-graduate level and on a lifelong basis in order to acquire the most advanced knowledge and technology. This type of education and training is one of the main factors for the success of universities in the 21st century. In some countries, universities have very valuably faced up to this challenge with some degree of sucess, notably through special structures such as “open universities”.

The current trend towards concentrating research in fewer institutions, coupled with the increasingly important teaching and training roles of higher education systems as a whole, is creating noticeable institutional tensions. This is particularly true in countries experiencing strong rises in higher education enrolments. Rising student populations and higher demand for retraining and continuing education increase the burden of teaching tasks. With resources not increasing and sometimes decreasing, funds and jobs will go first to teaching functions unless they are specifically earmarked otherwise. The problem of the balance between research and teaching is being posed with ever greater force to teachers and administrators as well as to decision makers.

Creative use of information technologies is already providing both students and teachers with access to library resources world-wide and recorded lectures especially prepared by renowned specialists. Future developments along these lines promise to enrich possibilities for creative teaching in a broad spectrum of fields of knowledge and applications. The increasing convergence between on- and off-campus modalities offers students greater independence and the possibility to learn in a variety of university settings.

This report has repeatedly noted that universities are uniquely situated to conduct long-term basic research and that government policies should recognise this. However, the teaching and training functions of universities, as pacesetters for national systems of higher education, may be an even more unique resource. Certainly, providing adequate training for the 21st century will be essential for the knowledge-based economy. Thus, government and university policies need to maintain an appropriate balance and seek to ensure that their teaching and training functions are not undermined by an excessive concern with research and knowledge transfer – or the reverse. On the contrary, they should seek to ensure that all the functions of universities are mutually reinforcing.

The status of university researchers

The status and recognition accorded to academic researchers should be consistent with the differing roles they are called upon to play in fulfilling the multiple functions of modern universities. Although teaching and supervising the research of doctoral degree candidates have long been regarded as important responsibilities, contributions to basic research, as judged by publications in peer-reviewed journals, have, until recently, remained the principal criterion for decisions regarding salaries and promotion. This situation is changing, at least in some countries, so that excellence in teaching is also regarded as worthy of recognition and reward. Increasing recognition of the value of the knowledge-transfer function further complicates the assigning of appropriate rewards.

In most, although certainly not all, OECD countries, rewards and promotions for university researchers are made on the basis of centrally determined regulations, with individual universities enjoying some flexibility in their application. A central issue to be addressed both by governments and university administrators is the extent to which existing rigidities in the academic reward system inhibit the creative potential of university researchers and thus limit universities' contributions to the knowledge-based economy.

Most procedures for apportioning rewards to academic researchers are still based on the outmoded assumption that, no matter what their level, they are potentially long-term members of university faculties. However, the increasing prominence of mission-oriented, contract-based support has altered the balance between the numbers of university researchers on short-term contracts and the more traditional tenured faculty. Procedures that encourage the mobility of younger researchers among academic institutions and between the academic and industrial sectors can be regarded as essential to the vitality of science systems. However, when a sizeable majority of university researchers qualify as short-term personnel, as is now the case in several OECD countries, professional as well as institutional instability can result, and scientific creativity can suffer. Contract personnel will, of necessity, devote a good deal of attention to seeking their next professional positions, publishing and/or seeking new contracts, rather than to long-term, in-depth investigations.

A final important aspect to be considered in connection with the status of university researchers involves the conditions that encourage – or discourage – their entrepreneurial efforts, including the creation of their own firms. Entrepreneurship has been clearly identified as a major vehicle for technological innovation and, therefore, one of the principal mechanisms for knowledge-transfer from universities to the business sector. Yet entrepreneurship appears to be an extremely limited phenomenon in most OECD countries' research communities. Entrepreneurial dynamism in the academic and publicly funded research communities depends, of course, on broader parameters, such as the availability of venture capital, as well as on locally conducive climates such as active science parks. But it is also affected by regulations that can encourage entrepreneurial risk, such as those that allow temporary detachment from academic positions and subsequent reintegration, if necessary, after some years. Such provisions could be particularly useful in countries where inter-sectoral mobility and risk-taking have not been the norm.

The training and employment of scientists

One of the principal challenges facing universities is the training of new generations of scientists who are more flexible, more attuned to interdisciplinary research, more prepared for entrepreneurial ventures, and more at ease in an international setting. Of course, the initiative to modify and expand existing curricula and educational policies and practices so that new scientists are adequately prepared to meet the demands of the next century must come primarily from universities themselves. But governments also have an important role to play. In countries where university curricula and policies are determined by central authorities, governments may want to ask themselves whether regulations intended to achieve a degree of uniformity in all institutions of higher education are consistent with the objective of providing optimal educational opportunities for young creative scientists.

There is also the fact that certain countries confront a potential future shortage of researchers, including university researchers. Large contingents born in the "baby boom" will retire over the next decade. Meanwhile, there is the concern about a "flight" from science among youth, many of whom prefer other types of studies. This situation, which cannot be generalised to all countries and does not affect all disciplines equally, should be a serious source of concern for governments. Appropriate measures are needed to motivate young people to consider careers in the expanding and increasingly vital scientific sphere.

Problems of employment related to the profound changes taking place in economic systems presently dominate our societies. They obviously affect the university system, a primary role of which is to furnish young people with the means of earning a living. In terms of preparation for jobs in science, the situation is somewhat contradictory. On the one hand, there is the apparent lack of interest in science and technology; on the other, a wish to enter professional life as late as possible, or to enter it with a maximum of assets, leads some to prolong their studies up to the doctorate and beyond. However, young people with doctorates do not easily find jobs. The university system can no longer absorb them owing to budgetary constraints. For their part, firms are hesitant. There is, as a result, at least in the United States and in the European Union, a floating population of highly qualified post-doctoral researchers who move from one laboratory to another in different countries in their search for a stable job. If post-doctoral studies are undeniably valuable, they have, when carried on too long, undesirable effects. This is one of the significant problems facing those responsible for research.

Science education for non-specialists

Even though young people in some countries and disciplines may be turning away from science as a career, there is strong evidence of continued public interest in science and technology throughout the OECD area. One reason is an intrinsic interest in the subject matter; another is the recognition that a certain level of understanding of science is necessary in order to grasp the complexities of the modern world. In addition, young people in particular understand that, up to a certain level, course work in science is essential to a wide range of non-scientific careers in the knowledge-based economy. Higher education systems thus face the challenge of ensuring that adequate educational opportunities in science are made available to non-specialists with a wide range of interests and career aspirations. Both in institutions that are research-oriented and those that are not, it is important to ensure that the quality of science courses for non-specialists is adequate and suited to their needs.

