Governance of Public Research

TOWARD BETTER PRACTICES

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Toward Better Practices

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- to achieve the highest sustainable economic growth and employment and a rising standard of living in member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
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- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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Gouvernance de la recherche publique

Vers de meilleures pratiques

FOREWORD

This is the final report of a project entitled "Steering and Funding of Research Institutions" carried out under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP). The project was launched in response to concerns related to the financing of basic research in universities and public institutions that were expressed by Ministers in charge of science and technology at the CSTP meeting at Ministerial level held in June 1999.

Over the year that followed the Ministerial meeting, the CSTP discussed the scope of the project, the main policy issues that were to be addressed and the way in which the project would be carried out. During these discussions it became quite clear that the question of funding of basic research had to be addressed in a broader perspective than that of governments' R&D budgets or financing of public research institutions. Rather, the relevant policy question was deemed to be that of governing the science system as a whole, *i.e.* the decision-making process that governs priority setting, the allocation of funds and the management of human resources in a way that efficiently responds to the concerns of the various stakeholders involved in the system. To reflect this emphasis, the CSTP launched the "Steering and Funding of Research Institutions" project and agreed that it would be carried out under the aegis of an ad hoc working group composed of government officials responsible for the management and/or financing of public research programmes, or national experts.* This working group was chaired by Hugo von Linstow (Denmark), assisted by four vice-chairs: Sveva Avveduto (Italy), David Schindel (United States), Steve Shugar (Canada) and Shinichi Yamamoto (Japan).

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* This ad hoc working group comprised representatives from 26 OECD member and observer countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Japan, Korea, Mexico, Netherlands, Norway, Poland, Portugal, South Africa, Spain, Sweden, Switzerland, United Kingdom, United States.

In collaboration with the Secretariat, the Working Group agreed that the project would be implemented as follows. First, main challenges concerning the governance of public research systems were identified, notably as regards the response to societal needs, the increasing multidisciplinarity of scientific research and the evolving interactions between institutions involved in the funding and performance of research activities supported by public funds. Work then focused on three interdependent governance areas that are strongly influenced by government action: priority setting, funding, and the management of human resources. Three sub-groups were established to deal with these matters in detail. In addition, country specificities in terms of institutional structures which influence decision-making processes in these areas were reviewed.

Information on existing problems, ongoing reforms and good practice with regard to policy responses to identified challenges was collected through country surveys, based on responses to a questionnaire sent to participating countries on case studies of science systems of selected countries (Germany, Hungary, Japan, Norway, United Kingdom, United States; available at www.oecd.org/sti/stpolicy), and on additional material that was provided by participating countries or collected through literature surveys.

Over the course of the project, some participating countries hosted workshops on issues of specific interest which also fed into the final report: "Policy Relevant Definition and Measurements of Basic Research (Oslo, Norway, 29-30 October 2001), "Science Funding in Transition – Changing Paradigms and First Experiences of Implementation" (Berlin, Germany, 6-7 May 2002), and "Fostering the Development of Human Resources for Science and Technology" (Rome, Italy, 5-6 June 2003). Information on these workshops is available at www.oecd.org/sti/stpolicy.

The first chapter of this publication, "Challenges and Policy Responses", synthesizes the main findings of the study. It draws on the analyses developed in the subsequent chapters devoted to the institutional structures of science systems, trends in priority setting, funding mechanism patterns, and the management of human resources.

This report has been prepared under the aegis of the Ad Hoc Working Group on Steering and Funding Research Institutions, under the supervision of Daniel Malkin.

The report is published on the responsibility of the Secretary-General of the OECD.

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EXECUTIVE SUMMARY

In the 1990s, science systems in nearly all OECD countries experienced increasing pressures for change. These pressures reflect new challenges that go beyond the important issue of ensuring sustained funding for the research enterprise as a whole and should be addressed within the broader perspective of the *governance of science systems*, which encompasses wider concerns related to the decision-making processes governing priority setting, the allocation of funds to the public research sector, the management of research institutions and the assessment of their performance in terms of contribution to knowledge creation, economic growth and responses to societal needs.

The aims of this report are:

- To provide a comprehensive review of the challenges that call for changes in the governance of OECD countries' science systems.
- To highlight emerging policy responses developed in these countries.
- To draw policy lessons that can inspire the reform process.

Challenges

Governance challenges broadly fall into the following areas.

Responding to a more diverse set of stakeholders

In addition to the scientific community, and the government as the main funder of the public research enterprise, the business sector and civil society in general have become more active stakeholders. Beyond securing appropriate funding, the main stake of the *public scientific community* is its ability to preserve a degree of autonomy deemed necessary to pursue its research agenda and fulfil its mission to create highly skilled human resources. *Governments*' main stakes are to seek greater efficiency in their research investment aimed at sustaining national capacities of knowledge production that can benefit society and provide spillovers in the economic sector. In this context, governments tend to have a more outcome-oriented approach as regards the governance of science systems. The *business sector* has become a more active stakeholder. Its increasing share in the funding of R&D performed in the public research institutions reflects its growing involvement in knowledge production. This trend and the often blurred distinction between basic and applied research have given rise to more intensive and diversified linkages between public and private research activities. Moreover, business has a particular stake in the capacity of public research institutions to train and supply highly skilled human resources in science and technology. *Civil society* increasingly weighs on research priorities as it expects a greater responsiveness of the public research system in areas such as health and environment where scientific advances are deemed to directly contribute to social welfare. Governance structures have to account for, and balance, the diversity of these stakeholders interests.

Exploiting emerging opportunities

This challenge is linked to the transformation of the processes of knowledge generation and diffusion characterised by a shift from research systems based on scientific disciplines to another one that gives a premium to multidisciplinarity and institutional networking. Such a system is more responsive to new research opportunities arising from societal demands and better adapted to expanding the frontiers of scientific research with breakthroughs that are at the interface of traditional disciplines (*e.g.* nanosciences and neuroinformatics). Such an evolution has strong implications on aspects of governance related to institutional reform, priority setting, funding allocation and the development of human resources.

Ensuring the long-term sustainability of the research enterprise

The third challenge faced by governments is that of ensuring the long-term sustainability of the research enterprise as it adjusts to the pressures outlined above, namely the need to respond to a more diverse set of stakeholders and more effectively capitalise on emerging scientific and technological opportunities. Doing so implies ensuring adequate breadth of the research portfolio, insulating the science system from the business cycle and other rapid shifts in funding or interests, maintaining public confidence in the objectivity of the science system, and attending to needs for research infrastructure and human resources.

Policy responses

OECD governments have initiated a number of steps to address these challenges. They involve changes in governance structures and organisational settings, in priority setting processes, in the allocation mechanisms for funding public research, and in measures that aim to ensure an adequate supply of highly qualified human resources. However, the scope and effectiveness of policy responses partly depend on country-specific characteristics of the science systems, notably as regards the degree of centralisation of decision-making processes governing the public research sector and the autonomy of its institutions. In some cases, policy reforms have been of an incremental nature whereas in others they involve deeper governance reforms. This report provides evidence of the reforms that have been developed and attempts to highlight better practices from which policy lessons can be drawn.

Reforms and changes in governance structures and organisational settings

- Efforts have been made to better co-ordinate research government-wide, involving different levels of government in research policy making and funding to a greater extent.
- Governments have engaged in more strategic planning and monitoring of public research institutions.
- Institutions have been granted a higher degree of autonomy.
- Formal structures and mechanisms for stakeholder participation in research policy making, funding and review have been created or strengthened.
- In a number of countries, intermediate-level funding structures within research systems (*e.g.* research councils) have been strengthened.
- The balance among research performing institutions is changing. A stronger role for higher education institutions as compared to other public research institutions is developing.
- Partnerships between different researcher performers are increasingly being developed.

Reforms and changes in research priority setting

- OECD member governments are attaching greater importance to research priority setting. This trend reflects the growing intensity of competition among various stakeholders in the public research enterprise. As a result, in many countries the balance is shifting between bottom-up and top-down priority-setting procedures.
- Governments are developing and using tools and mechanisms to set priorities in research, such as research/technology foresight and central or decentralised advisory councils that are adapted to the structure of their research systems.
- Governments are primarily implementing new "thematic" priorities with new budget allocations. Shifting priorities within existing or non-increasing budget packages is more difficult.

- Increasingly, research priorities are set in multidisciplinary research areas or problem areas that require a multidisciplinary approach to research.

Reforms and changes in funding and funding mechanisms

- Funding of public sector research is increasing, but new funding is often attached to specific priorities or new schemes (*e.g.* centres of excellence).
- The proportion of funds distributed through competitive grants schemes is increasing relative to institutional funding.
- The use of institutional funds by public research institutions is increasingly evaluated with measurable performance indicators.
- Business funding of public research is increasing, giving rise to new relationships between funding sources and research performers.
- Public research institutes are looking for new sources of funding, including business, private charitable foundations, university tuition fees, overhead coverage for research funded with grants and contracts.

Reforms and changes in the management of human resources

- In order to ensure an adequate supply of human resources, countries are moving to make S&T education more attractive by redesigning curricula, increasing expenditures on higher education and enhancing the quality of science teachers.
- To respond to industry demands for the "right" skills, several OECD countries have reformed university degree programmes, in particular at PhD level.
- The demand for more multidisciplinary competences has led to new multidisciplinary curricula and degree programmes.
- Measures to increase the mobility of researchers at national as well as international level are being taken in many countries.
- Initiatives are being taken to renew public sector employment. These include an increased number of positions, programmes to encourage the recruitment of women and salary increases in order to compete with the private sector.

Policy responses and reforms may differ among OECD countries for a variety of reasons related to institutional, cultural and historical factors that structure national science systems. Thus, there is no optimal governance pattern to which countries should adapt. However, there certainly are lessons to be drawn from the policy responses to the identified challenges. These lessons can inspire the process of governance reform and the implementation of better practices in many countries. They are described in the following chapters of this report.

Chapter 1

GOVERNING THE SCIENCE SYSTEM: CHALLENGES AND RESPONSES

Abstract. This chapter synthesizes the findings of the study on "Steering and Funding of Research Institutions". It describes the main challenges for the governance of science systems, describes different policy responses to such challenges and draws policy lessons.

Introduction

As it is now well recognised that science and innovation significantly contribute to economic growth and social welfare, public research institutions — and science systems in a broader sense[1] — throughout the OECD area are under increasing pressure to reform in response to new challenges.

As in other areas of public spending, governments seek greater efficiency in their research investment. Legitimate demands of society at large for greater public accountability of decisions regarding research priorities and outcomes have to be addressed, notably in areas such as health, environment and energy. A third challenge pertains to relationships with the private sector. Although an important share of innovative activities is not directly science-based, there is clear evidence that public research has played or is playing a key role in the development of new technologies in areas such as biotechnology, nanotechnology and ICT, and thereby contributed to major innovations. In these areas, increased knowledge transactions between the business sector and public research institutions through growing private funding of public sector R&D activities and the implementation of various forms of research collaboration and partnerships affect the organisation, financing and management of these institutions as well as their human resources.

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1. In this report, the term "science system" is used narrowly to refer to universities and other public research organisations. In a broader sense, science systems include other institutions involved in funding or performing scientific activities in the private sector or non-profit organisations.

These trends shed new light on the roles of governments in setting priorities for publicly funded research and decision-making processes pertaining to the volume and allocation of resources devoted to this research. Naturally, they also raise the question of the nature of research activities that governments are fund or support. Traditionally, the main roles of government were to fund basic research (mostly curiosity-driven) that was primarily carried out in the public sector, and to fund mission-oriented research in areas where social returns are potentially high, while private returns or high risks deter the business sector from undertaking R&D activities by itself (*e.g.* health, environment, transport, energy).[2] The results of such research were expected to expand the pool of knowledge for the benefit of society at large and in particular the industry sector which, using this knowledge, invests in R&D to develop new technologies to be incorporated in innovative activities.[3]

Although this perspective has provided a strong rationale for government investment in basic research, especially after World War II, at best it gives a very partial and biased view not only of the role of public research, but also of the way diverse stakeholders interact in the research enterprise. In the very process of knowledge creation, the distinction between, or respective importance of, curiosity-driven and problem-oriented research has already been blurred for a long time and is becoming less relevant for policy-making purposes.[4] In no way does this imply that the importance of public funding in knowledge creation is reduced. It emphasises the fact that the funding question is only the most visible part of a more complex issue that reflects changing relationships among stakeholders involved in the research enterprise.

The question of the higher priority to be given to the funding of basic or fundamental research as highlighted in a number of OECD countries' official statements has therefore to be addressed in a different and broader perspective than that of governments' R&D budgets or financing of public research institutions. Rather, the relevant policy question has become that of the governance

2. Another important role of government R&D funding that is not addressed in this report is associated with market and systemic failures that may lead to underinvestment in R&D by the private sector and hinder technology diffusion throughout the economy.

3. This view conceptualised in the so-called "linear model of innovation" provided a strong rationale to massive government R&D investment in public research institutions after World War II in the United States and other countries (Bush, 1945) as a means to foster innovative capacities of the economies while preserving the autonomy of research institutions. The importance of defence related research was another rationale.

4. Pasteur's scientific breakthroughs in the 19th century were in fact driven by industrial and health problems. Stokes (2000) showed that applied research is very often an integral part of curiosity-driven "basic" research and the two cannot (and historically were never in practice) dissociated.

of the science system as a whole, *i.e.* the decision-making process that governs priority setting, the allocation of funds and the management of human resources in a way that efficiently responds to the concerns of the various stakeholders involved in the system. In this context, a number of countries have engaged policy reforms or more important structural changes that, implicitly or explicitly, aim at improving the governance of their science systems.

The purpose of this introductory chapter is to spell out the challenges that call for changes in the governance of science systems and to highlight emerging policy responses being developed in OECD countries.[5] The challenges broadly fall into two areas: *1)* responding to a more diverse set of stakeholders and exploiting emerging opportunities to harness scientific and technological advances to meet social and economic needs; and *2)* ensuring the long-term sustainability of the research enterprise. Effective policy responses will depend in part on country-specific characteristics of the innovation and science systems and on the institutional structures for governing public research activities. Governance structures can be classified into three archetypes — centralised, dual and decentralised — that have particular strengths and weaknesses, outlined in Chapter 2. Subsequent chapters contain more detailed discussion of the issues and policy responses as they pertain to three major concerns of research policy makers: priority setting, funding mechanisms and the development of human resources.

Challenges

Responding to the changing needs of a more diverse set of stakeholders

The public research enterprise was long seen to have two major groups of stakeholders: the research community itself and those who funded it, mainly the government. The main stake of the research communities in universities and large non-dedicated public research institutions was, and to some extent still is, to be credited with the resources deemed necessary to pursue research agendas – determined in a largely autonomous manner – in order to fulfil the complementary missions of knowledge production and training of high-skilled human resources entrusted to them by society at large. Governments' main stakes were to maintain a capacity of knowledge production that could benefit society and provide spillovers in the economic sector. In the particular case of publicly

5. This chapter draws from and is complemented by the four subsequent chapters of the report, which are devoted to the issues of structures of science systems, priority setting, funding and human resources. It also incorporates information from a series of focused studies of science systems in selected countries: Germany, Hungary, Japan, Norway, the United Kingdom and the United States. These studies are available at www.oecd.org/sti/stpolicy.

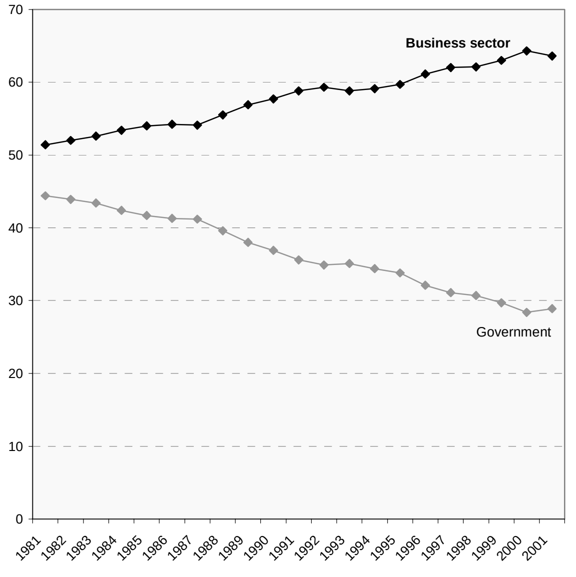
funded and performed mission-oriented research in such areas as security, health, and environment, governments have a more outcome-based approach. However, in many countries, powerful research constituencies in public laboratories retain (or used to retain) a strong influence in budget appropriations and research agendas.

The business sector and civil society have since become more active stakeholders in the public research enterprise. The business sector not only accounts for a rapidly growing share of the total research effort in OECD countries, but also funds a growing share of R&D expenditures in the public sector (higher education and government) even as government support has grown (Figures 1.1 and 1.2)[6]. These funding patterns reflect more intensive and diversified linkages between the public and private sectors. As innovation becomes more science-intensive and as firms restructure around their core competencies and restructure their R&D strategies, business makes more intensive use of public research, seeking access to both results of high-quality research and highly skilled young researchers and engineers. The relationships between industry and the science system take on many forms, all of which are expanding: funding of public research institutions, collaborative research and public-private research partnerships. Such intensified collaboration is reflected in the burgeoning of joint publications and patents and the increased flows of researchers between the public and private sectors. Internationalisation of these industry-science relationships is also on the rise. Foreign-owned firms are now key partners in the research enterprise in many countries and may finance a significant share public research in some countries, such as Hungary and the Czech Republic.

6. It needs to be noted that government funding of research in the private sector is not limited to direct funding, but also includes investments in indirect support such as R&D tax credits which are not captured in this data set.

Figure 1.1. Increasing share of business in total R&D funding

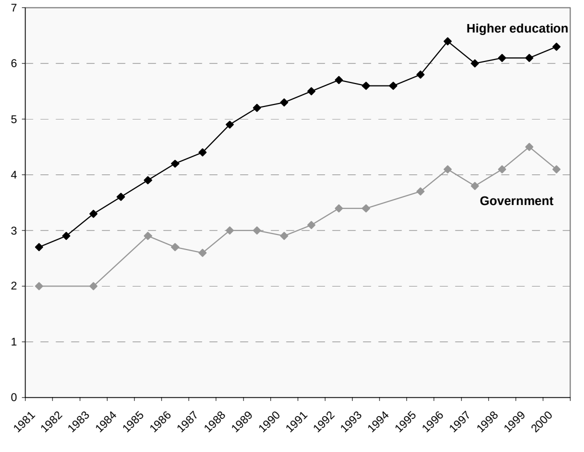
Percentage of total R&D spending in the OECD area



Source: OECD, *Main Science and Technology Indicators*, May 2003.

Figure 1.2. Increasing business funding of public research

Share of R&D in the higher education and government sectors financed by industry



Source: OECD, *Main Science and Technology Indicators*, May 2003.

The public (in general and through specific interest groups) is also exerting greater influence on the directions of research, both directly and indirectly. In some countries, private non-profit organisations already play a significant role in funding public research in some fields, especially those related to health and the environment. The interests of these groups are varied, but collectively they press for increased social relevance of public research and seek to win greater priority for their specific fields of interest in government-funded research. The public also expects governments to pay greater attention to ethical concerns and technological risks, and expects the public research system to provide independent information and advice in this respect. A civil society that is more active as a stakeholder in public research also encourages the government to seek greater accountability and efficiency in funding research.

Exploiting emerging opportunities

Changes in the demands of a growing number of stakeholders, combined with the changes in the frontiers of scientific and technological research themselves, are accelerating a fundamental transformation of processes of knowledge production and diffusion, with key implications for the public research system. The general trend is a shift away from *1)* disciplinary research which hinders fruitful synergies across scientific fields, and is carried out with a strict division of labour within or between different types of research organisations, toward *2)* more multidisciplinary research that is more directly responsive to societal needs is carried out with more interaction between different research performers.[7] This trend is not entirely new, but affects a growing part of the public research system.[8] One reason is that areas of research that are receiving increasing attention, such as health and environment, require a different approach to research which is more determined by problems to be solved than by scientific interests of researchers in specific academic disciplines. In addition, such problem-oriented research often requires a multidisciplinary approach, extending beyond the natural sciences and engineering and including many areas of the social sciences and humanities (*e.g.* management, sociology, ethics, and philosophy). Organising and funding such research

7. This trend has been described by Gibbons, *et al*. (1994) as a shift from Mode 1 to Mode 2 research.

8. Mode 2 has existed for a long time, and there is little evidence that it is replacing Mode 1 entirely (Godin and Gingras, 2000; Pestre, 1997). Rather, it is argued that there is a shift in the balance between Mode 1 and Mode 2 research (Martin, 2001).

challenges traditional arrangements for steering and funding the science system.[9]

The effect of this demand-driven shift toward more multidisciplinary research is compatible with the evolution occurring at the frontiers of scientific research. Many of the most active areas of breakthrough research, such as information and communication technology (ICT), biotechnology or nano-technology, are based on research that was originally undertaken at the interface of traditional disciplines. This is also true for many of the emerging areas of scientific opportunity: bio-informatics and work at the convergence of nano-technology, biotechnology, information technology and cognitive science (NBIC) are but two examples. Research results in many of these areas are closely linked to commercial opportunities, strengthening the interest of the business community as a stakeholder.