Universities may also want to examine their interest in, and responsibility for, science education at the secondary school level. One of the reasons given for the apparent flight from science among young people is the quality of their exposure to science at this level. Moreover, consistent and convincing data indicate that understanding of, and attitudes towards, science on the part of adults are directly and positively correlated with the amount of their science course work at both secondary and tertiary levels. As in the case of university-level education for non-specialists, universities, as well as individual researchers, may find that it is in their interest to try to influence secondary school scientific curricula so as to maintain, if not increase, the number of young people aspiring to scientific careers, and to help ensure that the broader public is equipped to understand and maintain positive attitudes towards science.

Whereas it may be relatively easy for universities to ensure that science is of adequate quality for both specialists and non-specialists at non research-oriented institutions of higher education, it will be considerably more difficult to do so at the secondary school level. Even in countries without national systems of education at either level, the authorities responsible for secondary and for higher education are not the same. Governments can help facilitate fruitful communication between the relevant authorities and individual institutions. They may also want to consider incentives to encourage productive partnerships between specific universities and secondary school systems, in the best long-term interests of both the higher and secondary systems of education.

The management of universities: towards greater autonomy

Many of the trends discussed in this report suggest the need to extend university autonomy, particularly in countries with centrally controlled systems of higher education. This autonomy, which also involves responsibility for the decisions made, is essential if universities are to enter into mutually advantageous partnerships with industry and engage in other forms of knowledge transfer. Moreover, greater autonomy can facilitate necessary innovations in instruction at all levels. In countries where centralisation and over-regulation are the norm, fundamental changes will be needed to allow universities to gain the control over decision making they require to function effectively in a changing framework.

At the same time, universities should demonstrate that they intend to make good use of their greater autonomy by increasing internal flexibility and adapting organisational structures accordingly. Many, if not most, universities still are organised along relatively rigid, traditional disciplinary lines, often to the detriment of interdisciplinary research and the emergence of new fields of knowledge. Such rigidities can also inhibit the establishment of effective co-operation with industrial research organisations, which are not structured according to disciplines. The establishment of government-supported centres, such as centres of excellence and co-operative R&D centres, constitutes a useful and efficient means of stimulating such adaptation. However, such centres will necessarily be limited in number and located selectively, and, in all countries, most universities will have to take the initiative in adapting themselves to conditions likely to prevail in the new century.

Evaluation and public expectations for university research

Ironically, a principal factor in the reshaping and restructuring of university research has been recognition by governments, as well as the broader public, of the contribution universities can make to the knowledge-based economy. This carries with it the expectation that universities can, in fact, make this contribution, and there is, as a result, a trend, in many countries, to evaluate the results of university research. Part of the motivation for evaluation is the desire to establish priorities in a rational way so that decreasing financial resources can be used most productively, but much of it also derives from the reasonable supposition that universities, together with other publicly funded institutions, should be held accountable for the use of their funding.

Universities themselves often evaluate their research activities in order to demonstrate that they are responsible stewards of public funds. Government agencies, primarily funding agencies, do so as well, for much the same purpose. Measures of research output, in the form of publications and citations, for example, have of course been used as evaluation tools for a long time. However, increasing interest in public accountability has led to attempts to evaluate broader, more long-term results, such as the contributions of research to technological innovation or to the training of students. These measures are more comprehensible and more meaningful to the public than traditional output measures.

There are many uncertainties and occasional risks involved in university research outcome evaluations. However, if properly constructed, conducted, and interpreted, they can be valuable both to universities and to governments. Because research, in a university setting, should be closely linked to teaching and knowledge transfer, the evaluation exercises should, at a minimum, be planned and conducted with a view to assessing the impact of the research function on these other, equally important functions.

Beyond the issue of formal evaluation, the extent to which universities, in their research function, will be able to meet public expectations regarding their role in society will continue to depend crucially on the extent to which those expectations are realistic. For example, there is considerable justification for the claim that basic research can lead to appreciable long-term benefits. However, there is a risk that if too much is made of this claim in an effort to obtain increased government funding, both governments and the public will be disillusioned when immediate, visible benefits are not forthcoming. Alternatively, governments may be tempted to provide support only to those disciplines with obvious commercial potential and short-term research projects to the detriment of the long-term, curiosity-driven basic research that should continue to provide the foundation of any national university research effort.

University research in the 21st century

Clearly, heightened public expectations present universities, collectively, with significant challenges, responsibilities, and opportunities. Whether universities, governments, and the broader public will seize those challenges and make the best use of those opportunities remains to be seen.

It is of course not known, in any detail, what the character and structure of universities will be in the year 2010 or 2020. However, present trends make it possible to discern broad future possibilities. Because financial constraints on government support for university research in most OECD countries are unlikely to abate, at least in the foreseeable future, the trend towards concentration of research capabilities as well as specialisation is likely to persist, as will competition among universities, a phenomenon that will increasingly assume international dimensions and may intensify as the quality of the research conducted by universities in non-OECD countries becomes more internationally competitive.

While research has always involved both co-operation and competition for recognition by peers, competition today mainly concerns obtaining resources – on a world-wide scale in the case of megascience. However, the educational system itself has become embroiled in these struggles. At national level, rivalries among various institutions take diverse forms, depending on their status. In countries where they are primarily publicly funded, private institutions can compete in particular niches, such as professional training or continuing education. Internationalisation also plays a role, with the appearance of “off-shore” campuses. The arrival of market principles in the higher education sector has consequences that are not yet well understood, particularly in the area of research.

This process has already caused pain in institutions obliged to reduce or eliminate particular lines of research, and even more so for the researchers who suffer as a consequence. Because it is likely to continue, so will the difficulties of certain institutions and individual researchers. In such cases, governments and universities should take steps to reduce the difficulties caused by these transitions as much as possible and to ensure that the talents of displaced researchers continue to be used to benefit society. In any case, mobility of researchers and teaching talent among institutions should be greatly encouraged. In those few countries where the decline in financing for university research may be said to have reached crisis proportions, particular care must be taken to maintain a core of excellence, in order to provide a basis for a later build-up of university research capabilities.

Consistent with the concentration of research capabilities, the internal dynamics of a growing number of scientific disciplines have led to an increasing need for large-scale apparatus that can only be made available at national research centres and, in some cases, internationally funded ones. This trend, including the need for international cost sharing, will almost certainly persist, reducing to some extent the need for universities to try to maintain expensive research facilities, while shifting the burden of support to the construction and operation of large-scale facilities. A challenge to governments at both the national and international levels is to ensure the optimum use of major centralised facilities in the best long-term interests of both science and society.

Although it causes difficulties for specific institutions and researchers, the trend towards concentration and selectivity can also lead to a more efficient and productive science system. Trends largely outside the control of national governments also suggest that the longer-term future of university research as a whole will be positive, whatever the precise structure of individual institutions. Most obviously, information technologies are already being used to connect teams of researchers at different institutions, thus creating virtual universities which in some cases already transcend national boundaries. These technologies can also be used to provide access to distant research facilities. Finally, information technologies are making the research and teaching resources of major research universities available to institutions throughout national systems of higher education and, to a still limited extent, to institutions at the secondary level as well.

While these trends will almost certainly continue, greater use of information technologies to link research groups with one another, as well as with other types of institutions, is unlikely to be entirely trouble-free. Indeed, on the basis of past experience, it is almost certain that there will be unforeseen consequences, both positive and negative. Governments need to ensure that the process is appropriately monitored in order to foresee and if possible eliminate or at least mitigate the negative impacts.

As the use of information technologies to link academic and quasi-academic research teams expands to encompass institutions in several countries, the concept of a purely national university research system will become increasingly blurred, resulting in novel challenges for both governments and universities. On the positive side, it is possible to envision a future in which links among universities become truly global so that they make significant contributions not only at national level, but at international level as well. However, many problems outside the scope of the universities will have to be resolved before this can happen.

Limitations on the future scope of university research are more likely to be due to the lack of sufficient human, rather than financial, resources. Perhaps the most significant issue, and one that must be monitored on a continuing basis, is ensuring that adequate numbers of creative, well-trained, and adaptable individuals choose to undertake research careers in universities and related institutions and that these institutions are in a position to make the best use of their talents. Otherwise, the positive trends foreseen in this report may well not be realised. It will require the joint efforts and good will of governments, universities, primary and secondary schools, and the public at large to address this complex issue.

Von Humboldt's vision of universities as institutions where long-term research could be linked with creative teaching and training for the benefit of society at large has been realised in most OECD countries over the past half-century. The broader public, which has traditionally valued universities primarily for their teaching function and their contributions to culture, now recognises their key role in the knowledge-based economy. Governments are therefore almost certain to take steps to maintain the capabilities of their national research systems, at least at some level. A major short-term challenge is to ensure that the role of universities as producers of knowledge is not sacrificed or compromised by the lure of short-term commercial gain and that the production, transmission, and transfer of knowledge are mutually reinforcing.

A fundamental longer-term challenge is to ensure that universities can continue to adapt so that their three functions can benefit society at the local, national, and global levels. Successfully addressing both the short-term and long-term challenges will require a concerted effort by universities, government, industry, and society at large, all of which have a stake in maintaining and increasing the vitality of university research.

ANNEX 1

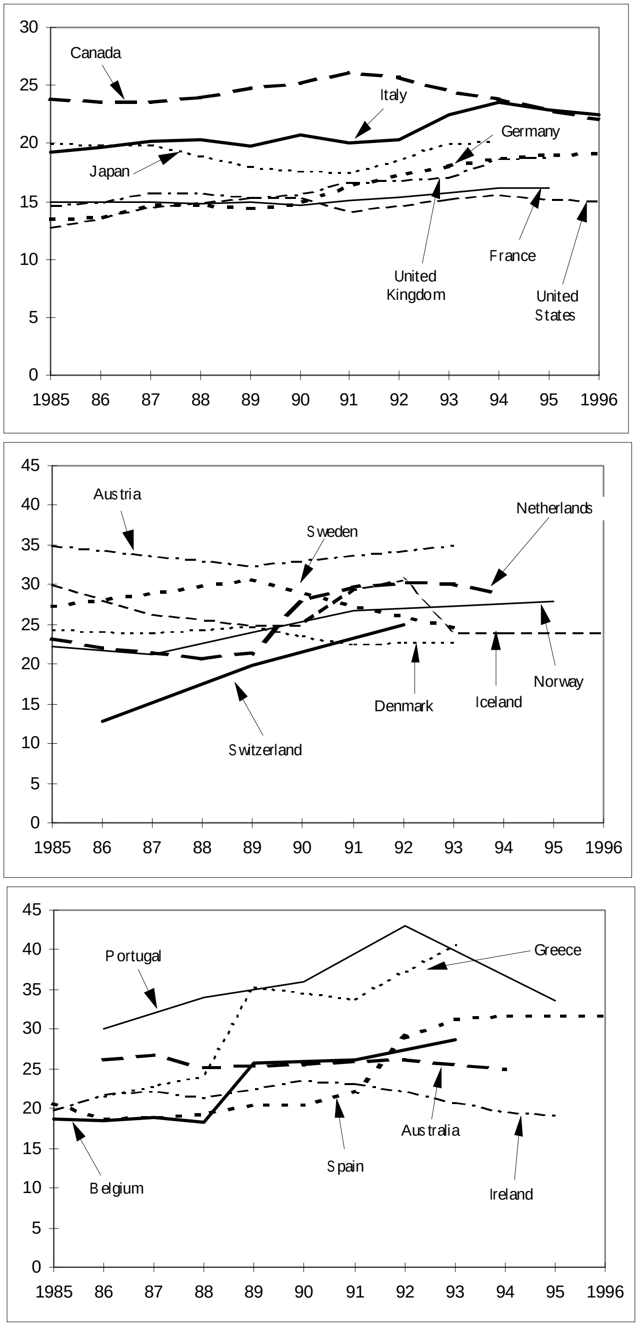
FIGURES AND TABLES

For details about the mode of gathering and computation of data presented in the following figures and tables, see *Main Science and Technology Indicators*, published annually by the OECD. Information is provided on changes affecting specific countries' databases and which may explain important, sudden variations. Explanations are also provided on technical issues such as the Purchasing Power Parity (PPP) indexes used for facilitating comparisons among countries' R&D efforts.