The proliferation of channels for bringing new science and technology to the marketplace (*e.g.* licensing, spinoffs), combined with improvements in framework conditions for operation of these channels (*e.g.* venture capital markets, IPR regimes, labour mobility), expand the scope for market mechanisms to contribute to making research more responsive to social needs.[10] These factors reinforce the convergence of interest among the business sector, civil society, government and the research community and strengthen the calls for increasing economic relevance of public sector research. For this convergence of interests to be effectively exploited, governments may need to reform structures and processes for governing the science system. A particular challenge will be to adapt the research system so that it can better accommodate multidisciplinary and interactive research.

Ensuring long-term sustainability of the research enterprise

The third challenge faced by governments is to ensure the long-term sustainability of the research enterprise as it adjusts to the pressures outlined above, namely the need to respond to a more diverse set of stakeholders and to more effectively capitalise on emerging scientific and technological opportunities. Doing so implies ensuring adequate breadth in the research portfolio, insulating the science system from the business cycle and other rapid shifts in

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9. As noted by C.P. Snow some decades ago, the different methods and cultures of intellectual inquiry between the sciences and the humanities hinder the solution of multi-disciplinary societal problems (Snow, 1959).

10. This should not overshadow the fact that the development of these emerging technologies required long-term public investments in R&D before reaching the current phase of increased commercial "affinity".

funding or interests, maintaining public confidence in the objectivity of the science system and attending to needs for infrastructure and human resources.

Maintaining breadth and diversity in the research portfolio

Countries face a dilemma in managing the research portfolios of their science systems. Creating sufficient capacity to pursue research in fields related to high-priority socio-economic objectives suggests concentrating resources to achieve critical mass. Nevertheless, past experience illustrates that serendipity plays a critical role in scientific and technological achievements and that important breakthroughs can come from unexpected sources. In addition, science systems need capabilities across a broad spectrum of research in order to absorb knowledge generated elsewhere and to generate complementary knowledge needed to advance innovation in priority areas. Balancing such demands requires consideration not only of how to allocate national R&D budgets across disciplines (*i.e.* questions of specialisation), but of the interaction between national and international science systems. This is of particular concern is small countries that have more limited R&D budgets and may lack the resources to maintain critical mass in a broad range of fields, but the efficiency of all national science systems will increasingly depend on their positioning within global science and innovation systems.

Ensuring resilience to external shocks

The increase in the share of financial resources coming from the business sector or that are earmarked for co-operation with the business sector entails greater vulnerability of the science system to the business cycle and to sudden changes in business strategies. This can significantly affect levels of business funding for public research, as firms reduce their budget for externally performed research, shift areas of research emphasis and relocate R&D capacity on a global scale. Long-term trends in overall funding of the science system will be similarly affected and core capabilities will risk being eroded unless compensated by government funding. When the cost of re-building the capacity that would be lost exceeds that of maintaining it through a downturn, there is a strong case for sustained government commitment to R&D support (*e.g.* a targeted, transitory increase in government R&D funding) and for other actions that will preserve or redirect capabilities with long-term importance.

Preserving the integrity and cohesion of the science system

Sustaining the health of a more adaptive scientific enterprise over the long term will require maintaining mutual trust among all stakeholders and sustaining a fair distribution of the benefits accruing to the actors of the science system in the context of evolving relationships among them. For the science system to remain adaptive in the long term, governments need to find ways to ensure that research institutions can directly appropriate some of the economic benefits derived from their scientific activities. However, as the research community pursues research with more tangible economic rewards, business, government and the general public must be able to maintain their trust in the quality and objectivity of research results. Strong frameworks are therefore needed to guard against potential conflicts of interest, promote ethical conduct, and create incentive structures that reward research that extends the knowledge frontier along a broad front. In addition, recognising that the potential economic benefits of public research (*e.g.* licensing revenues and entrepreneurial opportunities) will vary considerably across research fields and academic disciplines, universities will have to decide on wise systems to use the benefits for a strong science base as a whole, but at the same time not lessen the incentive for public-private partnerships. Universities and other public research organisations will need to develop their management capabilities to address these growing challenges.[11]

Securing sufficient funding for public research infrastructure

Attention also needs to be paid to public research infrastructure – research equipment, information networks, etc. – used in the process of conducting research and which cannot be allocated to specific projects. This issue has become of greater concern as the unit cost of certain research equipment (and facilities) has climbed, the rate of obsolescence of some equipment and components (*e.g.* software) has accelerated, and the share of project-based funding of public research has increased. In many countries research infrastructure is typically funded through institutional funding (*i.e.* block grants); project funding does not usually cover such costs. As project funding has grown within the public research system, a relative underinvestment in research equipment has resulted. Increased levels of research activity have not been matched by commensurate increases in equipment funding. Such shortfalls do not become immediately apparent, but over time can become an urgent concern, as has been seen most recently in the United Kingdom.

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11. Issues of university management are addressed by the Institutional Management of Higher Education (IMHE) programme of the OECD.

Adjusting to changing government missions

Changes in government missions over the past several decades also necessitate adjustments in the structure, organisation and roles of public research organisations. The role of non-university public research institutions has already diminished relative to universities in terms of R&D performance, in part because of reductions in the defence budgets of many larger OECD members and further restructuring of national science systems in response to changing priorities for mission-oriented research. Several countries, including Australia, France, Germany and Spain, are in the process of reforming non-university public research organisations, but such restructuring is far from complete in most countries. Questions remain regarding the organisational and institutional changes that are needed to improve their capabilities on a long-term basis to respond flexibly to evolving societal objectives and the role of government laboratories vis-à-vis universities in the public research system.

While government laboratories have made numerous contributions to industrial innovation and economic growth,[12] econometric analysis suggests that the effects of publicly funded R&D on productivity growth are larger in countries that devote more of their public research budget to universities rather than government labs (Guellec and van Pottelsberghe, 2001). This result reflects the fact that in some countries the very nature of the R&D missions entrusted to government labs limits the generation of economic spillovers, but additional structural impediments also appear to be in place. Although their size and research portfolios are diverse, public labs in a number of countries face common problems related to ageing staff, blurred missions and relative isolation from the main streams of knowledge exchange and the education system. Government labs do not generally participate in training students who can transfer knowledge to industry, and the disciplinary nature of many labs can impede their attempts to conduct research in emerging interdisciplinary areas. They may nevertheless play a critical role in providing government ministries with impartial, long-term, in-depth and interdisciplinary expertise that is

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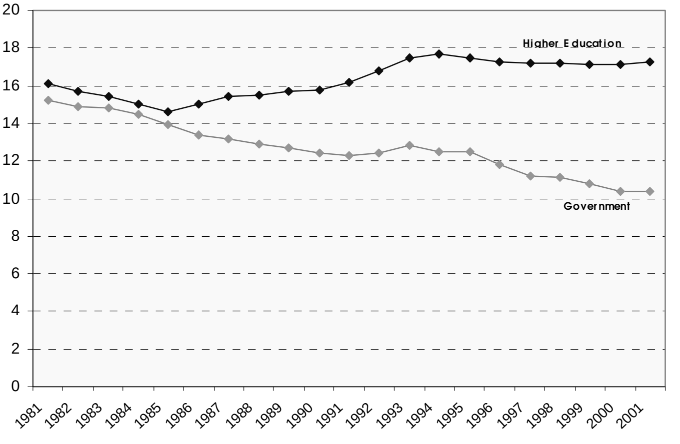
12. More recent examples include the contributions of researchers at CERN (the high-energy physics laboratory in Geneva, Switzerland that receives funding from several national governments) to the development of hypertext mark-up language (HTML), the World Wide Web, and the development of the first Web browser, Mosaic, by researchers at the government-funded National Center for Supercomputer Applications at the University of Illinois.

important to their missions and which cannot be suitably attained from the university system (Senker, 2000).[13]

Figure 1.3. Government expenditure for R&D (GERD) performance shares by higher education and government sectors

Percentage of GERD performed by the higher education and government sectors



Source: OECD, *Main Science and Technology Indicators*, May 2003.

Ensuring the supply of human resources

Safeguarding longer-term research capabilities has direct implications for human resources. Research in the public and private sectors depends on an adequate supply of researchers, and sustaining the flow of human resources in science and technology education and then into research careers represents a permanent challenge to the long-term health of the research enterprise. Despite the overall increase in tertiary university graduates across OECD countries, the number and share of graduates in S&T fields has declined in a number of OECD countries in recent years[14] and the participation of women and under-represented groups in science education remains low, especially at the PhD level. Although there is little evidence that the recent drops in S&T graduates or declines in enrolments have resulted in economy-wide shortages for S&T professionals, reports of oversupply of graduates in certain fields such as

13. This analysis concerns above all government laboratories largely or completely funded from public sources. There are public research institutions which are only to some extent funded by governments and which are strongly market-oriented. They might encounter less of the problems mentioned above.

14. Contrary to this general trend, the number of S&T graduates has grown in some smaller economies that are industrialising rapidly, such as Ireland and Portugal.

computer science and life sciences co-exist with reports of shortages for workers in ICT and biotechnology occupations. This suggests significant qualitative skills mismatches between the supply of graduates in S&T fields and demand for specialists in very narrow subfields, a mismatch that is further aggravated by low levels of geographic mobility.

Human resource issues are made more challenging by an increasingly imbalanced age structure in the public research sector in some countries such as Australia, Italy, Netherlands (particularly in universities), and, to a lesser extent, Norway and Sweden. Factors contributing to this imbalance include demographic shifts, decreases in the recruitment of new faculty, diminishing interest in scientific careers, and the relative decline in the attractiveness of public sector employment opportunities. Ageing patterns may also be aggravated by rigid or hierarchical organisational structures of universities and public research institutions which pose barriers to the promotion of young researchers and the renewal of faculty as well as by the rising share of temporary employment for R&D staff and faculty in the public sector, which while increasing job openings can lower job security and lengthen the time needed for post-doctorates and junior faculty to attain more attractive, tenure-track employment. The waning attractiveness of research careers is further aggravated by the long lead times required for obtaining PhDs in science compared to advanced degrees in other fields such as law or business, and the relatively lower salaries and uncertain career development prospects associated with the research profession.

Policy responses

OECD governments have initiated a number of steps to address the challenges facing the science system. They involve modifications to priority setting processes, institutional structures and financing mechanisms for funding research, organisational settings for performing research, and evaluation processes, among others. Although these responses are in their formative stages in many countries and considerable experimentation is still under way, they illustrate how countries can attempt to balance what are often seen as competing pressures to capitalise on emerging opportunities and respond to the needs of a more diverse set of stakeholders while preserving the long-term health of the science base.

Improving stakeholder involvement in priority setting

Many countries are experimenting with new mechanisms to involve a broader range of stakeholders more directly in priority-setting processes for public research. While research priority setting has long been associated with budget constraints, new approaches to priority setting are driven just as much by the pressures coming from a diverse set of stakeholders to enhance the economic and societal relevance of public research, while sustaining the long-term health of the research base. The response has been for governments and public research funding bodies to adopt or reform priority-setting procedures to include participation from these groups.

There is a clear trend toward increasing the involvement of business and civil society in setting priorities for government R&D. Participation in advisory councils to governments in science policy matters is becoming more widespread, as is participation in the boards and peer review panels established by research councils. Formal technology foresight exercises are also being adopted by an increasing number of countries, especially newer OECD members such as Hungary and the Czech Republic. Even in countries that have used such processes for some time (*e.g.* Japan and the United Kingdom), foresight exercises are becoming more inclusive, seeking participation of experts from industry and non-government organisations, as well as the public research community. In Canada, new types of foresight are being developed and adapted to the needs of specific research funders. For example, technology road maps are being developed by Industry Canada in consultation with industry leaders, university researchers, and government. The Canadian Institute for Advanced Research is working on behalf of the National Science and Engineering Research Council to gather information from an international network of scientists on new, exciting fields of research. In the Netherlands, the sector councils involve researchers, business and civil society in their foresight exercises. In the United States, the Federal Advisory Committees involve also all stakeholders. In Finland, the close contact of the funding councils (Academy of Finland and TEKES) with business or the academic sector ensures their involvement in priority-setting decisions. In the United Kingdom, business is represented in the council of all UK Research Councils (see Chapter 3).

More explicit involvement of different stakeholders in priority-setting can contribute to the increased accountability of the research enterprise and enhance the transparency of policy-making processes. By involving the research community itself, such practices can also protect the long-term health of the science system. Meeting the demands of different stakeholders, however, implies that stakeholders have an adequate understanding of the substance of scientific and technological issues and the operation of the science system. This task is increasingly challenging, as the scope of issues related to science and technology expands and the number of people affected by the issues continues to grow.

Restructuring research funding agencies

Countries are also taking steps to restructure the institutional mechanisms used for financing public research. Much of this effort relates to the establishment or reform of research councils or similar bodies that act at the interface between government ministries and the research-performing institutions. Since the early 1990s, the research councils in a number of countries, including Australia, Denmark, Sweden and the United Kingdom have been reformed or restructured to facilitate funding of emerging multidisciplinary research or of research areas that better respond to user needs (*e.g.* those of the business community). Much of this has been accomplished by merging or redefining the responsibilities of various research councils. Other countries, such as Japan, are considering establishing research councils to strengthen the voice of the research community in the decision-making processes concerning priority setting and funding allocation.

Improvements in research financing can be achieved through approaches other than institutional restructuring. In France, a new scheme, *Fonds National de la Science*, was established in 1999 to create incentives for research in priority areas. The fund offers competitive awards for research projects that require inter-institutional and interdisciplinary collaboration in emerging fields of research related to government-defined priority areas.[15] The programme also includes special support for young researchers beginning their careers by giving them funds for establishing their own research groups. A similarly structured public/private partnership programme (*Fonds de la Recherche Technologique*) supports pre-competitive technology development and innovation in priority areas.

Another approach has been to improve co-ordination among multiple research-funding agencies and government ministries that in some countries have responsibility for funding public research. This approach has been adopted to improve the responsiveness of science systems to more diverse stakeholder needs and to enhance the relevance and efficiency of research funded by multiple organisations. It has resulted in the generation of explicit research strategies by various ministries and the creation of bodies that facilitate co-ordination of research programmes and stimulate strategic thinking about overall national priorities. In the United Kingdom, for example, the Office of

15. Funds are allocated on the basis of peer review for a period of four years.

Science and Technology has recently set up Research Councils UK to pursue co-ordination of the research strategies developed by various ministries. In the United States, the White House Office of Science and Technology Policy plays an important role in helping co-ordinate the R&D programmes of federal agencies and attempts to set strategic directions for public research.

Adapting R&D financing mechanisms

Many governments are also adapting ways of financing research carried out in universities and other public research organisations. These responses tend to involve greater use of competitively awarded project funding, innovative schemes for funding priority areas of research, and better mobilisation of non-government sources of funding.

Competitively awarded research project funding

The challenge of enhancing the societal relevance and accountability of public research has prompted public research-funding agencies to opt to increase project-oriented funding of research as opposed to core institutional funding. Whereas institutional funding is usually provided in the form of block grants that are managed by the research-performing institutions, project funding is typically awarded for individual projects on a competitive basis.[16] In addition, institutional funding is usually allocated on a long-term basis, but now is increasingly allocated in a selective manner on the basis of performance assessment results. By tying funding to specific objectives, increased project funding is expected to help overcome rigidities in the discipline-based research system of the public research sector in many OECD countries and enable funding of interdisciplinary and emerging areas that reflect national priorities. Project

16. Broadly speaking, there are two different ways of funding research in the public sector. These are normally categorised as "institutional" funding and "project" funding. Institutional funding refers to block funds that governments or university funding agencies allocate to universities annually. Universities are free to use these funds in any way they see fit, *i.e.* these funds do come with strings attached. Basic or blue sky research is normally funded by this mechanism. Mission-oriented research in non-university public research institutions is also funded through "institutional" funding if governments directly give annual block funding. Institutional funding also finances the infrastructure of research institutions, costs of permanent staff, equipment and buildings. In general, institutional funding is allocated on a long-term basis, but could be selectively allocated according to performance assessment results. "Project" funding is normally granted when research performers apply for grants under competitive funding programmes of public research funding agencies such as research councils under specific themes. This includes funding through the "responsive mode", since application grants need to be made to get funding through this mechanism. Evaluation procedures are usually based on peer review. Contract funding of public sector research from business or NPOs also fall under this category because they are funded for specific projects.

funding has been common for federal funding of university R&D in the United States. It is now being used more frequently in Europe and Asia, especially in countries where government R&D funding is increasing. In Finland, for example, the share of institutional funding at universities declined from 52% to 47% between 1997 and 1999, while the share of project funding increased from 37% to 43%. Funding for the German Helmholtz Association laboratories has also shifted rapidly toward competitive research awards (see Chapter 4).

The shift toward more project-oriented funding gives rise to a new set of challenges. It has been argued that project-based funding mechanisms may have adverse effects on curiosity-driven research and the long-term health of the scientific enterprise by diminishing the autonomy of universities to set their research agendas. It has also been argued that project-based funding can lead to a decrease in the amount of curiosity-driven, basic research since many funding organisations will not cover full project costs but require a substantial matching of their project funding. While the argument that institutional funding schemes that give more autonomy to scientists' research agendas provide a stronger safeguard to the development of novel research avenues has merit,[17] it is important to emphasise that problem-oriented research is increasingly becoming a major driver of knowledge creation. Moreover, countries that have long relied heavily on competitively awarded project funding, such as the United States, continue to have strong science systems. While research is more closely linked to the mission of funding bodies, researchers continue to seek fundamental scientific and technological knowledge.[18]

17. Project funding of basic research is normally funded in response to applications for projects *not* aimed at specific objectives or falling under specific themes. While this approach has been used with apparent success in the United States, some doubts have been expressed as to its efficacy in fostering pioneering research in other countries, such as the United Kingdom (see United Kingdom country report).

18. Part of the pressure to improve the industrial and societal relevance of public sector research stems from the performance of the US economy in the 1990s. Advances in the ICT and biotechnology sectors in particular were seen as having benefited from the rapid diffusion and exploitation of knowledge generated in the public sector, much of it with project funding. As some observers acknowledge, it was excellence in basic, industrially relevant research — not applied research and near-term problem solving — that enabled US universities to contribute to the industrial base. See Rosenberg and Nelson (1994) and Pavitt (2000).

Sustaining research infrastructure

Countries are also developing ways to ensure that financing of research infrastructure will not suffer from changes in the approach to research funding, in particular the greater use of project funding. Reforms being undertaken or envisioned by a few countries point to possible approaches that may be adopted by others. Among these are: *1)* assessing the full cost of research carried out in public research institutions, including infrastructure and overheads, and making project-funding bodies pay the full costs; and *2)* establishing special funds with the participation of the major project-funding bodies (*e.g.* research councils, industry, non-profit organisations) to support the funding of infrastructure and overhead for university research. Infrastructure and overhead cost coverage has for long been a part of project funding of public research by the US National Science Foundation. In the United Kingdom, government agencies are examining methods of accounting for the full cost of research to pave the way for research councils and other project funders to cover costs of infrastructure and other overheads. In the intermediate term, the government has created successive streams of dedicated funds to be invested in university research infrastructure. In Canada, an independent foundation, the Canada Foundation for Innovation, was established in 1997 to help funds research infrastructure in universities, hospitals, colleges and non-profit research institutes.[19]

Better leveraging private research through partnerships

As economies grow, and innovation depends ever increasingly on scientific progress, industry can be expected to rely more and more on the results of public research to complement its own growing R&D efforts. At the same time, contributions from the business sector will become increasingly important in mobilising science for addressing societal needs. In other words, private returns on business R&D will become more dependent on complementary public investments in research, whereas business R&D will have a greater impact on social returns on publicly funded R&D. Better mutual leveraging of public and private investments in research requires an efficient interface between the innovation and the science systems. In particular, this requires exploiting better opportunities for public-private co-operation in research to correct market and systemic failures that hinder knowledge transactions between the two sectors. Greater use of research public-private partnerships is required to fill gaps in the science system and to increase the leverage of public support to business R&D

19. The Canada Foundation for Innovation (CFI) was established with an initial investment of CAD 800 million, which has since grown to more than CAD 3 billion. CFI pays for 40% of the costs of infrastructure projects, with the remainder coming from universities, the private sector, or other government departments.

through cost- and risk sharing. Almost all OECD countries are taking initiatives to establish such partnerships to advance research and innovation in areas of both high social relevance and mutual interest.