ABBREVIATIONS

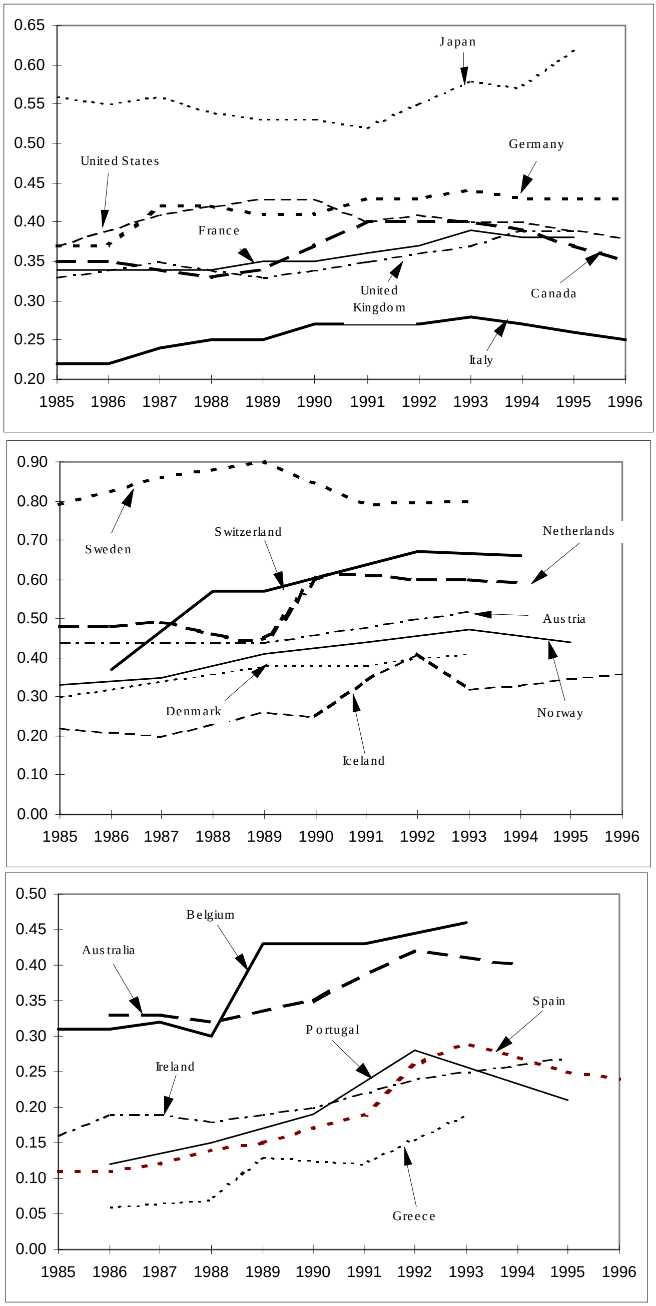
GERD	Gross Domestic Expenditures on R&D
HERD	Expenditures on R&D in the Higher Education Sector
BERD	Expenditures on R&D in the Business Enterprise Sector
GBAORD	Government Budget Appropriations or Outlays for R&D
GUF	General University Funds
HE	Higher Education

Figure 1. **Percentage of GERD performed in the HE sector**



Source: OECD, STIU database(DSTI), August 1997.

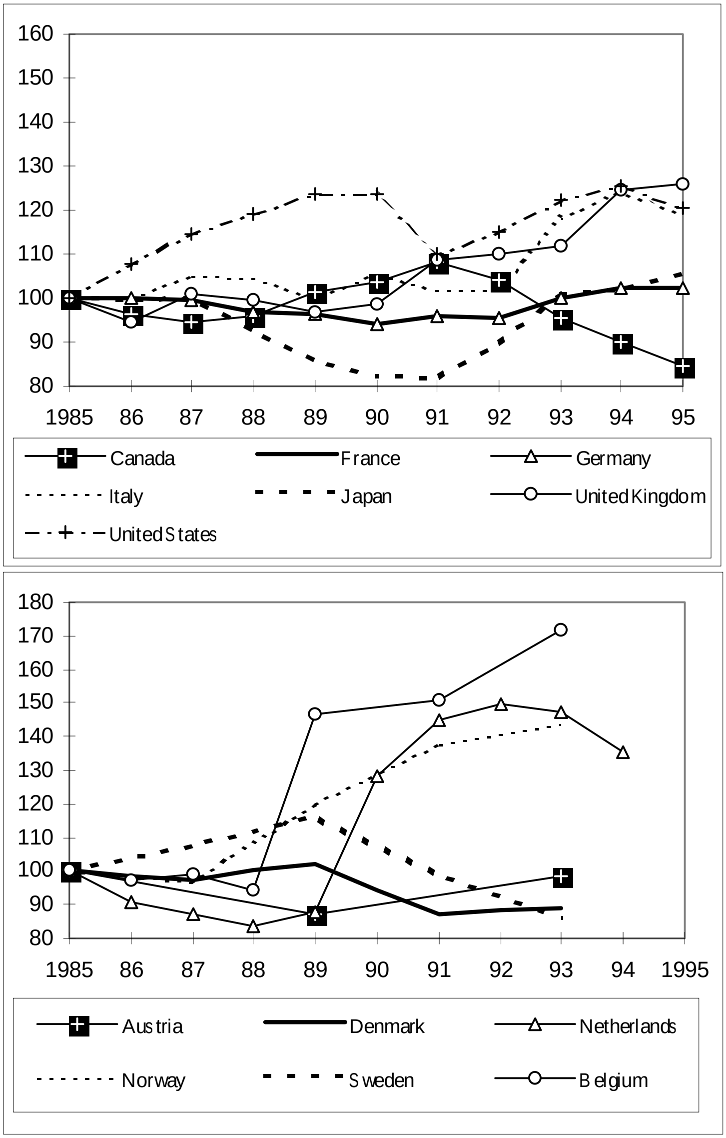
Figure 2. **HERD as a percentage of GDP**



Source: OECD, STIU database(DSTI), August 1997.

Figure 3. **HERD/GERD**

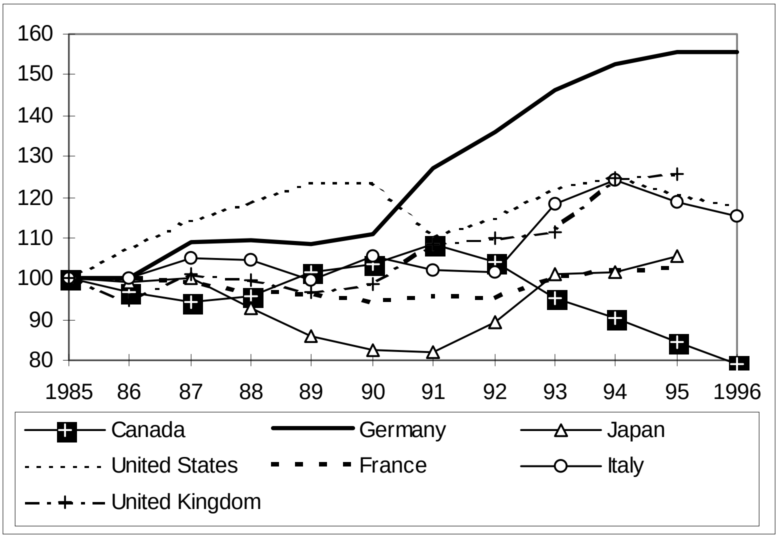
Index: 1985=100

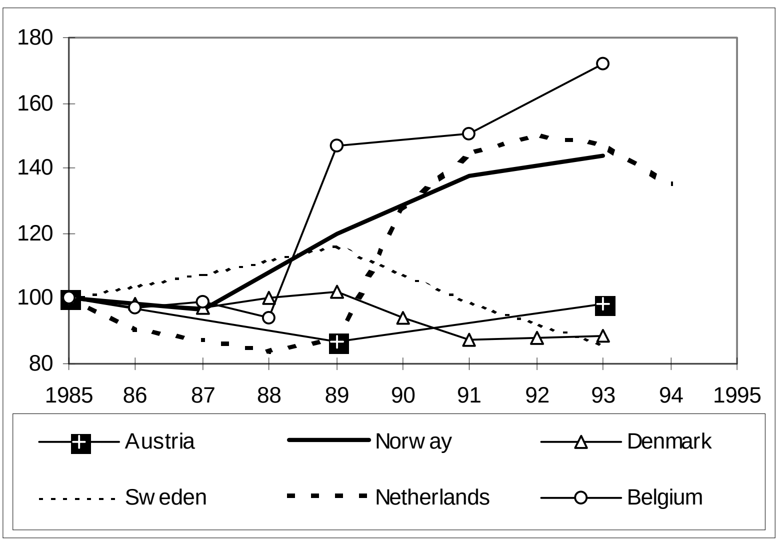


Source: OECD, STIU database(DSTI), August 1997.

Figure 4. **HERD/BERD**

Index: 1985=100

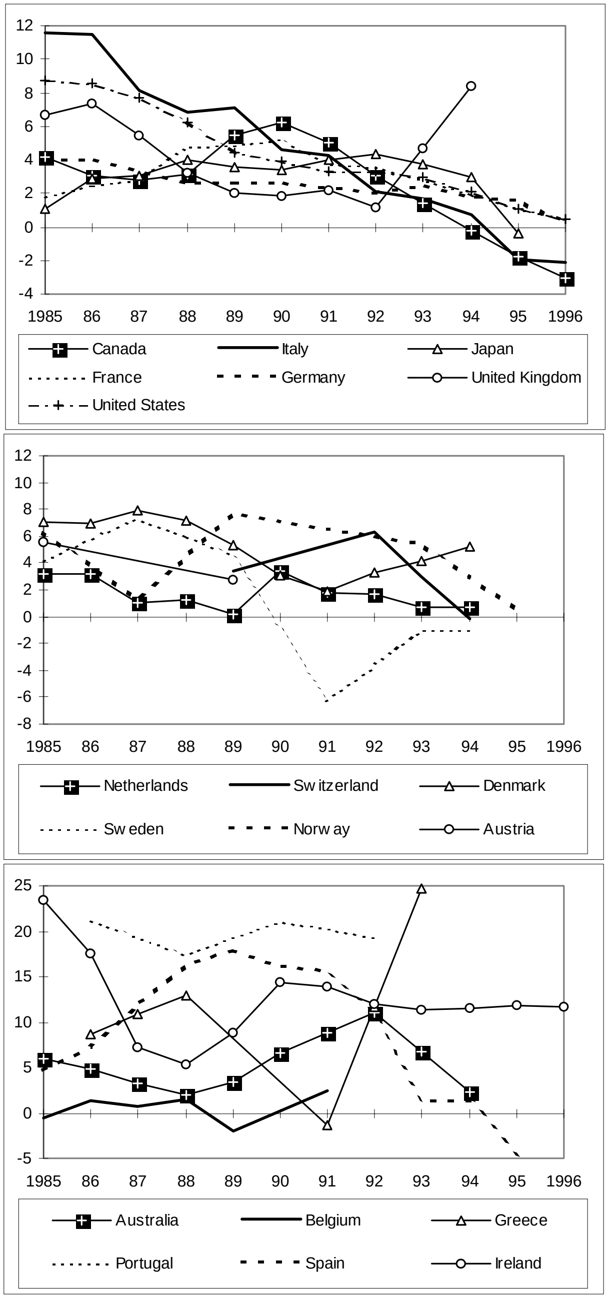




Source: OECD, STIU database(DSTI), August 1997.

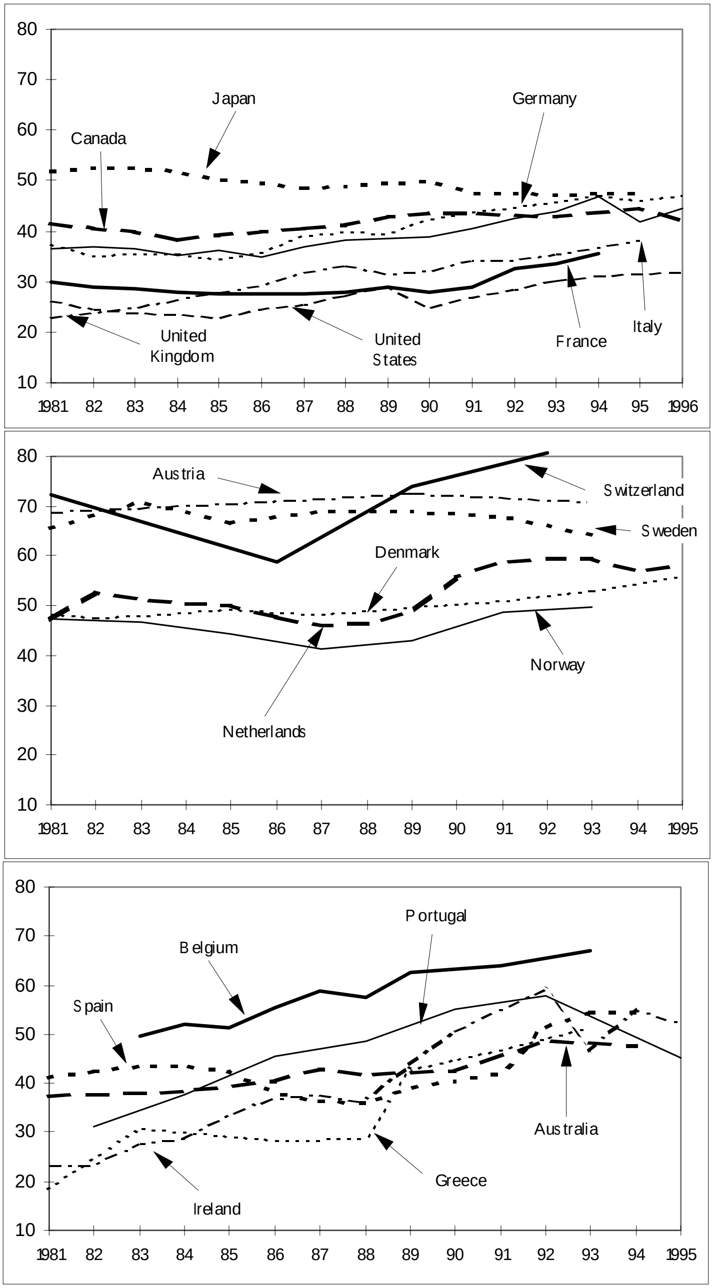
Figure 5. **HERD growth (constant prices)**