Non-budgetary sources of R&D financing

Several countries are experimenting with ways of financing R&D off-budget, using income generated by special funds established by the government. The Norwegian government has established an investment fund for research and innovation. The income from the fund is used to secure stable, long-term basic research generally and within the national priority areas as well as for quality measures such as the funding of centres of excellence. One-third of the funding is channelled directly to higher education institutions, and two-thirds are distributed by the Research Council of Norway. A variant of this scheme is the Bay Zoltán Foundation for Applied Research, established by the Hungarian government in 1992. Income from the fund supports applied R&D for the Hungarian business sector, particularly SMEs. It also finances the establishment of demonstration centres for teaching modern industrial and agricultural methods and the training of researchers, supplementing university PhD programmes. Sweden established five foundations in 1994, with capital from the former Employees Monetary Fund. Income from the funds finances strategic research, environmental research, research on caring and allergies, regional support and IT infrastructure for research organisations, and international activities. How these funds will operate during a period of economic slowdown and declining market valuations remains to be seen.

Reforming structures for research performance

Co-operative research structure & centres of excellence

A number of countries are making greater use of centres of excellence as a means of creating critical mass in specific research areas, promoting inter-disciplinary research and encouraging public-private collaboration. While most of the centres bring together researchers in a single location, other approaches, such as the National Networks for Technological Research and Innovation in France, link researchers from multiple institutions in less formalised, distributed groupings. Such centres (and networks) make use of new mechanisms for funding research, notably public-private co-financing, and many receive multiple-year funding. While some focus on specific areas of research (such as ICT or nanotechnology), many others conduct research related to specific socio-economic objectives. Centres of excellence in many countries, including Japan, the Czech Republic and Finland, aim first to improve the quality of scientific output at a world-class level and aim to fill gaps in fundamental research capabilities. Even those programmes with greater and more systematic private-sector participation, such as Australia's Co-operative Research Centres and Austria's K-plus programme, tend to pursue pre-competitive research that both contributes to business needs and advances scientific and technological frontiers.

Restructuring public sector research institutions

Attempts to improve the contributions and output of universities and other PROs have led to a number of reforms in OECD countries. One approach has been to centralise the administration of government research institutions. In Spain, for example, the main research organisations were transferred to the Ministry of Science and Technology in 2000 as a first step in developing organisational reforms and changes to enhance their missions and the diffusion of knowledge into economy and society. A more radical step has been to privatise government research institutions, establishing them as independent agencies or private entities. In the United Kingdom, for example, the Department of Trade and Industry turned its government research institutions into independent executive agencies and then privatised a few of them such as the National Engineering Laboratory and the Laboratory of Government Chemists. Japan is also implementing this type of reform. While this trend may become general to some extent, care will be needed when restructuring institutions whose mission is largely public. Again in the United Kingdom, privatisation is not envisaged for the government research institutions of departments with publicly oriented missions, such as the Department of Health.

Another approach has been to introduce more competitive funding mechanisms and greater interaction with industry for government research institutions. In Germany, public institutional funding for the Helmholtz Association laboratories is giving way to more programme-oriented funding in an attempt to link the labs better to industrial needs and improve the quality of their output. Even in laboratories with a greater focus on basic research such as the French *Centre National de Recherche Scientifique* and the German Max Planck Society have been reformed to enable partnerships with industry while preserving their capacity for basic research (see Chapter 4). However, these and similar institutions are in need of additional reforms to enhance the flexibility and relevance of their research activities.

Reforms have also been introduced in the university sector in order to strengthen schools' abilities to interact with other stakeholders and ensure the cohesion necessary for universities to fulfil their various missions. For example, many countries have followed the example of the United States in establishing institutional capacity for interacting with industry, such as through industrial liaison and technology licensing offices. Others, including France, Germany and Italy, have revised regulations governing the management of intellectual property resulting from publicly funded research and entrepreneurship by public researchers so they may take part in private-sector activities, including spin-offs. Royalty-sharing agreements in many countries ensure that the economic benefits of these activities do not flow exclusively to those directly involved in the relevant research, but to the institution as a whole so they can be used to support other missions of the university, including education and research in related or other disciplines.

Evaluation

Changes in the structure of public research organisations and the types of research they conduct have been accompanied by changes in the way PROs and public researchers are evaluated. As public and private funding for research are increasingly tied to socio-economic needs, evaluations have had to consider both criteria of research excellence and relevance. At universities in several countries, tenure and promotion decisions are based on professors' lists of published works as well as measures of their contribution to the commercialisation of public research, including the impact of their research on business innovation. A related direction for reform is to allocate institutional funding on the basis of assessments of research performance of public sector research institutions, especially universities. Performance assessments aim to improve the quality of research by selectively allocating funding to institutions that have been accorded a high ranking in terms of research excellence. The UK Research Assessment Exercise, used since 1986, is an example. There are also newly developed types of restricted institutional funding, such as target-oriented funding or fixed-term funding, which are also often connected with evaluation procedures or output indicators. The accelerated internationalisation of research and the objective of improving the quality of research coming out of public research institutions – especially centres of excellence – have led to the increased use of international benchmarking and international panels of experts in evaluation.

New human resource development strategies

In recent years the demand for researchers has increased faster in the private sector than in the public sector in most countries, although employment in the higher education sector has expanded significantly in a number of countries. The current trends point to an expanding researcher population in OECD countries, but there are clouds on the horizon due to concerns about countries' ability to ensure the long-term supply of S&T personnel. In the EU, for example, policy targets for increasing R&D are dependent on efforts to augment the supply of researchers to meet new demand, in particular in the business sector. In the United States, the long-term reliance of both the public and private research sectors on foreign-born researchers and faculty, especially in certain fields, is increasingly being questioned not least in light of the emergence of former sending countries as a source of research employment but also because of security concerns following September 11th. At the same time, the low participation of young US-born citizens (particularly those belonging to minority groups) in science education is attracting more attention to the need for increasing domestic supply and improving teacher quality. Finally, in Japan, the ageing of the overall population and the research population in particular, combined with waning interest in science among youth, is focusing policy attention on increasing supply and making science education more attractive and flexible. The policy initiatives in OECD countries can be grouped in the following three main areas.

Attracting more students into S&T careers

In order to address these challenges and attract young people into science-related subjects, several OECD countries such as Belgium, Finland and Portugal have redesigned curricula, increased the resources dedicated to schools and launched science exhibitions or established new science centres. Initiatives in the countries such as the United States and Finland also aim to update teacher skills in various scientific fields. Funding is critical to the supply of new PhDs and for post-doctorates. Several countries, including Australia and Canada, have intensified funding efforts to increase the number of PhDs and post-doctorates. Portugal has achieved one of the highest increases in new PhDs due to active funding and recruitment efforts. Several OECD countries have tried to increase the participation of women in science education through policy initiatives targeted at several points in the S&T supply pipeline, from tertiary education to the PhD level and through post-doctorate training and employment. While countries such as Canada, the United Kingdom and the United States have traditionally meet part of their demand for S&T professionals through the immigration of students and professionals, a larger number of countries including Australia and France seek to tap the global market for specialist talent by facilitating student migration, lowering immigration barriers for skilled students and investing in centres of excellence to attract leading researchers.

Adapting researcher training systems to stakeholder demands

OECD countries have also made efforts to reform graduate education. There has been a general move away from the apprenticeship model in the United Kingdom, Italy and more recently in Germany toward research training programmes focused on quality, efficiency and control, including coursework, joint supervision and monitoring of progress by a research committee. Some countries have sought to shorten PhD programmes or develop new ones. Many countries have also developed programmes to fund younger researchers in order to keep them in the research system. As industry funds a greater share of higher education research, industry involvement in graduate training including at PhD level is increasing. In Canada, industry co-funds student training at undergraduate, postgraduate and post-doctoral levels in the Industrial Research Fellowship and Scholarship programmes of NSERC. In the United States, ICT companies have long been involved in the provision of related training. France and Sweden have introduced industrial PhD programmes to foster closer collaboration between industry and students. Greater industry involvement in education coincides with an increased emphasis on networking and multi-disciplinarity in training and employment. New research funding for inter-disciplinary fields such as bioinformatics has led to the development of new multidisciplinary curricula and degree programmes in a large number of OECD countries.

Improving flexibility to reduce mismatches

Public research sector reforms to foster greater interaction with industry combined with greater reliance on project funding and contract research exerts pressure for jobs and researchers to become more flexible with regard to employment arrangements and mobility. Temporary employment positions are increasingly relative to tenure track positions in a number of countries such as the Germany, the United Kingdom, Italy and Japan. The creation of centres of excellence indirectly promotes mobility and training as researchers are generally posted on temporary positions. In response to demands for better research performance, universities are being granted greater autonomy to hire and promote qualified personnel. Overall, higher education institutions have a greater role in the recruitment, remuneration and career development of researchers. In many countries, professors have lost civil servant status. Performance-based pay systems, which have emerged in countries where universities have more autonomy in the management of human resources, are increasingly being adopted at universities in other countries.

Conclusions

Drawing upon the main results of the work carried out under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP) and its ad hoc Working Group on Steering and Funding Research Institutions as well as a wealth of information provided by OECD member countries, this chapter has highlighted the main challenges with which these science systems are confronted in most of these countries. It has attempted to show that beyond the valid concern about the funding of basic research in public research institutions, the main issues pertain to the governance of science systems:

- How do governance modes take into account evolving patterns of knowledge production?

- How do they effectively respond to the concerns of a broader spectrum of stakeholders?

Answers to such questions may of course differ among countries for a variety of reasons related to institutional, cultural and historical factors that structure national science systems. Thus, there is no optimal governance pattern which countries should adopt. However, there certainly are lessons to be drawn from policy responses to the identified challenges. These lessons can inspire the process of governance reform and the implementation of better practices in many countries.

Box 1.1. Key policy lessons

1. The importance of public sector research is not reduced but rather is further enhanced by the growing participation of the private sector in funding research and using knowledge produced in public research institutions. These institutions continue to have a major, albeit evolving, role to play in responding to the growing demand for high-quality research emanating from a more diverse set of stakeholders.

2. Responding to the challenges posed by changing modes of knowledge production, to demands for greater responsiveness to a broader range of stakeholders, and to the need to safeguard longer-term research capabilities can require more than incremental changes to existing structures and processes for governing national science systems. In many countries, more radical governance reforms need to be considered

3. While governments should retain a strategic role in priority-setting for public research, governance structures should involve other stakeholders and intermediary institutions more formally in the priority-setting processes. Public research institutions should retain a broad margin of autonomy in the implementation of priorities on their research agenda.

4. Changes in the balance between institutional and project-based modes of funding of the public research sector need to be considered in the context of a broader strategy to improve the efficiency, performance and adaptability of public research organisations and the linkages between them. A shift to more competitive, project-based modes of funding linked to performance assessment can help improve the responsiveness of public research to socio-economic needs and improve research quality. To be effective, such a shift often needs to be accompanied by more fundamental structural reforms aiming at redefining the respective roles of universities and other public research institutions.

Box 1.1. Key policy lessons *(continued)*

5. Institutional modes of funding remain important to safeguard the longer-term capabilities of knowledge creation and the serendipity of scientific discoveries. More performance-based institutional funding may help to ensure good accountability of public investment. However, attention must be paid to streamlining rigidities that may be caused by inappropriate systems for evaluating programmes and researchers.

6. Too great a reliance on project-based modes of funding can undermine the sustainability and development of research infrastructures. Funding mechanisms have to be such as to ensure that the full costs of research are covered, including those of infrastructures, regardless of the source of funding or form in which it is provided.

7. Knowledge creation is of an increasingly multidisciplinary nature. Centres of excellence can be an effective means to carry out multidisciplinary research activities and to facilitate participation of the private sector. Criteria for allocating research funding and evaluating research results often employ a disciplinary perspective and need to be adapted to new modes of conducting research.

8. A growing share of public research is in areas in which the advances depend on the intellectual contribution of the private sector, which cannot be secured through traditional procurement mechanisms. In these areas, the leverage of public investment in research on private R&D can be increased through a variety of mechanisms, including public-private partnerships, co-patenting and collaborative research.

9. The availability, development and mobility of human resources in science and technology are essential for the sustainability of the research enterprise at large. The ability to attract high-quality researchers is a requirement for contributing to public research missions, as well as for ensuring effective partnership with the private sector. Efforts are needed to attract more students into S&T fields and to improve the attractiveness of employment in the public research sector.

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Chapter 2

STRUCTURES OF SCIENCE SYSTEMS

Abstract. This chapter describes the institutional and decision-making structures for science systems in OECD member countries, their differences and how they influence the way public research is managed and funded.

Introduction

In the area of science policy, countries' decision-making structures have a major influence on how policy is designed and implemented and how public research is funded and managed. To a large extent they shape the governance of science systems[1] and their understanding helps shed light on governance reforms that may be needed to better respond to challenges that these systems are facing in terms of efficiency, accountability and long term sustainability of knowledge creation. As will be described later in this chapter, in some countries incremental changes to – or within the framework of – the existing structures may already allow them to cope with the challenges science systems are facing. In others, more substantial reforms may be needed to make structures more flexible in dealing with new demands and opportunities.

This chapter identifies the structures of different systems and highlights the changes that they are undergoing in order to better respond to policy challenges. In particular, the chapter attempts to review how countries with different structures respond to the demand for greater involvement of all stakeholders concerned with the governance of the science system and the long-term sustainability of the research enterprise. It will be shown that – while trends are not equally evident in all countries – there are common features across OECD countries despite variations in the structures of different national research systems.

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1. The scope of the study was public sector research, *i.e.* research performed in universities and public research institutions. Structures looked at in this paper are those that shape the nature and missions of such institutions and affect the way in which they develop their research activities.

The chapter is based on questionnaire responses[2] and other available sources of information. Questions regarding science system structures were the following:

- A first set of questions addressed the governmental structure for the overall management of the science system – also closely related to priority setting and funding (see related chapters).

- A second set of questions related to whether governments were directly involved in the management and funding of universities and other public research institutions, or whether this would be left to intermediary institutions such as research councils, being closely related to the question of how different stakeholders are involved in the process of decision-making about priority setting and funding.

- Another set of questions dealt with the relative importance of universities vs. other public research institutions.

These items were also the most important elements in identifying the three science system archetypes described below.

System governance

Countries' structures for governing their science systems are varied and complex. Looking at the various structures, it proved useful to analyse the relationships between structures and governance through the prism of three science system archetypes (see Table 2.1):

- First, the "centralised" archetype with a strong top-down management approach, a high share of institutional funding and an important share of research carried out in public research institutions that are not part of the university system.

- Second, the "dual system" archetype with a mixed system of top-down and bottom-up approaches to priority setting, a mix of institutional funding and competitive funding instruments, and a balance between research-performing institutions.

2. The following countries responded to the questionnaire and later provided additional information on some of the questions: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Sweden, Switzerland, United Kingdom and United States.

- Third, the decentralised archetype with relatively low top-down control, hardly any institutional funding apart from mission-oriented programmes, and a strong research base in universities.

These three archetypes are organised in different ways with regard to the features described above, and respond in a different way to the challenges related to governing science systems.

It should be stressed that the three archetypes are by no means a typology to categorise countries as belonging to one or another. Rather, they are intended to provide a mapping of possible governance systems and each country has elements that reflect some aspects of each archetype and would fit in the mapping that could be represented as a triangle whose apices would be the three archetypes. Such a representation is a useful conceptual tool as it facilitates the understanding of important features of countries' governance systems, and the identification of their strengths and drawbacks in relation to their proximity to the three archetypes. Also, as the governance of science systems is subject to changes through institutional or other reforms, this representation allows to highlight the possible effects of such changes on the performance of science systems and their responsiveness to the challenges they are facing.

Indeed, in most countries, incremental or more comprehensive reforms have been undertaken to overcome major systemic drawbacks. As reported by countries (see Box 2.1) the most important changes relate to the definition of priorities for public research, the strengthening of intermediate funding agencies (research councils), better co-ordination between different government levels, increased institutional autonomy for universities and public research institutions, and the introduction of performance measurement. As already outlined above, changes in regulatory frameworks are sometimes sufficient to achieve the desired effects, but at times deeper reforms are required. Although on the whole more centralised systems seem to be more rigid, once changes have been decided they might be easier to make because top-down procedures are shorter than those in the mixed approach of the dual system or the bottom-up approach of the decentralised system, both of which take more time for co-ordination and consensus building before decisions can be made.

Table 2.1. Science system archetypes

	Centralized archetype	Dual-system archetype	Decentralized archetype
Ministerial structure	• Single ministry of science (sometimes together with education and/or technology)	• Federal and state/regional ministries of science and/or education/technology	• Many government departments
Priority setting	• Primarily top-down from central government; stakeholder involvement only at advisory level	• Top-down and bottom-up; stakeholder involvement for part of the R&D budget	• Primarily bottom up from research community
Funding streams	• Primarily institutional funding; direct funding of public research institutions and universities • Relatively few competitive grant programmes • No independent funding agencies (research councils)	• Institutional funding of public research institutions and universities as well as competitive grant programmes in independent funding agencies for universities and public research institutions	• Hardly any institutional funding; primarily project funding; competitive grant programmes in independent funding agencies, primarily to universities • Secondarily mission-oriented funding of public research institutions
Role of research performers receiving public support (universities, public research institutions)	• Research primarily carried out in public research institutions, including short-term post-docs • Universities come second as research performers	• Balance of research performance between universities and public research institutions, including graduate students and short-term post docs	• Research primarily performed in universities, including short-term post-docs and graduate students • Public research institutions come second as research performers
Evaluation	• Periodic committee evaluation of plans and performance of research institutions	• Committee evaluation of research institutions; peer review of competitive proposals	• Peer review of competitive proposals

Table 2.1. Science system archetypes *(continued)*

	Centralized archetype	Dual-system archetype	Decentralized archetype
Primary strengths	• Autonomy at level of institutional management, provides freedom to pursue long-term high-risk research • Continuity of funding streams • Stable base of researchers available to pursue emerging opportunities • Attractive long-term career possibilities	• Responsive to regional and industrial priorities • Long-term research in public research institutions • Responsive mode for emerging topics • Research training combined with project funding • Flexibility for public/private co-operation	• Responsive mode reacts more quickly to emerging topics • Strong quality control • Research training combined with project funding • Opportunities for young researchers to be independent • Funding agencies protected from changes in government • Strong involvement of industry in public sector research
Primary drawbacks	• Slow to respond to new interdisciplinary areas • Hard to motivate or remove less productive researchers in permanent positions • Separation of research and training • More hierarchical, longer for career independence • Subject to changes in governments • Public-private co-operation needs government action	• Complicated landscape • Redundancy among public research institutions and funded research projects • Separation of research in public research institutions and university-based training • Need for co-ordination between federal and state/regional levels	• Lack of guaranteed long-term stable funding for researchers • Need for coordination among agencies • Some topics don't receive support • Risk of leaving research areas without experts • Increased use of temporary post-docs, reduces attractiveness of S&T careers

Box 2.1. Major structural changes and reforms

Australia. Independence and further strengthening of the Australian Research Council, establishment of quality verification framework for universities including annual research and research training management reports, introduction of new performance-based funding for research and research training, support for rural and regional research, identification of national research priorities.

Austria. Increasing autonomy for universities. Full legal autonomy to be reached by 2004.

Belgium. Flemish universities have been given more autonomy. In the future, budget allocations will be more strongly related to research performance.

Canada. Evaluation of research performance has been increased in order to increase accountability.

Czech Republic. A new science policy was initiated in 2000 with the aim of strengthening links with industry and preparing for EU accession.