Centered 3-year moving average



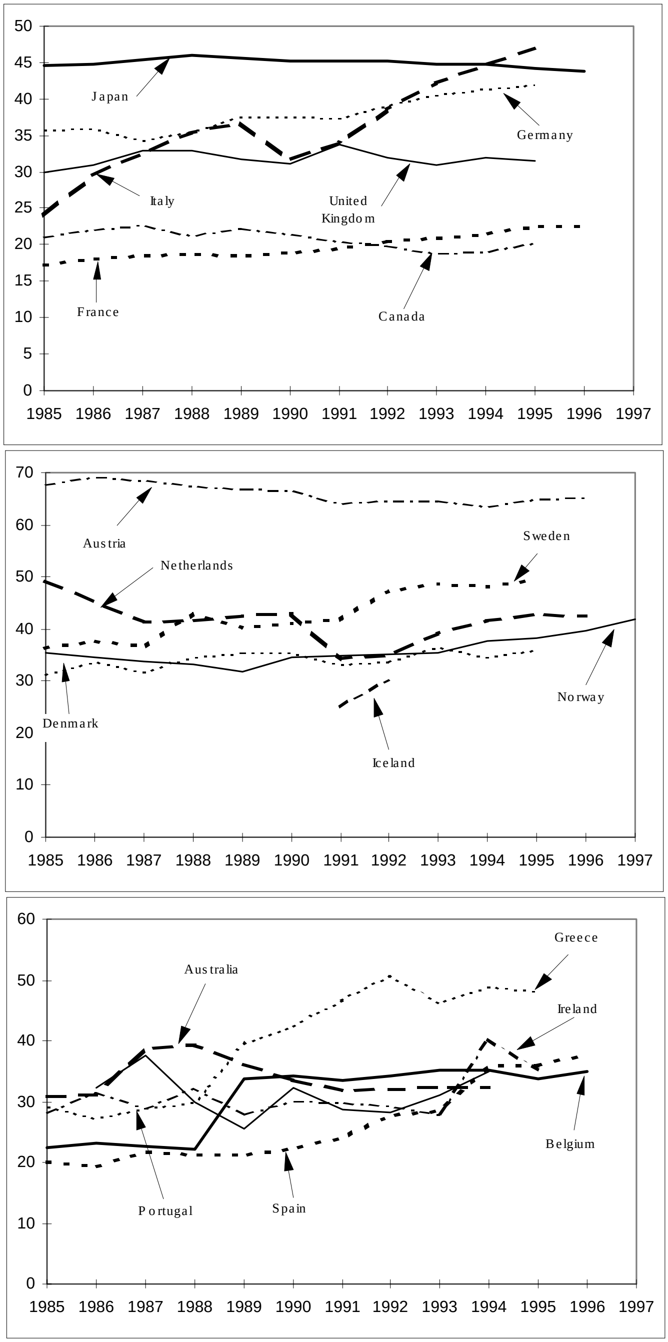
Source: OECD, STIU database(DSTI), August 1997.

Figure 6. **Share of government-funded R&D performed in the HE sector (percentage)**



Source: OECD, STIU database(DSTI), August 1997.

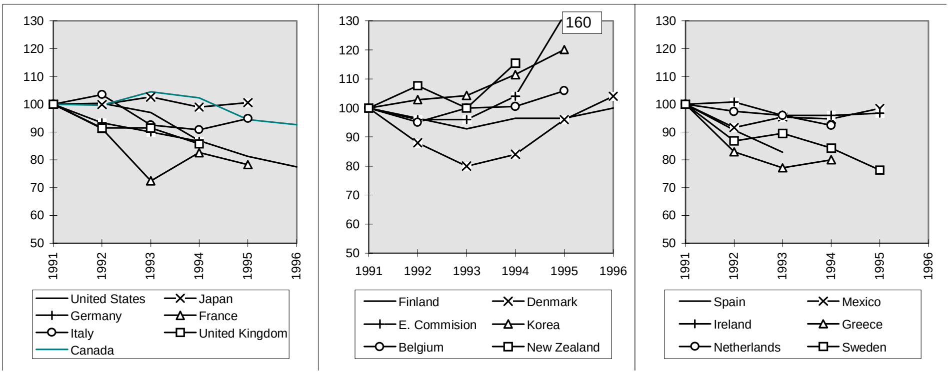
Figure 7. **General University Funds (GUF) as a percentage of civil GBAORD**



Source: OECD, STIU database(DSTI), August 1997.

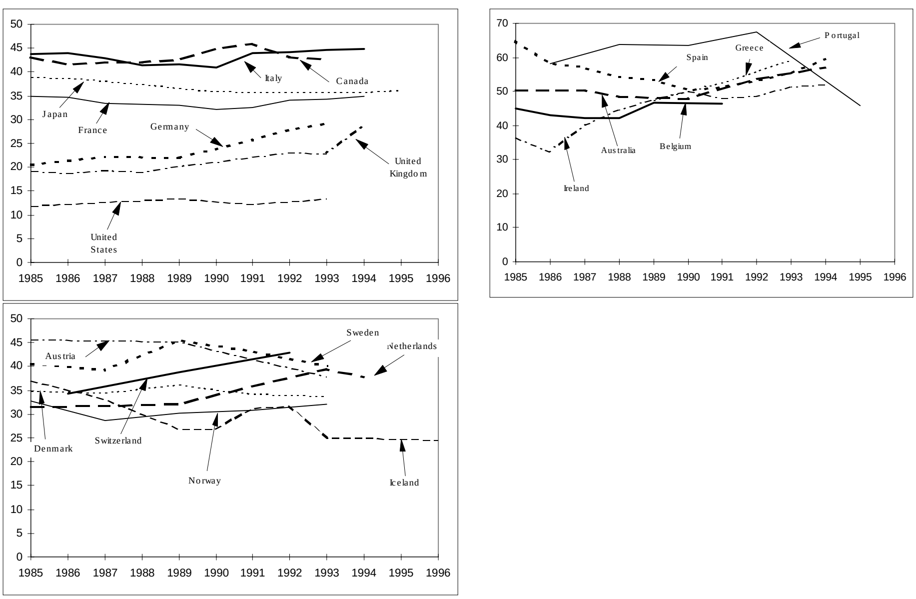
Figure 8. **Trends in government R&D budgets as a percentage of total budget**

Index: 1991=100



Source: OECD, STIU database (DSTI) and national sources.

Figure 9. **HE researchers (or university graduates) as a percentage of national total**



Source: OECD, STIU database (DSTI), August 1997.

Table 1. **HERD**

Million current PPP$

	1985	1990	1991	1992	1993	1994	1995	1996
Canada	1 280.0	1 882.6	2 055.1	2 158.1	2 232.8	2 292.7	2 288.6 [6]	2 260.8 [3]
Mexico	..	..	..	..	807.4	997.1	1 017.1	..
United States	14 809.3	23 831.0 [4]	22 657.0 [2]	24 055.0 [7]	25 235.0 [7]	26 352.0 [7]	27 300.0 [7]	27 800.0 [7]
Australia	..	960.9	..	1 245.2	..	1 361.9	..	..
Japan[1]	8 220.6	11 761.4	12 432.2	13 797.5	14 968.1	15 199.7	16 967.4	..
New Zealand	..	125.5 [2]	129.6	153.1	154.5	..	..	..
Austria	412.3	..	..	..	799.3	..	..	..
Belgium	371.6	..	747.8 [5]	..	898.4 [6]	..	..	..
Czech Rep.	..	..	30.6 [6]	15.7 [6]	37.2 [6]	50.9 [6]	95.6 [2]	..
Denmark	202.5	326.5	345.7	372.2	408.2	..	..	..
Finland	189.4 [2]	288.1 [5]	355.6 [2]	361.4 [5]	359.0	365.6	388.4 [6]	..
France	2 408.1	3 463.2	3 767.5	4 055.4	4 183.5	4 281.0	4 383.2	..
Germany	3 008.4	4 717.0 [5]	5 796.1 [2]	6 409.8 [2]	6 580.4	6 964.0	7 257.2	6 950.3 [3]
Greece	..	..	124.3	..	221.6	..	..	..
Hungary	..	..	132.9 [6]	136.7 [6]	136.2 [6]	152.2 [6]	124.9 [6]	..
Iceland	7.0	10.9	15.8	19.6	15.9	17.2	20.6	20.0
Ireland	42.0	80.4	96.1 [5]	115.1	128.5 [5]	149.1	166.1 [6]	..
Italy	1 443.3	2 481.2	2 581.7	2 751.5	2 867.1	2 920.2	2 901.7 [6]	2 866.5 [3]
Netherlands	819.2	1 437.0 [2]	1 508.0	1 592.5	1 639.4	1 692.5	..	..
Norway	188.0	..	348.8	..	436.0	..	437.5 [5]	..
Poland	..	..	..	..	..	373.4 [6]	401.0 [6]	..
Portugal	..	180.8	..	301.0	..	..	253.7	..
Spain	349.4	792.0	961.9	1 368.1	1 490.6	1 424.0	1 411.3	1 387.4
Sweden	861.0	..	1 146.1	..	1 180.7	..	..	..
Switzerland	..	..	..	1 055.7	..	1 108.4	..	..
Turkey	..	597.2	1 034.1	997.1	984.1	769.7	920.6	..
U. Kingdom	2 131.8 [2]	3 109.8	3 171.7	3 477.5	3 627.5 [2]	4 055.4	4 021.8	..
Total OECD	35 629.9 [3]	55 691.9 [3]	58 366.9 [2]	63 470.9 [3]	66 600.1 [3]	69 095.4 [3]	72 342.0 [3]	..

1. Overestimated, or based on overestimated data.
2. Break in series with previous year for which data is available.
3. Secretariat estimate or projection based on national sources.
4. National results adjusted by the Secretariat to meet OECD norms.
5. National estimate or projection adjusted, if necessary, by the Secretariat to meet OECD norms.
6. Provisional.
7. Excludes most or all capital expenditure.

Source: OECD, STIU database (DSTI), September 1997.

Table 2. **Share of R&D performed in the HE sector funded by business enterprise**

Percentage

	1980	1985	1990	1995
United States	2.5	3.8	4.7	5.8 [4]
Canada	3.9	4.3	6.3	10.7 [4]
Mexico	..	..	..	1.4
Japan	1.0	1.5	2.3	2.4
Australia	1.4 [1]	2.1 [2]	2.2	3.5 [5]
New Zealand	..	..	4.6	5.2 [6]
Austria	1.0 [1]	1.7	..	2.0 [6]
Belgium	8.1	8.7	15.4 [3]	14.6 [6]
Czech Republic	..	..	..	2.0
Denmark	0.6	1.0	1.6	1.8 [6]
Finland	2.1 [1]	..	3.6 [3]	5.7
France	1.3 [1]	1.9	4.9	3.2 [5]
Germany	2.0 [1]	5.9	7.8	7.5 [4]
Greece	0.0 [1]	..	6.1 [3]	3.8 [6]
Hungary	..	..	22.7	2.0
Iceland	1.2 [1]	0.6	6.8	4.3 [4]
Ireland	7.1 [1]	6.9	10.2	6.9
Italy	1.3	1.5	2.4	5.5 [4]
Netherlands	0.3	1.0	0.9	4.1
Norway	1.6	5.0	4.7 [3]	5.3
Poland	..	..	..	11.8
Portugal	0.1	0.9 [2]	0.7	0.8
Spain	0.0	1.1	8.9	5.9 [5]
Sweden	2.3 [1]	5.5	5.2 [3]	6.2 [6]
Switzerland	9.5 [1]	3.3 [2]	..	1.7 [5]
Turkey	..	..	10.3	13.1
United Kingdom	2.8 [1]	5.2	7.6	6.2

1. 1981.
2. 1986.
3. 1992.
4. 1996.
5. 1994.
6. 1993.

Source: OECD, STIU database (DSTI), August 1997.

Table 3. **Basic research as a percentage of R&D performed in the HE sector**

	1980	1985	1990	1995
United States	57.9	62.9	60.7	64.8
Mexico	..	..	..	41.2
Japan	55.8	54.2	54.5 [3]	54.6
Australia	66.5 [1]	63.8 [2]	63.0	60.9 [5]
Austria	..	48.3	48.9 [4]	50.2 [6]
Czech Republic	..	..	..	41.5
Denmark	..	60.1	59.0	61.0 [6]
France	..	89.3 [2]	88.8	87.9 [5]
Germany	76.6 [1]	76.3	73.4 [3]	73.5 [6]
Hungary	..	..	..	45.4
Iceland	70.3 [1]	38.9	46.3	..
Ireland	45.7 [1]	45.4	32.6 [3]	32.4 [5]
Italy	52.0	52.0	52.0	..
Norway	48.3 [1]	46.3	47.1 [3]	48.0
Poland	..	..	..	52.4
Portugal	44.2	43.9 [2]	45.5	53.2
Spain	50.0	50.0	51.2	51.2 [6]
Sweden	70.1 [1]	70.0	67.5 [3]	..