Denmark. A national research strategy has been introduced, and a political consensus has been reached between major political parties. Both aim to strengthen the higher education sector (both for research and training) and to create stable framework conditions for the science system. More recently, a single ministry has become predominantly responsible for science policy. Reforms are under way for the university sector, public research institutions, and the research council system. They will be approved by parliament in 2003.

Finland. Universities have been given more autonomy. On the other hand, the principle of "management by results" has been adopted for them to increase accountability. The research council structure has been reorganised to better respond to demands of interdisciplinarity.

France. No structural changes during the last few years. Government action concentrates on improving co-ordination between existing structures. Advisory bodies (*e.g. Conseil National de la Science*) have been created for this purpose. Institutional structures have been created to support inter-institutional and interdisciplinary research projects (*e.g.* 1999 law on innovation, technological research and innovation networks).

Germany. Major restructuring of part of the PRI sector.

Hungary. Changes in the government structure with the creation of a new ministerial department responsible for R&D. Changes in the relative importance between the government and the Academy of Sciences and Universities with regard to responsibility for science policy, research and researcher training.

Iceland. The Icelandic science system is currently being re-organised. The major change is the transformation of the Icelandic Research Council into a science and technology policy council with four ministries on its board. The creation of two funding organisations (one for research and one for development and innovation) aims for closer co-operation between science and industry.

Italy. Major plans to give universities and public research institutions more autonomy have been initiated.

Box 2.1. Major structural changes and reforms *(continued)*

Japan. A major administrative reform of the science system took place in the beginning of 2001: establishment of a central co-ordinating body for science and technology policy in the Cabinet Office of the Prime Minister; merger of the ministry responsible for education and science and the agency implementing research into one ministry. More autonomy was given to national research institutions. The Science and Technology Basic Plan outlining science policy objectives was approved by the government in March 2001.

Korea. Launching of a long-term strategic initiative for science and technology development. Establishment of a five-year plan for S&T.

Mexico. Passed a law for the development of scientific and technological research in 1999. The main objective is to give the government more responsibility for co-ordinating research done in different institutions and at different levels.

Netherlands. Some reforms – still in the conceptual stage – are being discussed. They relate mainly to the university sector and focus on subjects such as increased flexibility, a better management of human resources, increasing accountability to economic and social needs and improved transparency of the science system. An integral evaluation of TNO and the large technological institutes, a new strategic science plan and a new white paper on innovation are forthcoming.

Norway. A reform process to improve the quality of higher education institutions is currently in progress. The reform consists of the following main elements: freedom for institutions to decide upon their organisational structure, more institutional autonomy, a more result-oriented funding system, an agency for quality assurance of education, a new degree structure (bachelors and masters), continuous evaluation and assessment of students, improved system of financial support to students and increased internationalisation.

Portugal. Creation of a Ministry for Science and Technology in 1995. Introduction of a new evaluation scheme and, consequently, reform of many research centres.

Sweden. Major changes have occurred in the structure of funding institutions: 11 councils and agencies were transformed into three new research councils and one R&D agency.

Switzerland. Increased autonomy for universities; increased pressure from the government on universities to co-ordinate or even merge activities; more focus on technology transfer from universities into the innovation process.

United Kingdom. No major changes.

United States. No major changes.

Trends in the structures of public sector research

Varying structures notwithstanding, several trends in structural change and policy directions common to many of the participating countries emerge from the questionnaire responses and country studies. These trends often concern measures countries have taken to counteract some of the drawbacks identified for the different system archetypes.

The following major trends have been identified:

- Moves towards greater government-wide co-ordination of research effort.
- Greater participation of different levels of government in research policy making and funding.
- More strategic planning and monitoring by governments.
- Greater institutional autonomy for research performers.
- Increasing use of formal structures and mechanisms for stakeholder participation in research policy making, funding and review.
- Strengthening of intermediate level funding structures within research systems (*e.g.* research councils).
- Changing balance among research performing institutions, *i.e.* a stronger role for higher education institutions as compared to other public research institutions.
- Developing partnerships between different researcher performers.

Moves towards greater government-wide co-ordination of research

A key characteristic of national research efforts is that they concern departments, ministries and agencies across the whole of government. It has become common for governments to develop or strengthen structures which enable greater co-ordination across the research domain. There are several reasons for this: the scale and the complexity of research require better interaction, different policy domains show a growing interest in research and its results, and countries coming close to the dual system and decentralised archetypes need increased co-ordination between different government levels and agencies. Two approaches stand out in particular:

- Consolidating major research funding responsibilities within a single department.
- Developing formal structures for interdepartmental co-ordination.

Consolidating major research funding responsibilities

About half of OECD countries have a single department responsible for more than 50% of the overall research budget (GERD), including the funding of public sector research institutions. Two countries – Japan and Australia – moved into this category in 2001. In France, 80% of the research budget is allocated through the Ministry for Research and New Technologies. Hungary is also moving towards consolidation, with the merger in 2000 of a former government agency for applied research and technological development with the Ministry of Education, becoming its new R&D division. The single department enables – at least in theory – greater internal co-ordination and rationalisation. Evidence from Japan supports rationalisation of research funding programmes between the Japan Science and Technology Corporation (JST) and the Japan Society for the Promotion of Science (JSPS) following the amalgamation of the Science and Technology Agency and Monbusho into the Ministry of Education, Culture, Sports, Science and Technology (MEXT) as part of a broad governmental reorganisation in 2001 (Box 2.2).

Box 2.2. Reforms in the Japanese science system

In Japan, a major administrative reform of the science system took place in the beginning of 2001, including the establishment of a central co-ordinating body for science and technology policy in the Cabinet Office of the Prime Minister (Council for Science and Technology Policy – CSTP), and the merger of the ministry responsible for education and science and the agency implementing research and development into the newly created Ministry of Education, Culture, Sports, Science and Technology – MEXT). More autonomy was given to national research institutions and national universities. The second phase of the Science and Technology Basic Plan outlining science policy objectives was approved by the government in 2001, following the first phase, implemented in 1996.

The objectives of the Council for Science and Technology Policy are basic/comprehensive science and technology policy planning and general co-ordination among the ministries concerned, with an overall and panoramic view. The new MEXT is expected to play a more comprehensive administrative role with regard to science and technology policy by combining various types of research, academic included.

National universities are being re-organised into independent administrative institutions, with the aim of making them more autonomous and more accountable for their results. This re-organisation is scheduled to be finalised in 2004.

With these reforms, the Japanese science system aims to prioritise the allocation of resources to make R&D more effective, to improve the R&D infrastructure, to view R&D investments in terms of a return to society and industry, and to position Japan's science and technology as a contribution to world knowledge. Great expectations are attached to the results of these reforms.

Beyond the major ministries responsible for research and their funding agencies, mission-focused research responsibilities are held by a range of other ministries: defence, health, agriculture, forestry, fisheries, environment, energy, social affairs, and transport. These are particularly strong in countries with a system close to the decentralised archetype with no science ministry (United States). Other countries, mostly those coming close to the dual-system archetype have an overall public research budget spread out over various government levels and departments. While some sectoral ministries maintain their own dedicated research institutes, their research budgets are tending to be increasingly allocated through competitive project grants or contractual arrangements to research performers across the public sector (*e.g.* the US Department of Energy gives 25% of its budget to universities, and NASA laboratories have to compete with universities for NASA funds).

Formal structures for interdepartmental co-ordination

Most countries appear to have some formal structures for interdepartmental co-ordination – frequently at the level of the Prime Minister's office – and to be strengthening these, as governments and the research community continue to seek ways to improve effectiveness, make further efficiency gains and seek synergies among elements of the research system.

In some countries one ministry or agency is formally designated to co-ordinate research and science policy on a cross-ministry basis, and such practices may be found as co-ordinating committees/councils at both senior ministerial and civil servant level (Denmark, France, Norway) and roles such as chief scientist (Australia, United Kingdom).

Several countries, either in addition to or in place of the above, have a co-ordinating body which draws in external members (Science and Technology Policy Council, Finland; the planned National Assembly for Science and Technology, Italy; the Science and Technology Policy Council replacing the Iceland Research Council in 2003; the Council for Science and Technology Policy, Japan; the Research and Development Council of the Czech Republic; the Prime Minister's Science, Engineering and Innovation Council, Australia; the Science and Technology Policy Council, Hungary).

Greater participation of different levels of government in research policy making and funding

Changes in decision-making with regard to R&D also concern different levels of government. Particularly in federal countries, but also in countries with centralised systems (notably where strong regional governments exist), different sub-national governmental levels are increasing their participation in research policy and funding. This is one of the attempts made to overcome the drawbacks of centralised systems and involve more stakeholders than in the traditional top-down approach to governance.

The most significant engagement of different levels of government occurs in the case of federal countries, but its pattern is far from standard. With regard to the public research sector, Germany, the United States and Canada show the greatest engagement of both government levels, with the federal government dominant in Australia and Austria and the local governments dominant in Belgium. Germany has the most detailed set of arrangements for sharing the funding of research institutions and co-ordinating policy-making between levels (see German country report). In the United States and Canada, by and large, the state/provincial and federal levels tend to make complementary but separate contributions to public research, without a national forum for co-ordinating research policy between government levels (see country report on the United States). This indicates that there might be a danger of research funding overlap in the dual-system and decentralised archetypes.

At international level, intergovernmental structures are playing an increasing role, notably within the European Union. Thus, the research environment is becoming much more complex, and national governments, while still key, are by no means the only significant players. The EU Framework Programme provides resources for which researchers in member states compete – through special agreements, the Framework Programme is open to certain countries beyond EU member states (*e.g.* Norway, Australia). This programme is not only significant due to its level of resources, but also because of the priorities it defines and the way in which it encourages international engagement. Researchers from countries with science systems in which competitive funding instruments play an important role (decentralised archetype, dual-system archetype) might have a better chance when competing for EU funding. Also, the fact that the EU programmes can also require matched funding from government or industry has major implications for the participation of research performing institutions in countries where access to matching funding may be difficult under current national policies. The requirement that countries need partner institutions for the research funding directorate of the European Commission has instigated institutional changes, in particular in countries accepted for accession to the EU in the near future. In the future, the European research programmes may still become more important with the establishment of the planned European Research Area. This might give rise to more institutional changes in EU member states in the near future.

More strategic planning and monitoring by governments

The trend towards more strategic planning and monitoring by governments is, above all, supported by the following changes. First, there is the move by governments to define broad national goals and priorities for the research system (see Chapter 3). Such priorities are partly enforced by allocating new research funds to priority areas or making the latter a funding criteria for competitive funding programmes (see Chapter 4). They are also supported by introducing or re-enforcing new structures for monitoring research institutions, including reporting and compliance measures, as well as a variety of evaluation mechanisms. Whereas it is relatively easy for countries with systems coming close to the centralised archetype to set priorities compared to countries with mixed top-down/bottom-up or mostly bottom-up approaches (dual-system archetype, decentralised archetype), these countries have greater difficulties in changing their system with regard to funding instruments and evaluation methods. Established institutions which have been almost entirely funded without undergoing any type of competition may resist a rapid change in this type of funding and a sudden switch to peer review evaluation.

Another structural change is to grant greater autonomy to public sector research-performing institutions with respect to various matters, notably staff appointments (including salary and conditions), financing, and governance. This seems to be a trend supported by governments in all OECD countries, notwithstanding which of the three archetypes described in Table 2.1 they come close to. As institutions develop more autonomy, they develop their own plans, staffing profiles, sources of funding, governance structures, etc.

Recently both Austria and Japan (as concerns national universities) legislated to change universities into self-employer rather than government-employer institutions. Norwegian universities, while retaining government employment, have achieved considerable flexibility in appointment and salary conditions. A royal commission responsible for drafting a new bill for universities and university colleges (both public and private) is currently considering types of legal status for higher education institutions. While German academics are not by and large civil servants, German universities are bound to the salary scales of the civil service; moves to change this restriction and to free up employment, particularly for junior academics, have recently been made. By and large, universities in the English-speaking countries and the Netherlands already enjoy considerable autonomy in governance, but inflexibilities remain in certain areas, such as salaries and conditions for Australian academics where government (as part of a broader strategy beyond the research sector) is presently trying to introduce "workplace" rather than national union-based bargaining arrangements.

There is general support across countries for movement towards increased institutional flexibility. This trend is pursued particularly in order to give institutions an opportunity to seize new opportunities and overcome the limitations of increased fixed-term funding. At the same time there is a move towards increased performance measurements of such institutions (see above). This might change the character of research and the conditions in which it is carried out, since – depending on the criteria used – performance measurement can pressure institutions to behave in a certain way (*e.g.* focus research agenda on priority areas, getting closer involved with industry).

Increasing formal structures and mechanisms for stakeholder participation[3]

It is increasingly common for countries to seek established formal structures through which advice from the research and broader communities can be provided to government on research policy as a whole or in part. Some of these bodies are purely advisory (mostly in countries with systems close to the centralised archetype), others combine advisory with funding roles, and governance and management roles (to some degree in dual-system archetypes, strong involvement of stakeholders in decentralised systems). A number of advisory structures may co-exist within the same country.

Representative advisory bodies in Finland (Science and Technology Policy Council) and Netherlands (Netherlands Advisory Council for Science and Technology Policy) exist in addition to and drawing on research councils. The United States has a dense structure of advisory bodies at the federal level which are each supposed to include all stakeholders, including industry. In other countries, advisory councils vary in their independence from government, and maintain representation from independent granting agencies (Finland, Flanders, Japan, Germany). Countries where external participation is essentially through advisory structures with no attached funding roles include France and Italy where a variety of different committees exist. Governments are increasingly looking to this category of body to conduct or commission reviews, evaluative and prospective studies.

Where independent granting agencies such as research councils act as intermediate structures between government and research-performing institutions, they increasingly have a combined funding and advisory role for government on research policy (Australia, Canada, Denmark, Germany, Norway, Sweden, United States). Such agencies generally already have various committees in place drawing on the research community and frequently a broader representation including industry and community interests. The re-

3. See also the section on co-ordination in this chapter and Chapter 3.

search community has had long-standing involvement in peer review processes linked to project grants through such agencies. There is a potential for conflict of interest in this type of structure where advice could become special pleading for an increased funding role for the organisation. Internal structural separation, such as exists in the case of the National Science Board and the National Science Foundation in the US, goes some way to addressing potential conflicts of interest. Also, multiple sources of policy advice for governments help minimise scope for difficulties arising from conflicts of interest.

Strengthening of intermediate-level funding structures within research systems (*e.g. *research councils)

In only a few countries is authority over project funding granted directly from government to research-performing institutions. In France and Italy, where major directly funded public research organisations with a large network of different research centres exist, decisions on project allocation are internal to the organisation. In both these countries, some minor funds are distributed from these networks to external bodies, but amounts are not yet significant (less than 2% of the budget). German research organisations are also directly funded by government, although using varied means (see country report on Germany). Particularly in those countries where the universities are the dominant public research performers, intermediate-level funding agencies are being strengthened as agencies at arms' length from government and through which competitive programmes can be run. These are mostly organisations which are administratively independent from government ministries, but they receive annual subsidies through the usual government budgeting process via one or more designated ministries. Research councils are the most common example of this structure, and are found in Australia, Belgium, the Czech Republic, Denmark, Germany, Iceland, the Netherlands, Norway, Sweden, the United Kingdom and the United States.

Countries have increasingly realised that research councils are important players in the science system. Systems using this institutional element seem to be more flexible and – above all – respond best to the demand of stakeholder involvement. Therefore quite a number of countries have recently changed these structures to adapt them to changing requirements such as a higher degree of flexibility to change funding areas and instruments, improved user orientation, more interdisciplinary research (hence the merger of discipline-oriented councils into larger cross-sectoral councils, or councils related to a socio-economic field), and more strategic and systemic thinking.

Governments have followed three strategies to reform funding agencies and overcome resistance. First, they have, like in Canada, modified the existing system by creating new agencies (an option which might have its shortcomings since it increases the institutional complexity of the system). Second, they have put financial pressure on existing funding agencies to adopt a more strategic and flexible approach, sometimes accompanied by a thorough evaluation of the existing system, or they have, third, completely rebuilt existing funding agencies to integrate social responsibility and strategic thinking (which might be difficult because of the change in organisational culture). Despite the difficulties mentioned, all three approaches seem to have led to a satisfactory change, and have been accepted by the stakeholders concerned (Braun, 2002).

Box 2.3. Restructuring research councils: some examples

In the **United Kingdom**, research councils (RCs) have been gradually established since 1920 to manage and fund generally applicable or basic research, the priorities of which are in principle to be determined autonomously by the scientific community. They were established as independent non-departmental public bodies to support basic, strategic and applied research, postgraduate training and the public understanding of science.

In 1994 the UK RCs underwent re-organisation as a result of the 1993 White Paper "Realising our Potential". The rationale was to get them closer to potential users and structure them so that RCs could "identify areas for cross-fertilisation and integration along the continuum of basic, strategic and applied research" (Flanagan and Keenan, 1998). The restructuring resulted in the creation of seven research councils. Each was provided a mission statement recognising the importance of research undertaken to respond to user needs and support wealth creation. Each council came to have a part-time chairman from industry. They receive most of their funding (67%) via the science budget of the Office of Science and Technology (OST), but also from government departments, industry, charities and overseas sources.

The **Australian** Research Council (ARC) has been established under the Australian Research Council Act 2001 within the portfolio of the Ministry of Education, Training and Youth Affairs. Its mission is to "advance Australia's capacity for quality research to the economic, social and cultural benefit of the community". This clearly shows that social accountability ranks high on its agenda.

The ARC is one of the main funding agencies in Australia for basic research. It administers a range of highly competitive granting schemes which provide funding support to Australian researchers and universities across all areas of research endeavours except clinical medicine and dentistry. However, the fact that the Council has identified priority areas (*e.g.* nano- and bio materials, genome/phenome research, photon science and technology, complex and intelligent systems) shows that not all disciplines and subjects receive equal funding, but that those areas which are judged to have the most promising future for Australia have a preference over others (ARC, 2002a).

Beyond funding, the ARC also has a strategic role in advising the government on research policy; helping to form and maintain effective linkages between the research sector and the business community, government organisations and the international community; developing and improving public understanding and appreciation of the contribution that research makes to the community; and reporting on the comparative performance of Australia with other research active countries and assessments of the national return on investment in research.

Box 2.3. Restructuring research councils: some examples *(continued)*

The fact that the ARC has a "strategic plan" covering a period of three years also shows that its role goes far beyond the classical mission of a research-funding agency. This plan sets out the vision of the organisation for the next three years, and enables the ARC to demonstrate accountability to the community through the government for its investment in research and research training. It identifies the objectives and investment strategies as well as the specific actions the ARC will undertake in its seven key areas of discovery: linkage, research training and career development, research infrastructure, priority setting, community awareness and governance. It also identifies the key performance indicators which will enable the ARC to measure its progress in delivering outcomes of benefit to the community (ARC, 2002b).

With effect from 1 January 2001, the **Swedish** parliament decided to re-organise its public research-funding agency system. This new structure was created to serve several purposes: concentrate efforts in key scientific fields, promote co-operation between different fields of research, stimulate interdisciplinary work, support outstanding research talents, improve the dissemination of information about research and research results and support work related to important societal questions (gender equality, ethical issues).

The new structure replaced a system of responsibilities which were dispersed in a variety of institutions (11 different research councils). It now comprises the *Swedish Research Council*, consisting of three separate councils (humanities and social science, natural sciences and technology, medicine) and a special committee for educational science. While the Council's main task is still defined as "supporting fundamental research in all scientific fields", tasks also include more general items relating to managing the science systems such as promoting renewal, profile establishment and mobility in the research community, creating a good research environment and advising the government on research policy issues.

Funding from the Council is mostly granted on the basis of competitive procedures. In its funding decisions, the Council has to take special account of support to young researchers, heavy equipment and support for "minor" subjects in the humanities.

In addition to the major Research Council, two special research councils have been established: the Swedish Research Council for Working Life and Social Sciences and the Swedish Research Council for Environment, Spatial Planning and Agricultural Sciences. The Swedish government saw a great need for new knowledge in these areas. This new funding structure for research was complemented by a new public authority for supporting applied research, technical development and innovation: the Swedish Agency for Innovation.

The transition to the new structure was facilitated not only because extensive resources were carried over from the old system, but also as a substantial proportion of the new funds made available for research were allocated to the new institutions (Swedish Ministry of Education and Science, 2000).

The Research Council of **Norway** (RCN) was established in 1993 by merging five primarily discipline-oriented research councils. The research council reform and the RCN were subject to a thorough international evaluation in 2000–2001. As a result of the evaluation the RCN will be reorganised. The six former divisions of the council organised by discipline will be replaced by three broad divisions, organised by function (*i.e.* advancement of subjects and disciplines, innovation and user-initiated research, strategic programmes). One of the aims of the reorganisation is that the RCN will put stronger emphasis on long-term basic research as well as on R&D-based innovation. Other aims are improved user orientation and a stronger focus on interdisciplinary co-operation.

Changing balance among research performing institutions

A changing balance is evident among research-performing institutions. While the relative importance of university research in quantitative terms has remained constant over the past 20 years averaged over OECD countries, standing at 17% of government expenditure for R&D (GERD) in 2000, that of public sector research institutions has diminished from 15% in 1981 to 11% in 2000. Over this period, several countries have moved from having strong public research institutes in balance with or stronger than universities, to a position where universities dominate their public sector in performance terms. With the exception of Sweden, Hungary, Japan and Mexico between 1981 and 1999 the proportion of overall government R&D funds going to higher education has increased significantly, often at the expense of government institutes. It needs to be remembered, however, that the 1990s saw a significant decline in defence-related research, much of which was undertaken in government laboratories. This may be one of the reasons explaining the growing importance of university research.

In contrast with higher education, the prime mission of public research institutes is research, although service and advisory functions are important elements for some institutes. They are heterogeneous, with a considerable range in institutes' size, status, research focus and linkages to government ministries. There are *i)* mission-focused institutes owned and run by government departments for the purpose of undertaking research needed to support their policy and regulatory responsibilities; *ii)* institutions which undertake a mixture of fundamental and applied research across a range of fields, and which in a number of countries are organised into sizeable research organisations (*e.g.* France, Italy, Germany, Australia); and *iii)* public research institutions, focused on more applied research and development. These include a variety of mainly independent bodies which receive considerable contract funding from business as well as from the public purse.

Public research institutes vary markedly in their importance across countries. In Sweden and Belgium they are virtually absent (performing 3.5% and 3.1% of GERD respectively in 2000), whereas they performed more than 30% of GERD in Hungary, Iceland, New Zealand, Mexico and Poland, and even around 50% in France and Germany. Although no clear link can be made between the three system archetypes and the importance of the research-performing sectors (consider the strong share of institution-based research in France and Germany), it seems that decentralised systems – as a rule – have a stronger university sector as compared to public research institutions. In countries with such systems, public research institutions tend to be mission-oriented (under the authority of a sector ministry) rather than pursuing a broad range of research subjects.

Whereas within any one country the legislative status of most higher education institutions is relatively similar, there is much greater heterogeneity within countries in the case of the public research institute sector, in both legislative status and size of operation. There is a much greater variety of types of organisation which undertake publicly funded research and overall they link to a wider range of government ministries. It is not clear that such arrangements reflect clear and consistent policies. They are commonly historical survivals or a result of specific initiatives sometimes from competing ministries and departments.

Several consequences and issues for steering and funding emerge from the trends outlined above. First, the main beneficiary of publicly funded research is increasingly the university system which, beyond its traditional and important role in the training of highly qualified personnel, is diversified and can more easily respond to new opportunities. Second, in those countries where the public research institute sector is significant, despite the considerable change evident at present within the sector, the diversity presently found is likely to remain, and with it the co-existence of small independently functioning units, and large research organisations. Considerable rethinking of the missions given to this sector should occur if public research institutions are to respond to the changing demands of interdisciplinarity and socio-economic relevance of research.

Developing partnerships between different research performers

Due to both financial pressures and the potential for intellectual synergies and economies of scale in research, close links exist, and ever closer links are being urged in many countries between public research institutes, the higher education sector and industry.[4] Partnerships of a wide variety of types between higher education institutions, public research institutions and industrial research performers are acting to blur the lines between research activities among the different institutions. In some countries (mostly those coming close to the dual-system archetype or the decentralised archetype) this type of collaboration seems to be easy to establish without any major formal procedures. In other

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4. Two other OECD publications deal with co-operation between science and industry: *Benchmarking Industry-Science Relationships* (2002), and *Public-Private Partnerships for Innovation* (forthcoming).

countries new funding procedures have to be developed or legislative action is needed to facilitate this type of partnership.[5]

Encouraging the joint use of expensive and/or large facilities based in one institution in order to take the greatest possible advantage of them is of increasing policy interest. Providing access for different research teams through competitive and peer reviewed processes is common at US user facilities or in the German *Helmholtz-Gemeinschaft Deutscher Forschungszentren* (HGF) facilities.

Joint laboratories of universities and public research institutions are common in some countries. In France, the majority of the laboratories of the *Centre National de Recherche Scientifique* (CNRS) are jointly operated with universities and university and CNRS staff intermingle in the workplace. In Germany the *Max Planck Gesellschaft* (MPG) has for many years had a policy of locating an institute in proximity to a university with strength in a similar research field, undertaking joint work but from separate bases. Recently, however, a new and experimental mode of working in the form of establishing jointly located teams within universities was put in place for a five-year period. Questions of institutional autonomy are clearly raised by some of these developments, *e.g.* who is responsible for managing human resources?

Joint appointments are common in Germany for directors of institutes within the major networks (*e.g.* MPG, *Fraunhofer Gesellschaft*) and local universities. Secondments of researchers to different research establishments are also common procedures for varying periods of time. Research training is also a key area of collaboration between the sectors. Only universities have the authority to award research degrees, but many doctoral students work in public research institutes, using this experience towards their research degrees. Institute staff take supervisory roles (Norway) or students may have placements in different research organisations during the course of their studies.

Thus, linkages between research institutions or performers exist both formally and informally, are increasingly common, and are actively encouraged by a number of governments, notwithstanding whether the structures come close to any one of the three archetypes. While there are tensions and a continuing debate over financial, managerial and intellectual rights and responsibilities – not to mention institutional autonomy and institutional distinctiveness – closer linkages of all kinds are growing in importance and seem set to

5. For instance, the 1999 French Innovation Law, or the institutional framework which has been created in France to support national programmes on networks for technological research and innovation.

feature prominently both in the public domain and between the public and enterprise sectors. Many of the linkages between the higher education and public research institute sectors extend equally to the research sector in business and industry.

Conclusion

This chapter has identified a number of important structural features which vary between the research systems of OECD countries: the ministerial structure for governance, the way priorities are set, funding streams – both linked to stakeholder participation – and the balance between different research performers (universities vs. public research institutions). The differences between systems have been captured by defining three science system archetypes (see Table 2.1). However, although a country may be closer to one of the archetypes, no country can be categorised within a single one.

Structural change has been widespread over the past decade (see Box 2.1). Serious attempts to co-ordinate research efforts on a government-wide basis have been undertaken by most countries. Efforts have also been made to involve stakeholders more centrally in research decision making, either by establishing advisory bodies or by strengthening the role of research councils responsible for advice on R&D policy as well as for funding R&D and managing research programmes.

Several trends were identified with regard to the structural changes of research systems, suggesting a strong convergent tendency in research policy-making among OECD countries despite structural differences. Policies have broadly been aimed at changing the role played by government in supporting research – moving towards more strategic planning and oversight, within a structure where research-performing institutions function more efficiently and competitively through enhanced autonomy, and engaging in a range of different partnerships and collaboration with all stakeholders involved.

As pointed out before, some countries can comply with the demand to better respond both to stakeholders' needs and new opportunities by introducing marginal changes. In other countries, major reforms of the science system are required. This is – at least to a certain extent – related to the archetype a country comes close to. Countries with a more centralised science system tend to have very stable research institutions being able to pursue long-term objectives on a sound basis. However, they also tend to be rigid, slow in taking up new opportunities, and require formal or even legal reforms to introduce changes. Countries closer to the dual-system archetype are more responsive to stakeholders' needs and flexible enough to undertake partnerships and collaboration with different stakeholders, but they tend to be very complex and therefore require major co-ordination efforts. Countries with decentralised systems probably have the greatest flexibility in responding to stakeholders and their emerging needs; on the other hand, they lack a co-ordinated approach and their science systems might lack long-term stability.

When implementing further structural reforms and changes, countries should pay attention to the following:

- Achieving coherence in research policy – whether through structural consolidation or enhanced co-ordination.[6]
- Ensuring the most productive involvement of stakeholders in the functioning of the research system – whether through enhanced advisory and/or decision-making roles.
- Achieving enhanced performance among institutions in the public sector – whether through increased institutional autonomy, increasing the competitive elements in their funding, or through changing the balance between universities and public research institutions.
- Maintaining or developing institutional structures which enable support for research over the medium to long term.

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6. In centralised systems, there is a risk of moving too far toward "a system lacking co-ordination and clear long-term strategies" when decentralising (Commissariat Général du Plan, France, 2002).

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Chapter 3

PRIORITY SETTING: ISSUES AND RECENT TRENDS

Abstract. This chapter describes priority setting as a strategic process to increase the return on public investments in research. It shows that governments use various institutional mechanisms for this: national science and technology plans, (de)centralised advisory bodies, foresight processes and public consultation. It further describes how priorities are reflected in research funding decisions, and how recent reforms reflect the changing balance between top-down and bottom-up approaches.

Introduction

The increasing evidence of the direct relevance of knowledge gained through scientific research to economic growth and enhanced welfare poses a challenge as to how governments could best utilise the available resources for research. There is also growing demand for how resources are spent to be accounted for. Despite the importance attached to science and technology, public investments in research are not increasing rapidly in many OECD countries compared to private investments. This sets the background for the need for setting priorities in research.

A previous OECD Committee for Scientific and Technological Policy (CSTP) study on priority setting in science and technology already identified the demand for more direct relevance of research to economic growth as an important element of the context for priority setting (OECD, 1991). Other major conclusions include:

- Priority setting is "essentially a complex political process involving many people who interact with one another".
- The concept of priorities is being broadened from "thematic" priorities to "structural" priorities, *e.g.* training of research personnel or balancing different kinds of funding instruments,
- New approaches to decision-making processes are being adopted, including broadening of consultation processes that involve scientific experts together with policy, business and community representatives;

preparation of strategic medium-term plans; and the use of science and technology "watch" (foresight).

The same trends still persist, with some becoming even more evident. This chapter discusses why and how OECD member governments are tackling priority setting for research, the issues they are confronted with and the policy responses. The information is drawn mainly from the responses to the questionnaire and country reports for the OECD project on Steering and Funding of Research Institutions.[1] The questionnaire addressed the following aspects of research priority setting:

- Reasons for research priority setting.
- Institutional features and mechanisms for priority setting.
- Challenges policy makers face in research priority setting.
- Impacts of emerging areas and societal needs.
- Recent reforms in priority setting procedures.

Who are the actors in priority setting and why do they set priorities?

All actors in research funding and performance take part in setting priorities. Since the future direction of a researcher's work depends on the results of his or her current research, researchers themselves are the best placed to set priorities within their projects. However, prioritising different fields of research is subject to a complex decision-making process involving not only the scientific community but also stakeholders outside science, including societal groups (such as in health, agriculture and industry). Therefore, priority setting in research requires a balance between "science push" and "demand pull". In recent years, "demand pull" has become more important in priority setting, giving rise to various tensions between the two opposing forces.

The resources that can be put into research are not unlimited, and this inevitably gives rise to the sponsors' need for priority setting in the public research system. Indeed, many countries cite budget constraints as a major reason for priority setting. For example, the Czech Republic pointed out that *budget constraints* are causing a shift in research priorities. The key issue is

1. The following countries responded to the questionnaire: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Sweden, Switzerland, United Kingdom, United States.

how "hard" the budget constraint is. Shifting priorities within a very constrained budget is naturally more difficult, and is reflected in the fact that in some countries, only the increased part of the research budget is often allocated to priority areas identified by the government or other public research-funding agencies. For example, the annual increase in the science budget of the UK government is allocated to priority areas identified collectively by the Research Councils and through the foresight exercise.

In many countries, budget appropriations for research increased in the 1990s. Even under such circumstances, policy makers face priority-setting problems for budget reasons. For example, in Denmark, public research funding increases in the beginning of the 1990s resulted in the expansion of supported research areas as well as numbers of research personnel, creating a budget problem and a need for priority setting.

Finland - where budget constraints are not a major issue for research priority setting - cites the existence of a *broad consensus on priority* among different stakeholders. Finnish consensus is to become a "knowledge-based" and leading information society. The increased public funding of R&D in the second half of 1990s was targeted and research appropriation was channelled by means of competitive bidding. The funds were principally allocated by increasing the resources of the Academy of Finland and the National Technology Agency (TEKES).

This illustrates that *compliance with other national priorities* is a determinant of research priorities. National priorities for welfare objectives such as health and environment as well as techno-economic objectives such as "knowledge-based" or "information" society influence research priorities. In Denmark, compliance with other national priorities is especially strong in public research institutions belonging to government ministries, since research in these institutions contribute directly to policy making in the respective domains.

In general, policy makers in member countries have a strong feeling of *public pressure to respond to societal needs, maximise returns on public investment and enhance accountability*. Public pressure is said to be not so significant in newer member economies such as Hungary, but achieving efficiency in utilising resources is still an issue. Achieving greater flexibility, efficiency, collaboration, multidisciplinarity and restructuring the research system to accommodate these needs are other reasons to set priorities (Sweden). *Identifying emerging areas* is also a major concern for some countries large and small (United States, Denmark). For Korea, identification of research priorities is directly linked to selecting engines of future economic growth.

Some countries have enumerated current priorities, which range from "structural" research priorities (*e.g.* increasing research funding, strengthening university research, promoting basic research) to identifying broad "thematic" challenges or disciplinary areas (women's participation, sustainable development, marine sciences) and specific technology areas (ICT and biotechnology).

How governments and research institutions set priorities – institutional features

In many countries, governments make some attempt to centralise and co-ordinate priority setting. This may be done through research funding decision-making mechanisms. Broadly speaking, there are countries in which a top-down approach dominates and others in which a bottom-up approach is more important. In all countries, both top-down and the bottom-up forces exist, and some countries attempt to integrate the two approaches. The recent trend is that in many countries there seems to be increasing tension and shifts in this balance, making priority setting a major issue in research policy.

In countries where a top-down approach is predominant, the central government adopts explicit strategies, policies or plans that specify priority areas for research (Austria, Czech Republic, Hungary, Japan, Norway). Most of these countries, as well as others (Denmark, Germany, Korea and the Netherlands) have some kind of central advisory body that makes recommendations about priorities. In the case of France and Italy, the advisory bodies are inter-ministerial committees.

The power of such advisory bodies is usually limited to making recommendations, but they nonetheless have a strong influence on priority setting. In some countries this goes much further. For example, Austria has recently reformed its research decision-making system, moving to a highly centralised mode. The Austrian Council for Research and Technology Development, which was set up in 2000, drafts visions and research strategies for the government as a whole, including research priorities. The Council's advice becomes top priority for government departments. What gives this body true power in research priority setting is that the responsibility for making decisions for the use of specific public funds totalling roughly EUR 500 million have been transferred to it from ministerial departments.

At the other extreme is the bottom-up, decentralised approach. In the United States and Canada, the government advisory bodies on research are decentralised and serve different government agencies in priority setting. In other countries where a central advisory body does not exist, Sweden for example, priority setting is left to individual government ministries and agencies.

In the United States, advice on priorities comes from Federal Advisory Committees which are set up by different agencies that fund research. These committees make recommendations based on reports from the President's Committee on S&T, the National Academy of Sciences, the President's science advisor, workshops organised by the agencies, and the advice of professional societies. The membership of Federal Advisory Committees is supposed to include all stakeholders including industry.

In some countries, there is an integration of top-down and bottom-up approaches. For example, Germany has a decentralised research system with strong autonomy of public research institutions as well as universities. Priorities are set at individual institutional level as well as a result of dialogue between the government, and the scientific community represented in research-funding bodies and the publicly funded research-performing institutions, which make proposals on research areas of priority. However, despite its decentralised structure, Germany has a science council, which is an independent advisory body consisting of representatives from the scientific community, government, business and the civil society. It plays an important role in making recommendations on priority areas and conducting evaluations of research institutions and programmes.

Australia has generally taken a sectoral and "pluralistic" approach to priority setting in research: priority setting has been the responsibility of sectoral ministries which made decisions between priorities that involve R&D and those that do not; for example, a ministry responsible for health making decisions would decide between support for health services and research on particular health issues.

The government's Innovation Action Plan released in January 2001, *Backing Australia's Ability*, flagged the need for an emphasis on research in which Australia enjoys or wants to build competitive advantage. A significant shift in priority setting was announced by the Minister of Education, Science and Training in January 2002, when four research priority areas were announced for the Australian Research Council's (ARC) 2003 funding round under the National Competitive Grants Program: nano- and biomaterials, genome/phenome research, complex/intelligent systems, and photon science and technology. A total of 33% of ARC funding not yet committed in the 2003 round will be targeted to these priority areas to support project grants and centres for up to five years at a total cost of AUD 150-170 million. This funding will enable Australia to focus its research effort on particular areas in which it will have world-class, leading-edge capabilities.

In 2002 the Australian government began a process to identify national research priorities that would influence the agenda of all major Commonwealth research funding and performing agencies. This process forms an important part of the government's efforts to strengthen the national innovation system. Worthy of note is that this process was based on an extensive consultation process involving participants from municipalities and regions as well as the development of short list of priorities by an expert committee from suggestions in more than 180 public submissions. As a result, in December 2002, the government identified four thematic priorities: environmentally sustainable Australia, promoting and maintaining good health, frontier technologies for building and transforming Australian industries, and safeguarding Australia. The participating public research bodies are expected to put forward plans to government by mid-2003 on how they propose to implement the priorities. This exercise has succeeded in cutting through government departments and engaging the government at the highest level.

In all countries, research-performing institutions, especially universities, enjoy a high degree of autonomy and are free to set their own priorities through processes they have devised. However, the priorities of the public research funding agencies will inevitably be reflected in the priorities of the performing institutions. Programme/project funding, especially, is tied to priorities of the funding agencies.

The Austrian Academy of Sciences set their priorities through a medium-term research programme and by adjusting their institutional framework accordingly. Likewise, in Austria, the Ludwig Boltzman Society, which is currently in being reorganised, will set priorities in the future by establishing or closing institutes according to selected criteria.

In some countries, priority setting for research is directly linked to funding decisions. In France, the Ministry of Research and the CIRST (Committee on Scientific and Technological Research) are the major players in setting priorities. The parliament, in voting annual finance laws and making the inherent appropriation decisions, carefully discusses the proposals and related budgetary information and interacts with the priority-setting bodies. In the United States, the annual budget cycle in Congress, through which new investments are proposed each fiscal year, drives the priority-setting process. Agencies propose draft budgets to the President's Office of Management and Budget (OMB) which, in turn, decides how much of the proposed budget will be submitted to Congress in the President's Budget Request. Thirteen

Congressional appropriations committees consider and revise these requests, and appropriate funds. The discussions are about proposed increases, not about the "base budget". The latter increases by the creation of new "initiatives" or "priority areas". Some of these are inter-agency initiatives (*e.g.* the National Nanotechnology Initiative). The federal government-wide budget cycle allows agencies to co-ordinate their proposals and receive funding for identified priority areas.

Foresight as a tool for priority setting

Needs and capacities are often identified through technology foresight processes of some form in many OECD countries to differing yet increasing degrees. Many governments use foresight processes in priority setting or to stimulate dialogue on the subject or integrate results. Canada uses different types of foresight, adapted for various priority-setting needs (Box 3.1). The United Kingdom has had a government-level foresight programme since 1994, and government departments are obliged to take account of foresight when developing their science and innovation strategies. In Austria, the results of the Delphi study conducted in the 1990s were used to prepare public research programmes in certain areas such as transport. The Czech Republic has recently adopted a technology foresight process in prioritising its oriented research, which accounts for 75% of total R&D expenditures in the country. The Czech process involves researchers, business and civil society. Policy makers recognise technology foresight as a good practice.

In Germany a new type of foresight, FUTUR, provides a forum for open dialogue between diverse stakeholders in identifying future priority fields of research. Choices influence project funding decisions. The Science Council is also developing a new tool, "research prospection", to identify novel research topics and fields as a means of developing priority setting approach which are responsive to both national interests and global issues. Japan has been conducting periodic technology forecasting exercise using the Delphi method since 1970. Korea also uses foresight and the results are implicitly integrated into national priorities by experts who are involved in evaluation and pre-budget review.