Note: For Japan, figure includes only natural sciences and engineering.
1. 1981.
2. 1986.
3. 1991.
4. 1989.
5. 1994.
6. 1993.

Source: OECD, STIU database (DSTI), August 1997.

Table 4. **Share of business enterprise-funded R&D performed in the HE sector**

Percentage

	1980	1985	1990	1995
United States	0.8	1.0	1.4	1.4 [4]
Canada	2.9	2.5	3.8	4.9 [4]
Mexico	..	..	5.6 [3]	3.6
Japan	0.4	0.5	0.6	0.7
Australia	2.0 [1]	1.5 [2]	1.4	1.9 [5]
New Zealand	..	..	4.4	4.4 [6]
Austria	0.7 [1]	1.2	..	1.4 [6]
Belgium	2.5	2.5	6.2 [3]	6.7 [6]
Czech Republic	..	..	..	0.3
Denmark	0.4	0.5	0.7	0.8 [6]
Finland	0.9 [1]	..	1.4 [3]	1.9
France	0.5 [1]	0.7	1.6	1.0 [5]
Germany	0.5 [1]	1.3	1.8	2.4 [4]
Greece	0.0 [1]	..	9.4 [3]	7.6 [6]
Hungary	..	..	4.7	1.1
Iceland	5.4 [1]	0.7	7.1	3.2 [4]
Ireland	3.0 [1]	3.0	4.1	2.0
Italy	0.4	0.6	1.1	2.5 [4]
Netherlands	0.1	0.5	0.5	2.5
Norway	1.3	2.1	2.8 [3]	2.8
Poland	..	..	..	9.6
Portugal	0.1	1.0 [2]	0.9	1.3
Spain	0.0	0.5	3.8	4.6 [5]
Sweden	1.2 [1]	2.5	2.3 [3]	2.4 [6]
Switzerland	2.5 [1]	0.5 [2]	..	0.7 [7]
Turkey	..	..	26.3	29.3
United Kingdom	0.9 [1]	1.7	2.4	2.4

1. 1981.
2. 1986.
3. 1991.
4. 1996.
5. 1994.
6. 1993.
7. 1992.
8. 1989.

Source: OECD, STIU database (DSTI), August 1997.

Table 5. **Share of government-funded R&D performed in the HE sector**

Percentage

	1980	1985	1990	1995
United States	26.2	23.0	25.1	31.9 [5]
Canada	45.0	39.2	43.7	41.9 [5]
Mexico	..	..	28.7	54.3
Japan	53.0	50.2	49.8	47.4
Australia	37.3 [1]	40.5	42.5	47.7 [6]
New Zealand	..	..	29.5	..
Austria	68.9 [1]	70.7	72.6 [3]	..
Belgium	51.7	51.4	63.9 [4]	..
Czech Republic	..	..	..	21.7
Denmark	48.6	49.3	50.4	56.0
Finland	48.8 [1]	..	49.3 [4]	49.6
France	30.0 [1]	27.4	28.1	35.7 [6]
Germany	37.4 [1]	34.7	40.1	47.3 [5]
Greece	18.4 [1]	28.3 [2]	46.8 [4]	..
Hungary	..	..	38.4	46.4
Iceland	23.9 [1]	35.1	27.0	34.0 [5]
Ireland	23.4 [1]	33.4	50.5	52.5
Italy	35.0	36.3	38.9	44.6 [5]
Netherlands	49.5	50.1	55.9	58.1
Norway	49.2	44.4	48.6 [4]	53.4
Poland	..	..	..	31.4
Portugal	28.5	45.5 [2]	55.2	45.3
Spain	40.5	42.6	40.3	54.2 [6]
Sweden	65.6 [1]	66.5	67.9 [4]	..
Switzerland	72.2 [1]	58.7 [2]	74.0 [3]	..
Turkey	..	..	86.3	89.5
United Kingdom	22.9 [1]	27.8	32.3	38.2

1. 1981.
2. 1986.
3. 1989.
4. 1991.
5. 1996.
6. 1994.

Source: OECD, STIU database (DSTI), August 1997.

ANNEX 2

GROUP ON THE SCIENCE SYSTEM: LIST OF DELEGATES

Country	Delegate
Chair: Mr. W.A. BLANPIED (United States)	
Australia	Mr. M. GALLAGHER
Austria	Mr. R. SCHURAWITZKI
Belgium	Mr. M. LUWEL
	Ms. D. SIMOEN
Canada	Ms. E. ISABELLE
Czech Republic	Mr. Z. VEDRAL
Denmark	Mr. B.L. JENSEN
	Mr. H. von LINSTOW
Finland	Ms. M. SORSA
France	Mr. P. BARUCH
	Mr. P.-Y. MAUGUEN
Germany	Mr. K. WEBER
	Mr. K.D. JACOBY
Hungary	Mr. J. IMRE
	Ms. E. VIZVARI
Iceland	Mr. V. LUDVIKSSON
Italy	Ms. S. AVVEDUTO
Japan	Mr. S. YAMAMOTO
	Mr. D. MACHIDA
Korea	Mr. S.W. KO
Netherlands	Ms. J.R. BAX
Norway	Mr. H. SKOIE
Poland	Mr. A. WIERZBICKI
Portugal	Ms. M.J. MIRANDA
Spain	Ms. M.L. PENACOBA
Sweden	Mr. E. FORSSE
Switzerland	Mr. R. FORCLAZ
United States	Ms. J.S. BOND
European Community	Mr. M.W. ROGERS
Slovak Republic	Ms. S. STRAKOVÁ
OECD Secretariat	Mr. J.-E. AUBERT, Secretary to the Group on the Science System
	Ms. C. STEVENS, Head, Science and Technology Policy Division
	Ms. H. CONNELL, Consultant

SOURCES

Note: This document draws on papers prepared by national representatives of the OECD/DSTI Science System Group. Contributions were made by Austria, Australia, Belgium (Flanders), Canada, Finland, France, Germany, Hungary, Italy, Japan, the Netherlands, Norway, Portugal, Sweden, Switzerland and the United States. Details from these papers are not specifically referenced.

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