Box 3.1. Foresight in Canada

Technology road maps (TRM) for industry R&D

Technology road mapping is a planning process driven by the projected needs of tomorrow's markets. It helps companies to identify, select, and develop technology alternatives to satisfy future service, product or operational needs. Via the TRM process, companies in a given sector can pool their resources and work together with academia and governments to look five to ten years into the future and determine what their specific market will require. The TRM process is led by industry and facilitated by Industry Canada.

Strategic Project Grants Programme of the Natural Sciences and Engineering Research Council of Canada (NSERC)

The Strategic Project Grants programme funds project research in target areas of national importance and emerging areas that are of potential significance to Canada. The research is at an early stage with the potential to lead to breakthrough discoveries. Targeted areas are identified in consultation with experts from all sectors.

NSERC Circle

This is a new body created by NSERC to provide advice on the key areas where Canada may have an opportunity to leapfrog into the front ranks of research in the natural sciences and engineering. The NSERC Circle comprises all the recent winners of NSERC E.W.R. Steacie Memorial Fellowships and the Gerhard Herzberg Canada Gold Medal for Science and Engineering.

In the Netherlands foresight processes are conducted by a number of (advisory) bodies. The Royal Netherlands Academy of Arts and Science engages in foresight processes from the perspective of promising scientific developments. Several other bodies conduct or are involved in foresight processes from the perspective of knowledge demand. For instance, the Sector Councils, which cover a broad array of societal sectors, draw up research agendas formulated on the basis of inputs from government, science and the sector involved. A recent example of a priority-setting mechanism with a direct follow-up in investment funding is the ICES-KIS programme (Box 3.2), which involves extensive consultation with various stakeholders.

Even for countries that do not conduct foresight, some governments take into account the results of other countries' foresight exercises (Denmark, Iceland). In the United States, following the 1993 Government Performance and Results Act which replaced foresight as a means of priority setting for government agencies, the latter now integrate use from the research community in their strategic planning.

Box 3.2. The case of ICES-KIS in the Netherlands[2]

ICES-KIS projects are financed from a fund constituted by natural gas revenues. Realizing that the natural gas reserves would eventually be depleted, the government chose to set aside a portion of the revenue for long-term investments in structural aspects of the economy. This portion was put into a special fund, called the Fund for Economic Structure Improvement (FES). The FES law deals with issues such as input, output and management of the fund.

In the early 1990s the knowledge infrastructure (KIS) was incorporated into the investment strategy. It was argued that an investment impulse was needed to create multidisciplinary networks of knowledge in order to address some of the complex future bottlenecks and challenges in Dutch society. To implement this strategy, a separate, inter-ministerial task force (ICES/KIS) was formed with the mission to prepare the strategy for investment in creation, development, diffusion and implementation of knowledge in the Dutch economy. Responsibility is shared by all participating ministries, particularly the Ministry of Economic Affairs and the Ministry of Education, Culture and Science.

A third ICES/KIS-round was initiated in 2000. ICES/KIS-3 is different from the previous two rounds in that the process was changed from a top-down to a bottom-up approach. More transparency and participation from all parties on the knowledge market (universities, research institutes, industry, and government) was called upon to secure wide support for the process and the final outcome. Another important suggestion for improvement was to create a three-step approach. In the first step, a long list of thematic perspectives was created. With the input from representatives of about 40 organisations involved in science and R&D, 200 ideas were generated, which were clustered into eight thematic categories. In the second step the Dutch cabinet selected six out of the eight thematic categories. In the third step, a call for tender was put out. On 20 November 2003, the Dutch cabinet will decide which tenders will be awarded with funds. The decision-making process will be supported by the reviews of scientific experts and other experts who will have considered the societal and economic merits of the proposals.

The budget available for ICES/KIS 3 is EUR 805 million. With ICES/KIS, the Netherlands created a tool for initiation and management of large multidisciplinary R&D projects, while at the same time strengthening the knowledge infrastructure and improving the economy through public-private participation. A secondary objective of ICES/KIS is to reduce the rigidity of the Dutch research system by stimulating the scientific research structure to form an integral part of the national innovation system.

2. In Dutch: *Interdepartementale Commissie Economische Structuurversterking – werkgroep Kennisinfrastructuur*.

Challenges policy makers face in priority setting

Balancing competing pressures: basic vs. more oriented research, core vs. project funding, competition from increasing industry funding

The challenges felt by policy makers are diverse and competing pressures are a major issue. The most fundamental issue is balancing basic research and research directed toward specific objectives (Austria, Denmark, Italy, Korea, Norway).[3] For other countries, the challenge is more in balancing core institutional funding as opposed to programme/project funding limited to certain subject areas (Austria, Denmark)[4]. The United States feels the competing pressure of industry funding of university research, which is felt to sacrifice openness and academic freedom. Italy finds it "virtually impossible" to separate out "basic" research from applied and development research in some emerging areas; hence, how to foster curiosity-driven basic research rather than applied research in these areas is felt to be a challenge. Iceland sees the challenge of choice and co-ordination in meeting diverse needs that even a small society must meet.

Rigidity of the research system, autonomy of research-performing institutions, financing of high risk pre-competitive research

Rigidity of the research system, in terms of the predominance of "core institutional" funding, is felt by some countries (Netherlands, Sweden, Portugal) as a major challenge. Sweden finds it difficult to free up funds to focus efforts on emerging areas of "basic" research and multidisciplinary areas. Portugal sees the rigidity clearly dominating disciplinary research and also remarks an "extremely low" involvement of business and civil society in priority setting. Related to the rigidity issue is the worry of some countries (*e.g.* the Netherlands) that the high degree of autonomy of research-performing institutions may hinder priority setting at the national level.

Canada feels it important to fund high-risk research in the pre-commercial stages. NSERC has proposed an opportunity fund to address this need. The

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3. There are other evidences of this fundamental problem. For example, the US National Institutes of Health attempted to define a priority-setting method several years ago. The document explicitly recognises that the complexity of its mission arises from the difficulty of deciding how much to devote to basic research in scientific disciplines on one hand, and how much to devote to research on specific diseases on the other (National Institutes of Health, 1997).

4. Denmark has a specific formula to define the balance. Over the last 10 years publicly funded basic and project research has been balanced at a 60/40 ratio.

objective is to seize the opportunities that come out of basic research and turn them into "made-in-Canada" advances and innovations when other means of exploitation are not available.

In general, policy makers in countries with decentralised research decision-making structures feel more challenges. Canada identifies the challenge of developing a strategic federal policy overview in its decentralised S&T structure. Germany feels that the decentralised structure as well as the strong autonomy of research institutions demands time-consuming discussion processes for balancing various interests of academia, politics and social demands. Denmark is committed to a high degree of decentralisation in priority setting, but policy makers often feel the lack of a basis for decisions. For example, the results of ongoing research programmes are not known when decisions need to be made to terminate them or allocate more funding. Also, universities and research councils, for different reasons, are not suited to advise government on overall priorities, leaving the government unable to change existing priorities[5].

Responding to emerging technologies, and societal needs

In some countries, the need to respond to emerging areas has resulted in the introduction of new procedures for priority setting and funding. In Canada, NSERC has adopted a procedure to increase flexibility in funding to respond to emerging areas. This reallocation exercise redistributes a portion of the Discovery Grants programme[6] budget among the various grant selection committees. The redistribution aims to respond to changing research priorities, transfer resources to initiatives identified as the most important by the relevant community, and ensure support for research in new and emerging areas. This process is becoming a national process of identifying and responding to new and emerging areas. Other countries respond in an ad hoc manner to the need to accommodate emerging technologies. For example, in the Netherlands, ministers can decide to establish ad hoc advisory committees to advise them on policies in emerging areas. In Norway, bottom-up initiatives from the research community resulted in the inclusion of a special programme on functional genomics, effectively adding another area to the national priorities from 2002.

In other countries, dealing with emerging areas has not required new priority-setting mechanisms. In these countries, the existing frameworks for priority setting are able to accommodate these challenges. In Germany, the in-

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5. In Denmark, universities have clear interests of their own which do not necessarily correspond to those of the government. Research councils willingly give advice on new money, but reluctant when the issue is re-allocation.

6. The Discovery Grants programme funds basic research.

crease in biotechnology and genome research, as well as the switch from nuclear research to research on renewable energies were implemented in both institutional funding and project funding within the existing priority-setting framework.

Promoting multidisciplinary research

Whereas emerging areas do not necessarily present a need for changing priority-setting procedures for some countries, promoting inter- or multidisciplinary research is a clear challenge for many governments. Governments attempt to promote multidisciplinary research in various ways. Denmark has enlarged the scope of new research programmes and introduced a number of broad problem-oriented programmes that include a number of disciplines rather than just one. Also, as a result of 2001 Finance Act, the government pooled the separate budgets of six research councils and a large number of boards running research programmes. Hence the research councils and their boards were empowered to carry out cross- and interdisciplinary priority setting and to award grants to the research areas in need. Likewise, the Research Council of Norway runs a number of broad problem-oriented programmes that include different research areas or disciplines. Italy addresses multidisciplinarity through an evaluation process. Evaluation committees are set up on criteria meeting specific research goals rather than linked to single disciplines. Sweden, Norway and Finland have restructured their research council system to promote multidisciplinary research. In France, the interministerial CIRST (Committee on Scientific and Technological Research) created new project funding instruments to foster interdisciplinary research. France feels it a challenge not just to foster thus, but also emerging areas at the interface of the disciplines.

For some countries, the solution for promoting multidisciplinary research is sought in setting up new types of research performing institutions or networks of institutions that integrate or encourage multi-disciplinary approach. Canada has introduced the Networks of Centres of Excellence programme, a university-government-industry partnerships programme that employs both a bottom-up approach of open competition based on research excellence criterion and targeted competitions in which proposals are invited in specific target areas. All three granting councils are involved in administering the programme and this favours the support of multidisciplinary research. The Austrian programme of setting up “K-plus” centres is a similar attempt to form public/private collaborative centres of excellence through a competitive selection process based on bottom up approach and stimulate pre-competitive R&D as well as long-term research. Portugal has introduced the scheme of setting up associated laboratories which are based on thematic and multidisciplinary programmes proposed by high-quality research centres, including partnerships between existing centres. In the Netherlands, the Leading Technological Institutes (LTIs) are another example of public-private partnerships in multidisciplinary research fields. The four LTIs are organised as virtual institutes, where researchers from different research institutes and universities jointly carry out a strategic research programme which is formulated in collaboration with industrial partners. Currently there are four LTIs: in food sciences, metals research, polymers and telematics.

Stakeholder involvement

Diverse stakeholder involvement in priority setting is a salient trend, and is undertaken in the interest of increasing transparency as well as in response to the genuine requirement to better respond to societal needs. This is done in different modes and at different levels.

Some governments involve business and civil society at the level of the central advisory council on science and technology. This is the case with the Finnish Science and Technology Policy Council which involves ministers and experts from public and private sectors as well as employer and employee organisations. The German Science Council is represented by the scientific community, the administration and civil society. The Italian National Assembly for Science and Technology, which prepares the strategic three-year plans on science and technology, involves participation of the government, universities and other public research institutions as well as business and civil society.

Multi-stakeholder involvement also exists at the level of the bodies that co-ordinate or directly fund research, most often research councils in many countries as well as decentralised advisory bodies attached to government ministries. In the Netherlands, the sector councils involve researchers, business and the society in their foresight exercises. In the United States, the Federal Advisory Committees involve all stakeholders, including business. In Finland, close contact that the funding councils (Academy of Finland and TEKES) have with business or the academic sector ensures their involvement in priority-setting decisions. In a novel attempt to make its procedures more transparent, the UK Natural Environment and Resources Council is opening its council meetings to the public.

The most recent development in stakeholder involvement is the adoption of the public consultation process in identifying national research priorities. For the Australian government, which launched such consultation processes in 2002, an open and extensive priority-setting process can ensure that research users have a say in directing the strategic flow of government funding, thus increasing the probability that it will produce a significant return to the nation.

Such processes seem to be a powerful tool in getting public research funding and performing bodies to take into account the identified priorities.

Conclusions

One of the principal reasons for setting priorities is the budget constraints faced by many governments. It should be stressed that budget constraints do *not* necessarily imply budget decreases. Oddly enough, budget constraints seem to be quite independent of changing trends in research budgets, which have been increasing in most member countries in recent years.

This demonstrates that budget pressures alone are not reasons for governments to set priorities. Rather, priority setting is viewed and used as a strategic process to increase the return on public investments in research and to demonstrate to the public that the government is managing the budgets effectively. This includes exploiting the expanding areas of scientific research that require public funding.

Although priority setting is often decentralised and research funders and research performers set their own priorities, governments have various institutional mechanisms to set priorities at the national level. Research priorities often form part of national science and technology plans or strategies adopted periodically by governments. Some governments have central advisory bodies that advise government ministers on science and technology matters including research priorities, and government ministries or research councils often have such advisory bodies. Technology foresight is often used as a tool in identifying priorities, or to stimulate dialogue. The extent of its use in the priority-setting mechanism varies greatly according to country. Public consultation processes are now starting to be used as a tool in identifying and enforcing national research priorities.

Governments have procedures or mechanisms by which identified priorities are reflected in the research funding decisions. This is normally associated with annual budget decision procedures. Budget increases are often allocated to programmes in areas of identified priorities. It is more difficult to shift existing funds to newly identified priorities. Some research funding agencies implement exercises to re-allocate existing funds to identified priority areas.

Prioritising emerging areas and especially promoting multidisciplinary research are felt to be challenges for many governments, which are devising various priority-setting and/or funding mechanisms to shift funding to emerging areas as well as promoting multidisciplinary research.

Balancing basic research with more oriented research is also felt to be a major challenge. This problem is in part felt as balancing "core institutional" funding with programme/project funding. This is also related to the relative rigidity or flexibility of the research system which some countries feel. Striking the balance between basic research and more oriented and applied research, and/or between core institutional funding and programme/project funding, is a fundamental challenge in priority setting for many governments.

Priority setting in research therefore not only concerns *thematic* priorities, but also *structural* priorities, such as basic research or human resource development. It also implies prioritising organisational features of the research enterprise, such as multidisciplinarity or partnering with industry.

Stakeholder involvement, including business and the civil society at various levels of priority setting, is becoming a widely used process. This is a means to respond to societal needs as well as to increase accountability and transparency. Research priorities, when they are identified through processes involving stakeholders, seem easier for governments to enforce.

Recent reforms in the priority-setting procedures by member governments reflect the changing balance between top-down and bottom-up approaches to priority setting. The balance is shifting because of increasing public pressure for societal relevance of research (demand pull), while the research community attempts to safeguard autonomy in setting the research agenda (science push). This is the fundamental tension in priority setting and is likely to continue. The challenge for governments is to devise ways to set a judicious balance, and identify priorities that contribute to knowledge and the advancement of society in the long term.

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Chapter 4

PUBLIC FUNDING OF R&D: TRENDS AND CHANGES

Abstract. This chapter describes the trends, changes and practices involved in funding public sector research. It includes such questions as the shift from block funding to contract funding, continued support for basic research and the increasing involvement of business in funding public R&D.

Introduction

This chapter describes trends and practices in the funding of public R&D. It is based on questionnaire responses and other available material.[1] The following questions were asked with regard to funding:

- Did or will funding levels increase substantially in your country? If so, for what reasons?
- What are the sources of income for research by universities and other public research institutions in your country?
- Is there a certain share of funding for which institutions are not accountable or that is not earmarked/pre-allocated for specific purposes?
- Have you recently introduced new funding mechanisms/agencies that increase competition between different research performers?
- Do you use evaluation procedures related to the different funding instruments in order to assess the effectiveness of such instruments?

1. The following countries responded to the questionnaire and later provided additional information on some of the questions: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Sweden, Switzerland, United Kingdom, United States.

Countries' answers were to provide information on the structures and schemes for the funding of public R&D, development trends, changes and the reasons for such changes.

Funding levels

The following graphs show that – apart from Switzerland – all countries have increased government funding for public sector research over the last few years. These are figures for 2000-01 or closest available year.

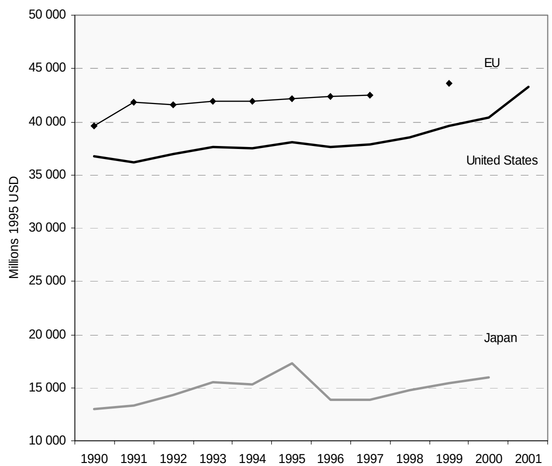
While sizeable in absolute terms, increases in funding for public sector research have only kept pace with the expansion of OECD economies. As a share of gross domestic product (GDP), funding for R&D in universities and other PRIs remained essentially flat at 0.61% between 1981 and 2000 at the OECD level, although considerable variations exist across countries. While the larger OECD countries tended to see declining levels of funding for R&D in universities and other public research organisations as a share of GDP, many others, including Austria, Canada, Portugal, Spain and the Nordic countries, posted significant gains (Figure 4.2).

As regards the future development of R&D funding in the public sector, nearly all countries reported that they will increase their funding for research in the years to come. Denmark is an exception: it reported a sharp increase of 30% until 1999, and now intends to decrease research funding by 25-30% between 2000 and 2005. Most recently, however, other countries have announced that – in view of budget difficulties – they cannot completely fulfil commitments made for increased funding of universities or major research organisations (Germany, Italy). Naturally, this has been met with major opposition from the scientific community, which argues that research funding should not be regarded as a subsidy but as an investment in the future that therefore should not be cut in the interest of future economic growth.

In those countries which envisage increases, these are mostly fed into special programmes or new funding instruments such as centres of excellence (discussed later in this chapter), all funded on the basis of competitive approaches. As a rule, only a small amount of increases (mostly related to salaries and overhead costs) is spent on institutional funding of research institutions that comes without strings attached. This has caused major concerns in fields of research which are not high on the priority lists. Funding for them might stagnate or even be reduced, although advances in knowledge generation might be forthcoming.

Figure 4.1. Development of government funding for public sector research

US, EU and Japan



The largest EU countries

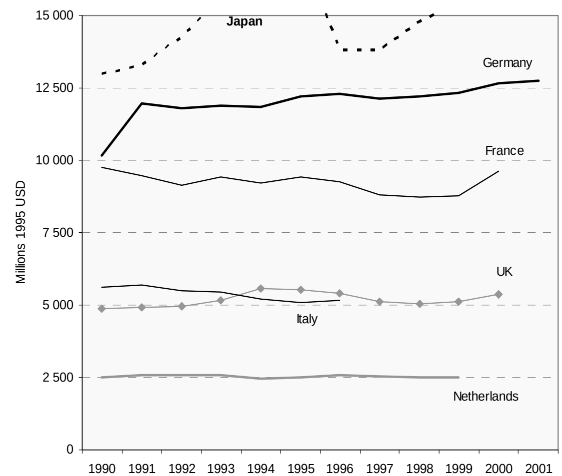


Figure 4.1. Development of government funding for public sector research *(continued)*

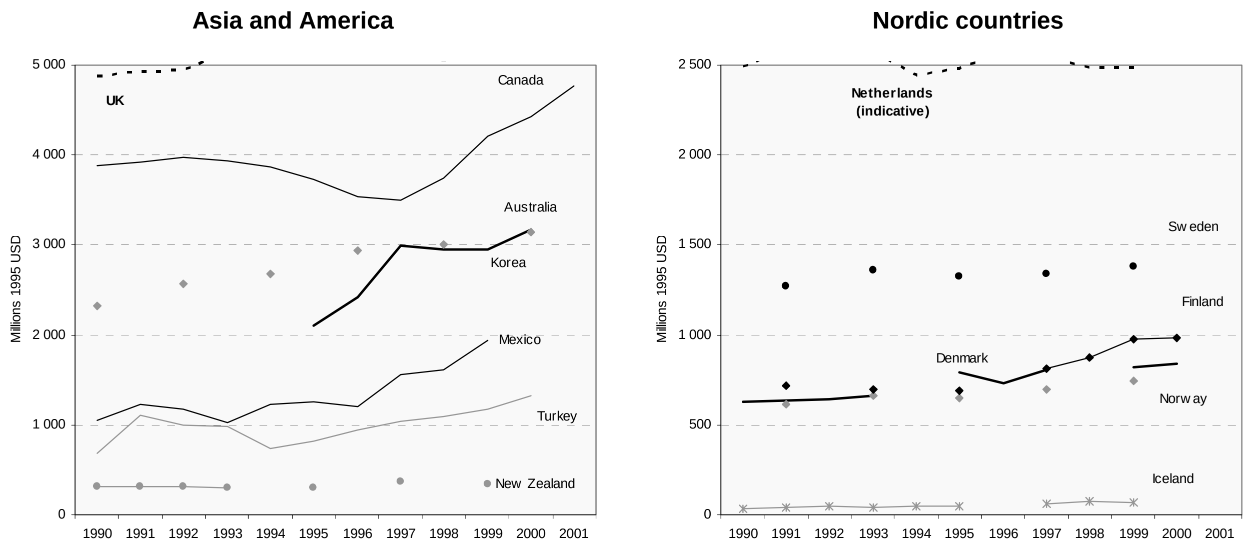
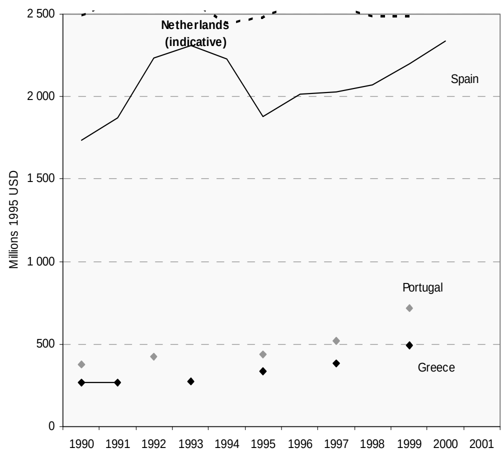
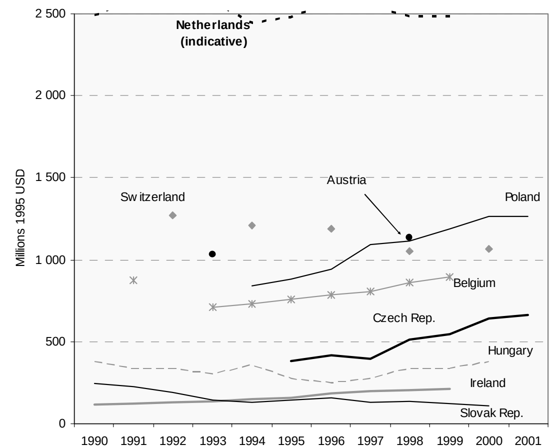


Figure 4.1. Development of government funding for public sector research *(continued)*

Southern European countries



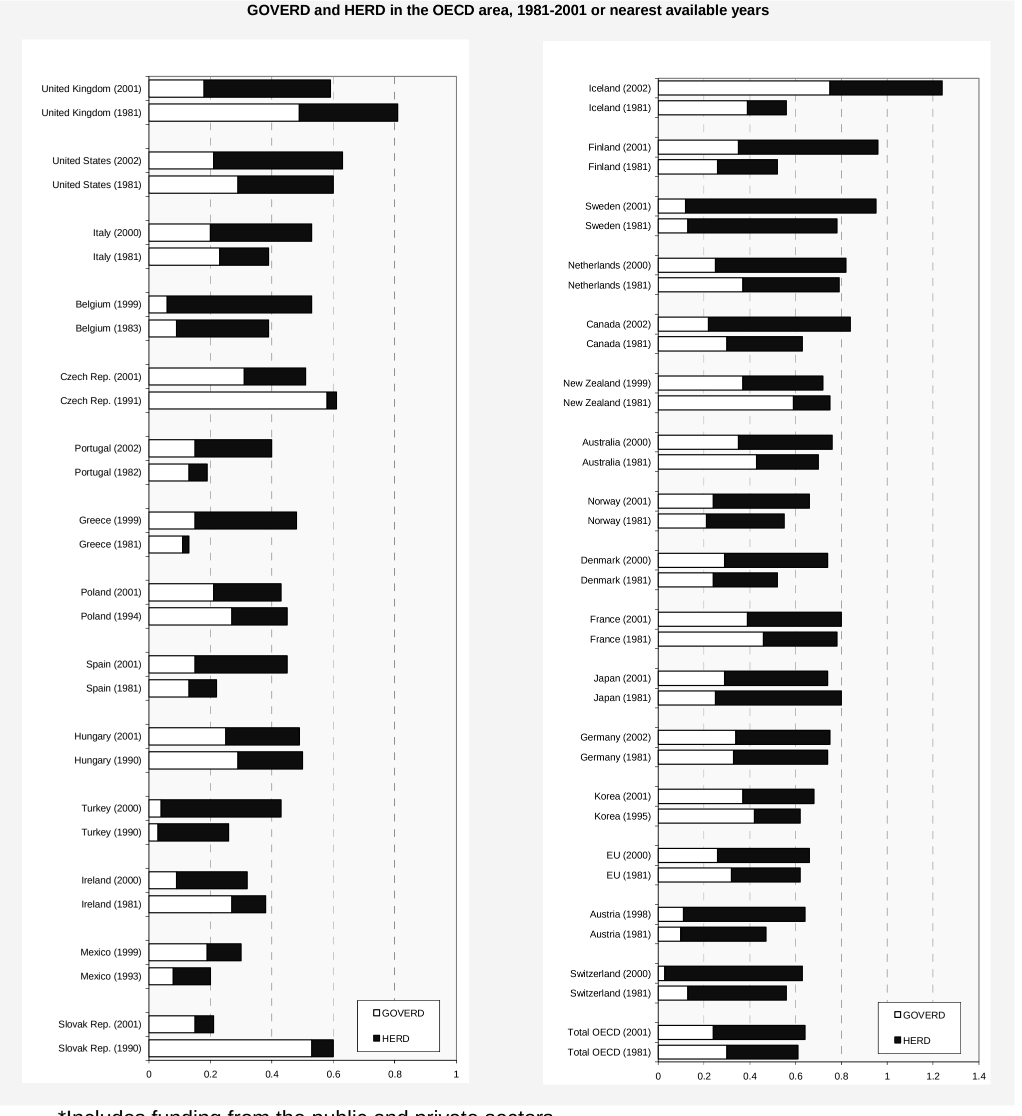
Central and Eastern European countries



Note: The series for Japan (in the second figure), the United Kingdom (in the third figure), and the Netherlands (in the last three figures) are indicative to highlight the change in the scales on the left side of the graphs.

Figure 4.2. Total funding of R&D performed in the public sector, 1981 and 2001*

Percentages of GDP



*Includes funding from the public and private sectors.
Source: OECD, MSTI Database, May 2003.

Funding structures

The largest share of income for universities and other public research institutions (PRI) comes from government sources (either federal or state/provincial). It is either provided directly by the ministries involved in the funding and managing of such institutions, or funding is delegated to intermediary agencies such as research councils.[2]

In principle there are two different ways of funding research in the public sector. These are normally categorised as "institutional" funding and "project" funding. Institutional funding refers to block funds that governments or funding agencies allocate to research-performing institutions annually. Institutions are free to use these funds in any way they see fit, as they do not come with strings attached. Basic research is normally funded by this mechanism. Project funding is normally granted when research performers apply for grants from competitive funding programmes of public research funding agencies, usually research councils. This includes funding through the "responsive mode", since application grants need to be made in order to obtain funding through this mechanism. Contract funding of public sector research from business or private non-profit organisations also falls into this category because funding is for specific projects. A third funding mechanism, which is also based on competitive criteria, is through special programmes either to advance specific research sectors or to promote excellence in general.

Institutional funding

Institutional funding for universities and PRI can take different forms, though in most countries it is based on numbers of students or research units (*e.g.* chairs in Japan) for universities. Most OECD countries claim that research funding comes without strings attached (one exception being Korea), and that the institutions have free reign in using the funds. However, several factors must be taken into consideration. While it is true that institutions can freely distribute these funds internally, the funding depends on overall science policy objectives and strategies established by funders, and utilisation of these funds is tied to overall legislation and regulations (in particular with regard to salaries). Many countries have introduced performance-based criteria for institutional funding. The United Kingdom, for example, is well ahead in doing this: funds are allocated to institutions on the basis that they can prove their strength in research by undergoing a peer review process, and there are periodic research assessment exercises. In some countries (*e.g.* Portugal) free disposal of funds is

2. Details on the structures of science systems are described in Chapter 2.

also limited by the fact that they are barely sufficient to cover basic salaries and equipment. In addition, it is difficult to define precisely what share of institutional funding goes into research since funding is normally for teaching *and* research. Some countries, however, separate funding for teaching and research (Denmark, Korea) or pay separately for undergraduate studies (Sweden).

Project-oriented funding

The call for greater accountability is obviously leading to a change in the mechanisms used by governments to finance R&D in the public sector. Government funding for academic research is increasingly mission-oriented, contract-based and dependent on output and performance criteria. Funding instruments are becoming increasingly competitive. Long-term institutional funding is on the decline. Fixed-term contract funding, funding for specific research programmes requiring networking between institutions and interdisciplinary research, is increasing.

In their responses to the questionnaire, most countries made a general statement to the effect that institutional funding for research institutions has decreased and a larger part is now coming from competitive funding instruments such as grants and project funding. Quantitative evidence is still scarce, but some countries have provided data (Table 4.1). These data clearly show that there is a tendency to decrease institutional funding in relative terms and increase the share of more competitive types of funding.

Table 4.1. Trends in institutional and competitive funding in selected OECD countries

	1996	1997	1998	1999	2000
Canada					
Universities					
Institutional funding	51.8%	51.6%	49.0%	46.1%	43.4%
Grants and contracts	29.8%	29.5%	31.1%	33.9%	36.7%
Czech Republic					
Universities					
Institutional funding	-	-	-	80.2%	75.2%
Targeted funding (grants)	-	-	-	19.8%	24.8%
PROs					
Institutional funding	-	-	-	42.5%	41.7%
Targeted funding	-	-	-	57.5%	58.3%
Finland					
Universities					
Institutional funding	-	52.0%	-	47.0%	-
Grants	-	19.0%	-	24.0%	-
Contracts/projects	-	18.0%	-	19.0%	-
PROs					
Institutional funding	-	50.0%	-	43.0%	-
Grants	-	7.0%	-	9.0%	-
Contracts/projects	-	24.0%	-	27.0%	-
United Kingdom					
Universities					
Institutional funding	37.3%	36.2%	35.1%	35.1%	34.8%
Grants and contracts	62.7%	63.8%	64.9%	64.9%	65.2%

For project funding, public funds are granted on the basis of applications that are submitted in response to a call for tender. Evaluation procedures are usually based on peer review. This is viewed as being similar to business funding of university R&D, which also tends to be contract-based, with specific objectives, deadlines and interim milestones. Such practices have been common for federal funding of university R&D in the United States but are being used more frequently now in Europe and Asia, especially with new (versus existing) funds (see section on new funding schemes below). By tying funding to specific objectives, increased project funding is expected to overcome rigidities in the discipline-based research system of the higher education sector in many OECD countries and enable funding of interdisciplinary and emerging areas that reflect national priorities.

Business funding for public sector research

Regarding global R&D expenditures, the relative role of the different sectors has changed over the last 20 years. Though the structure of performance and funding shows cross-country differences, an aggregate trend can be identified (Figure 4.3): an increase in R&D financed and performed by business (respectively shifting from 50% and 66% in 1981 to 63% and 69% in 2001) and a decline in the public sector's share in financing (down from 45% in 1981 to around 30% in 2001) and performance (stable 17% in higher education, but down from 15% to 11% in other public institutions).

The increasing share of business funding for global R&D has also led to increased business funding for universities (Figure 4.4) and PRI, though there are notable differences with regard to this aspect between countries.

An analysis of funding flows into the public sector has shown that financial support for public sector research from business has increased in many countries, in particular in the big "spender" countries. Though numbers are still small, the percentage increases are quite remarkable in some countries: in Canada business support for higher education increased by more than 50%; in Finland business support for higher education increased by 40% and by 36% for public research institutions; in France business support for public research institutions increased by about 80%; in Germany business support for higher education increased by 40% but decreased by 55% for public research institutions; in Iceland business support for public research institutions increased by a factor of 3.5; in Italy business support for public research institutions increased by about 40%; in Mexico business support for higher education has gone up by a factor of 1.2 and has more than tripled for public research institutions; in the Netherlands business support has increased for both higher education (26%) and public research institutions (18%); in the United

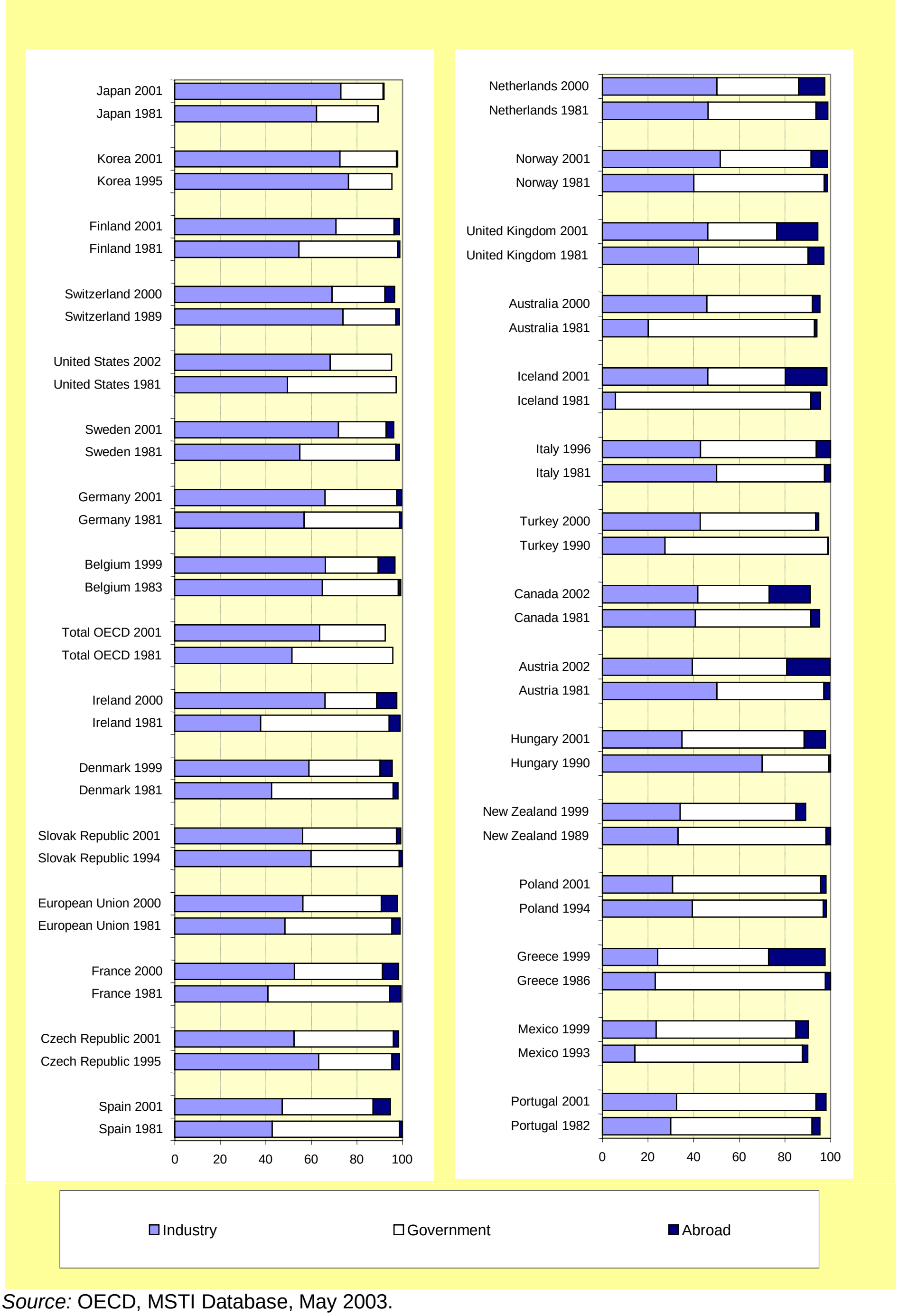
Kingdom business funding for public research institutions has gone up by a factor of 1.4 and for higher education it has increased by 27%; and in the United States business funding for higher education has increased by 25%. In Japan, business support for higher education and public research institutions has slightly increased, but is still small in numbers.

Korea is an exception as regards business funding for the public sector. Business support has decreased both for higher education (by 24%) and for public research institutions (by a factor of 1.5). It should be noted, however, that the decrease of business support for higher education was made up for in Korea by funding from government, which increased by about 100%.

Absolute numbers of business funding for the public sector are still small. However, for the receiving institutions, the inflow from business in some cases already presents a considerable part of their income (more than 10% in Belgium, Canada, Finland, France, Germany, Iceland, Ireland, Korea, the Netherlands, Norway, Poland, Slovak Republic, United Kingdom). The statistical material analysed does not convey information about the type of research funded by business. Experts' views differ on whether business funding goes into basic or more applied research.

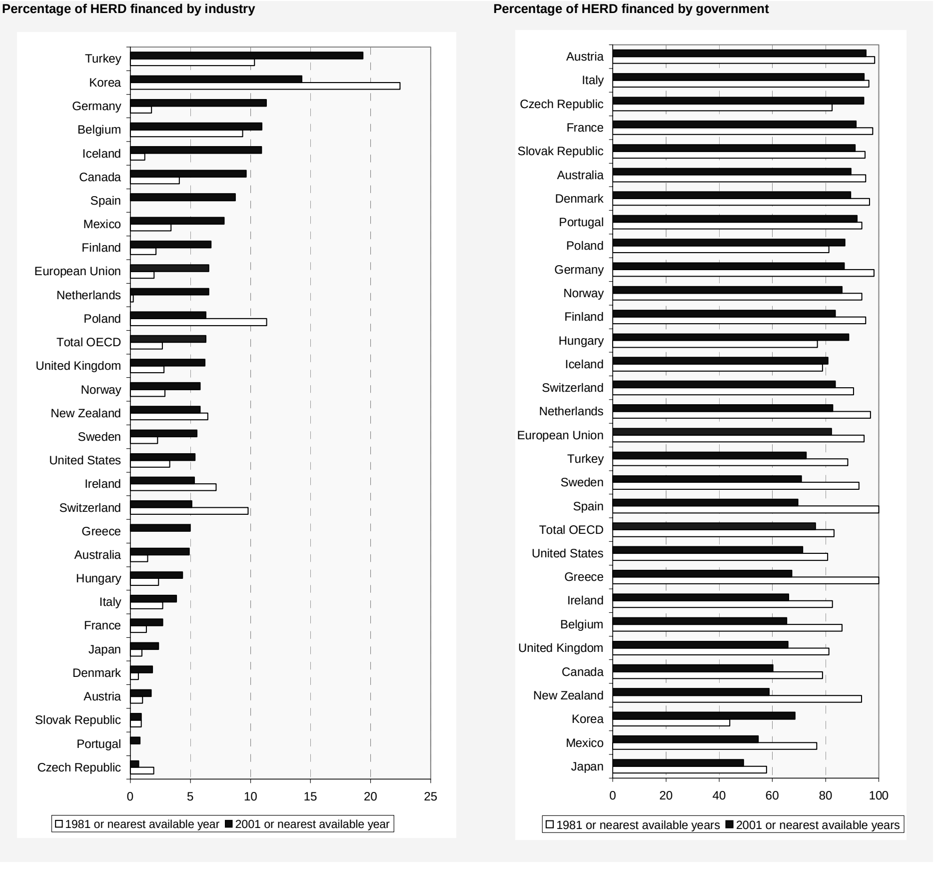
Figure 4.3. R&D funding in the OECD area, 1981-2001 or nearest available years

As a percentage of global R&D expenditures



Source: OECD, MSTI Database, May 2003.

Figure 4.4. Funding for higher education R&D



Source: OECD S&T Databases, May 2003.

Funding from other sources

Other sources of funding, mostly institutions' own income sources (tuition fees, income from endowments, patent licensing fees) also play a role in some countries. For example, 5% or more of available funding for higher education is financed by such income sources in Canada, France, Japan, Korea, Mexico, Poland, Spain and the United States.

Research institutions are increasingly seeking such external sources of funding, and have therefore embarked on programmes to increase income from patent licensing fees, endowments, private sponsorship or alumni contributions. Such income would give them more flexibility in a funding environment where less money than before comes without strings attached.

Discussion about tuition fees is therefore important in some OECD countries. While some have a long-established tradition of collecting tuition fees in the higher education sector (United Kingdom, United States) and some countries are not at all considering them (Nordic countries), this is subject to discussion - sometimes very controversial - in others (Australia, Austria, Germany). In a nutshell, discussion mostly focuses on two arguments: Those in favour of tuition fees claim that the working class is paying the education for the upper middle classes since the student body mostly consists of young people from the latter layer of society, and that this is unjust since the middle classes should pay for their own education. Those against tuition fees claim that young people from the working classes would be discouraged from entering higher education institutions if they had to pay.

While Germany passed a law in 2002 which guarantees that no tuition fees will be collected for first-time students, Australia successfully introduced tuition fees in 1989 and Austria also introduced tuition in 2001 (see Box 4.1).

Box 4.1. Tuition fees: two examples

Australia introduced the Higher Education Contribution Scheme (HECS) in 1989. This was a radical change at the time which was at first strongly opposed since it seemed to repudiate a commitment towards free university education. However, it was accepted quite rapidly, and changes proposed to HECS during a review of the higher education system in 1999 were not pursued.

Under HECS, students contribute to the cost of their tuition, while the Commonwealth pays the major part of tuition costs, (75%). Most students have the option of obtaining a loan to cover the cost of their contribution. This loan is indexed to maintain its real value but is otherwise interest free. Repayments are income contingent and are directly deducted by the Australian Taxation Office. During its ten years of existence, the scheme has become much less generous from the students' perspective (higher fees, higher rates of repayment, lower income thresholds) but this has not caused major opposition. Evaluations of the system have shown that the fact that higher education has to be paid for has hardly any influence on enrolment figures (Edwards, 2001).

Austria first introduced tuition fees for the second semester of 2001. This was strongly opposed by large groups of society. Main arguments were that enrolment would drop markedly, that student numbers would drop since those enrolled but not really following any courses or taking any exams would drop out, and that although student numbers might drop, graduation numbers would increase since students would finish their studies earlier than before.

Figures clearly show that the introduction of tuition fees led to a considerable drop in student numbers: from 210 000 to 220 000 until 2000 to 175 000 in 2001. The decrease in student numbers of about 20% from 2000 to 2001 might be due to the fact that inactive students dropped out of the system. The number of enrolments dropped by 14% from 2000 to 2001, whereas graduate numbers increased, the latter being a positive effect. In the 2002 winter term enrolment increased again by 10%.

As shown in the previous sections, government still provides the major share of funding for higher education institutions and – to a large extent –for public research institutions a well. Higher education receives the largest share of funding in many countries, since it is the most important research performer in the public sector. However, in some countries there is a balance between the two main sectors of public R&D, and in some countries public research institutions even play a more important role in terms of performance (Table 4.2).

Table 4.2. Main funders and performers of R&D in the public sector

Categories of main R&D funders	Categories of main R&D performers
Government All countries	***Higher education*** Austria, Belgium, Canada, Denmark, Finland, Greece, Ireland, Israel, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States
10% or more of available funding for either higher education or public research institutions from business Belgium, Canada, Finland, France, Germany, Iceland, Ireland, Korea, Netherlands, New Zealand, Norway, Poland, Slovak Republic, Turkey, United Kingdom	***Government (public research institutions)*** Czech Republic, Hungary, Iceland, Slovak Republic
5% or more of available funding for either higher education or public research institutions from private non-profit sources Australia, Canada, Denmark, Israel, Netherlands, Sweden, United Kingdom, United States	***Balance between higher education and government*** Australia, France, Germany, Korea, Mexico, New Zealand, Poland
5% or more of available funding for higher education, self-financed Canada, France, Ireland, Israel, Japan, Korea, Mexico, New Zealand, Poland, Spain, Switzerland, United States	

New[3] funding schemes

The requirements for increased accountability of public funds, increased flexibility of research institutions to adapt to changing environments, and a better inclusion of socio-economic objectives into the research agenda have led most countries to include changes in their research funding schemes in their science policy reform kit. Only two countries (United Kingdom and United States) report that they did not introduce new funding mechanisms, schemes or systems recently (Table 4.3).

3. "New" does not imply that such instruments have not been applied anywhere before; it means that the schemes or instruments are new to the countries mentioned, or that additional such instruments and programmes are introduced by the countries mentioned.

   Though most countries would subscribe to a shift described in the first column of Table 4.3, not all of them describe measures to this effect.

   Some of the measures described by countries concern several of the columns. (*e.g.* new centres are created with the aims of strengthening co-operation with industry and addressing problem-oriented issues.)

Table 4.3. New funding schemes and programme instruments

Shift to more performance-based and competitive funding programmes	Promotion of co-operation with the private sector	New centres of excellence	New foundations/ funds (established with public money)	New problem-oriented research programmes
Australia Austria Canada Czech Republic Germany Hungary Japan	Australia Austria Belgium Canada Denmark Finland France Hungary Iceland Italy Japan Netherlands Norway Portugal Switzerland	Australia Austria Canada Czech Republic Denmark Finland Hungary Japan Korea Netherlands Norway Switzerland	Canada Denmark Hungary Norway Sweden	Canada Czech Republic Denmark France Germany Hungary Iceland Italy Japan Netherlands Norway Portugal Sweden Switzerland

The reasons which are most frequently quoted for adopting new methods are increasing excellence and quality of research, encouraging interdisciplinary research, overcoming institutional and structural rigidities, facilitating networking between different institutions and promoting young researchers.

In most cases, more flexible and competitive funding mechanisms are attached to new and specific programmes which address specific priority subjects defined by governments or research councils. In some cases such programmes aim to support and strengthen research, in particular basic research (Canada, Korea, Italy, Norway).

Many governments also try to reduce the percentage of "funding without strings attached" for public research institutions or introduce more performance-based approaches for institutional funding. Even countries where universities could always rely on the main part of their funding being provided without requests for accountability are now changing their approach. While countries are not going as far as the United Kingdom, many of them increasingly submit their universities to regular research assessment exercises (Box 4.5) and they still try to introduce performance-based criteria for funding, *e.g.* not simple student numbers but graduates, completion of doctorate training etc., or they enter into performance agreements with their institutions, which have to be regularly reviewed and renewed (Australia, Finland, Denmark, Iceland). In introducing performance-based funding approaches, governments try at the same time to give more autonomy and flexibility to research institutions for use of the funds received. Some examples: let them decide how much should go to teaching and how much to research (Denmark), give them the possibility to carry over funds from one budget year to another (Germany).

In most countries the measures described above will not lead to increased funding for research institutions, but perhaps funds will be used in different ways. Canada is an exception. It reports to have "introduced a host of new funding mechanisms and agencies in the recent past that have changed how university research is funded in Canada. When these initiatives reach steady state, this may translate into a minimum of 50% increase in sponsored research expenditures in universities and hospitals."

Examples for new or changed funding schemes

Support for research in interdisciplinary priority areas

In France, a new scheme was established in 1999 to create incentives for research in priority areas. The new fund (*Fonds National de la Science* – FNS) was created to finance support for research projects that call for inter-institutional and interdisciplinary collaboration. It is designed to encourage the establishment of emerging fields of research, new research teams, networks of public laboratories and public-private partnerships. Under this programme, funds are allocated on the basis of peer review for a period of four years. The programme also includes special support for young researchers beginning their careers by giving them funds to establish their own research groups. However, the programme funds must be allocated to projects relating to government-defined priority areas. In 2000, a large proportion of the funds went to genome research, but work on AIDS, microbiology and the social and human sciences was also funded. In 2001, the life sciences were again a priority area, but money was also spent on research relating to GRID computing and remote sensing, as well as co-financing regional research initiatives. A similarly structured public-private partnership programme (*Fonds de la Recherche Technologique*) supports pre-competitive technology development and innovation in priority areas.

Another example where priority setting is backed up by additional funds is a new funding instrument in the Netherlands. Here, virtual institutes called Leading Technological Institutes (LTI) are funded. They aim to involve industry more in basic research and to facilitate transfer of research results to innovation. Within the framework of this system, business would take the initiative to establish virtual institutes and public research institutions that would respond to such initiatives. Once these virtual centres have been established, researchers from different research institutes and universities will carry out strategic research formulated together with the partners in industry. The government's role in this scheme is to match funds earmarked by industry and to facilitate co-operation between the private sector and public institutions. Currently, there are four such LTIs: in food sciences, metals research, polymers and telematics. An example of a temporary structure to stimulate important interdisciplinary research in the Netherlands is the government-financed Genomics Programme, but the four central research themes were identified jointly with industry, and options for co-financing of research by industry which fit the EU Support Requirements are being developed.

Public foundations/funds

Increasingly, public foundations are being set up to distribute research funds. Sweden established five such foundations in 1994, and funding started in 1997. The capital stock of these foundations is based on the former Employees' Monetary Fund.[4] The resources are allocated to the following priority areas: strategic research, environmental research, research on caring and allergies, regional support and IT, and internationalisation. These foundations distribute roughly 10% of total public funding for research in Sweden; this is of the same order of magnitude as the funds distributed by the Swedish Research Councils. These foundations are presently undergoing restructuring which might result in a decrease of available funding. On the one hand, these foundations were only planned for a period of ten years but now will be turned into permanent funding agencies, which means that funds have to be spread more thinly. On the other hand, the foundations lost money by investing in stocks, which will also lead to reduced funding at least for the next few years. Also, the foundations came under criticism when being evaluated by the Swedish Royal Academy of Sciences in 2001. An example is the Knowledge Foundation (KK), which was established with the aims of supporting exchange of knowledge between universities, research institutes and industry, supporting research at smaller university colleges and facilitating the use of information technology. This has been carried out via three programmes. However, the programme for research at university colleges failed to raise sufficient interest from local industry. It has also been difficult for the colleges to continue the funding after the external funding was terminated. The Royal Academy therefore suggested that the programme be more strongly directed towards research and graduate education since the interest from industry was relatively weak. It also recommended longer funding periods.

4. This is specific to Sweden. During the many years of social democratic government, every employee had to pay into such a fund and the money was earmarked for public tasks. After a change of government in the early 1990s, employees no longer had to contribute to the fund, and the accumulated capital was used to establish the research foundations.

The Hungarian government established a foundation in 1992 (the Bay Zoltán Foundation for Applied Research). Its purpose is to carry out efficient applied technological and scientific research and development. One of its major objectives is to establish an intellectual basis for an emerging small and medium-sized Hungarian business sector. Other objectives include the establishment of demonstration centres for teaching modern industrial and agricultural methods and the training of researchers, supplementing the universities' PhD programmes. The foundation operates as a non-profit organisation. It obtains its financial resources from the interest on financial investments from a fund first established by the government and from R&D and service contracts with business, and from international funding programmes (for details see country report on Hungary and Bay Zoltán Foundation, 2000).

In Norway, there is general political agreement to substantially increase investments in research in order to reach at least the OECD average (as a proportion of GDP) by 2005, by increasing both public and private funding. Since the increase can only partly be financed from the national budget, the government decided to create the Fund for Research and Innovation. The Fund is intended to secure comprehensive, stable and long-term public financing of research that cuts across sectors and long-term basic research in general within the four national priority areas: marine research, ICT, medicine and health care, and research at the intersection of energy and environment. The capital is placed with Norway's Central Bank, Norges Bank, at fixed interest. Since the creation of the fund, more capital has been added thus increasing its yield. Income from the fund (NOK 525 million in 2002 and NOK 793 million in 2003) was – up to 2001 – distributed by the Research Council of Norway according to government guidelines. This changed with the 2002 budget. Now, one-third of the funding is channelled directly to higher education institutions, and two-thirds are still distributed by the Research Council. The Research Council, for instance, uses its part to fund the new Centres of Excellence scheme. Thirteen new centres were created in 2002 based on international peer review as was a functional genomics programme (see country report on Norway).

The Canada Foundation for Innovation (CFI) is an independent body created in 1997 with an initial endowment of CAD 800 million. It has now been extended to 2010, and its total budget is CAD 3.15 billion. The foundation funds research infrastructure in universities, hospitals, colleges and non-profit research institutes. 40% of infrastructure project costs are covered by CFI with the remainder covered by universities, the private sector or other government departments (provinces in particular). The extension and the new investment made available provide the stability that universities and research institutions need to make further progress in planning their research agendas.

Centres of excellence

Austrian K-plus centres are funded by a government programme and set up after thorough evaluation of the position and quality of the partners in their scientific and/or economic field and the prospects for becoming a centre of excellence. These centres involve the collaboration of several partners to develop co-operation between science and industry, stimulate pre-competitive R&D and perform long-term research. The centres, of which there are 12 at present, are established through a competitive selection process based on a bottom-up approach. At regular intervals, the TIG (*Technologie-Impulse-Gesellschaft*), acting as programme manager, launches calls for proposals (similar to those for the EU Framework Programme), with government money set aside for funding. Proposals are not restricted to specified areas or types of submitting bodies, so that research groups can be formed from science as well as industry in a bottom-up manner. These groups submit brief proposals describing their research programme and the involved partners; proposals are then examined by special funding agencies that work closely with the TIG. Applicants that pass this first evaluation are invited to submit a full application, which is assessed on the basis of scientific and economic competence, possible economic benefit for Austrian companies as well as the general quality of the proposal. Final decisions are based on recommendations by an independent body of experts to the minister of technology.

The Czech Republic introduced a programme in 2000 for the establishment of "research centres" for a five-year funding period. This programme has several objectives: creating strong research environments by concentrating research capacity in selected research areas and on selected topics (critical mass), increasing excellence and research quality, supporting collaboration between different research teams, and supporting young researchers. The centres should also link up with other European research institutions, develop co-operation with local groups in business and society at large, and enhance Czech participation in European programmes. These centres are directed towards basic research as well as towards oriented applied research. So far three such centres have been selected through a call for tender.

Finland adopted a strategy to establish national centres of excellence in 1995. Its aim is to provide the framework for the development of high-quality, creative and efficient research environments in which research of international quality can be carried out. A Finnish centre of excellence is defined as "a research and researcher training unit comprising one or more high-level research teams with shared, clearly defined research goals and good prospects for reaching the international forefront in its field of specialisation. Centres of excellence are selected for a term of six years on a competitive basis, with evaluations provided by international experts" (Academy of Finland, 2000). For 2000-07, 26 such centres have been selected for funding. Many of their programmes and projects are co-funded from several sources, including industry.

Japan launched a new university resource allocation prioritisation scheme called the 21st Century COE Programme in 2002. The aim of this programme is to promote research units of world-class excellence in selected fields. The fields supported in 2002 were life science, chemistry and material sciences, information, electric and electronics, humanities and interdisciplinary subjects. Each research unit that is selected as a centre of excellence will be allocated resources around JPY 100 to 500 million for five years. 113 research units at 50 institutions were selected in November 2002 out of 464 applications from 163 institutions.

New approaches in funding for public research institutions

The reform of government research institutions has been an important part of government efforts to strengthen the science base and increase the contribution of government-funded research to meeting societal needs. Changes in funding modes are one of the major instruments for such reforms. One approach has been to introduce more competitive funding mechanisms for government research institutions.

In Germany, public institutional funding for the Helmholtz Association laboratories is giving way to more programme-oriented funding in an attempt to better link the labs to industrial needs and improve the quality of their output (Box 4.2).

Box 4.2. Reforms of the German Helmholtz Association centres

Between 1956 and 1992, Germany established 16 public labs which are non-university research institutions (other than Fraunhofer or Max Planck institutes) and are jointly funded by the federal and *Länder* governments. These labs had 23 000 employees in 2001 and received about DEM 3 billion a year in institutional funding, the equivalent of 25% of all public R&D funding.

In 1995, these laboratories organised themselves in an umbrella organisation, the Helmholtz Association of German Research Centres, but they were still criticised for a lack of inter-institutional co-operation and flexibility in their research approaches. Evaluations showed that their potential and resources were not being used efficiently. It was therefore proposed to gradually move away from institutional to programme-oriented funding that would allocate resources to inter-institutional thematic research programmes to be evaluated externally, in line with international standards.

Under the new system introduced on 1 January 2002, the government sets research priorities in consultation with the science community, the business sector and the labs concerned. Programme portfolios, running over several years and defining clear interim milestones, the share of work and budget of the institutions involved, are established for each project within these programmes. Research proposals submitted on this basis are evaluated *ex ante* by an international evaluation team. Of the total Helmholtz Association budget, 80% is allocated to centres on a competitive basis and linked to the defined programme areas (*i.e.* energy, earth and environment, health, key technologies, structure of matter, transport and space). The remaining 20% supports work to follow up on promising advances made within the defined programme areas as well as in other fields selected by the centres. The government anticipates that this reform will produce several benefits:

- More focused allocation of R&D funds with greater transparency in priority setting, selection of research proposals and allocation of funds.
- Improved planning owing to the fixed-term nature of the programmes.
- Greater competition for resource allocation, which should also result in increased networking between institutions and improved international collaboration.
- Strengthening of scientific excellence, promotion of interdisciplinary research and co-operative research with industry.

In Japan, since 2001, government-funded agencies have been progressively changing their status to that of Independent Administrative Institutions or National University Corporations (IAI) as part of the government's overall restructuring. This is a government-wide approach, affecting research organisations along with organisations with other purposes (*e.g.* museums). The effect will be to considerably reduce the number of civil servants, as this has historically been the status of staff of such agencies. The move to IAI status is generally presented in terms of the anticipated benefits of greater autonomy for the institution with regard to flexibility of management and financing. The implementation of the policy appears to be quite systematic, taken at a steady pace, and with due attention being paid to the special requirements of certain organisations such as universities (see country report on Japan for more details).

Support for basic research

Overall, the trend in basic research funding in OECD countries is difficult to define since only 15 countries reported data on this for after 1996. Also, in many cases data may be distorted since countries tend to label basic research according to the institutions where the research is carried out, although these institutions – though originally dedicated to basic research – may also perform other types of research (*e.g.* research carried out in universities or institutes of academies of sciences is always defined as basic research).

Available data show that funds invested in basic research have remained relatively stable over the last decade and have not been affected to a large extent by reductions in government R&D funding (Figure 4.5). However, there are countries in which the relative share of R&D expenditures devoted to basic research increased, and countries whose relative share decreased between the early 1980s and late 1990s.

Box 4.3. The scope of basic research: how the issue should be reframed

The notions of "basic research" and "applied research" have been standard elements of the policy maker's toolkit for many years. The dissociation of pure science from practical applications so far has been the basis for defining basic research, including the OECD *Frascati Manual*.[5] However, the blurring of the boundaries between basic and applied research, and the impact of this phenomenon on priority-setting and funding decisions in the public and private sectors have posed difficulties for policy makers.

During the course of the project on steering and funding of research institutions, the usefulness of the notion of basic research for actors involved in science systems has been scrutinised.[6] This included re-examining the definition of basic research in the *Frascati Manual*, and it was concluded that the definition was not sufficiently operational for science policy-making purposes. Though views with regard to a new definition of basic research vary widely, there is an understanding that such research has both components: pure curiosity-driven work without a particular use in mind and use-inspired work.

The 2002 edition of the *Frascati Manual* acknowledges the difficulties involved in categorising research as being basic or applied research or experimental development. It stipulates, however, that it is better to collect data about research expenditure in these categories until some better classification is found than to abandon it. This is perfectly valid for statistical purposes; however, to analyse science policy, basic research has to be defined as including use-oriented components as well.

The reality is that both components have been pursued in the public as well as the private sector, but with differing degrees of emphasis. For public sector research, the central issue is how to achieve an optimum balance taking into account current changes at the research frontier as well as the needs of the private sector. A balance needs to be struck between short-term vs. long-term research, knowledge-generation vs. application, and uncommitted funding vs. project/contract funding. Therefore, the key question is not to find a new conceptual definition for basic research, but to define its scope sufficiently broadly to cover the whole range of research types needed to establish a sound body of knowledge to achieve socio-economic advances. This implies that policies for public sector research need to complement private sector research in the public interest and define research priorities, research agendas and funding instruments accordingly.

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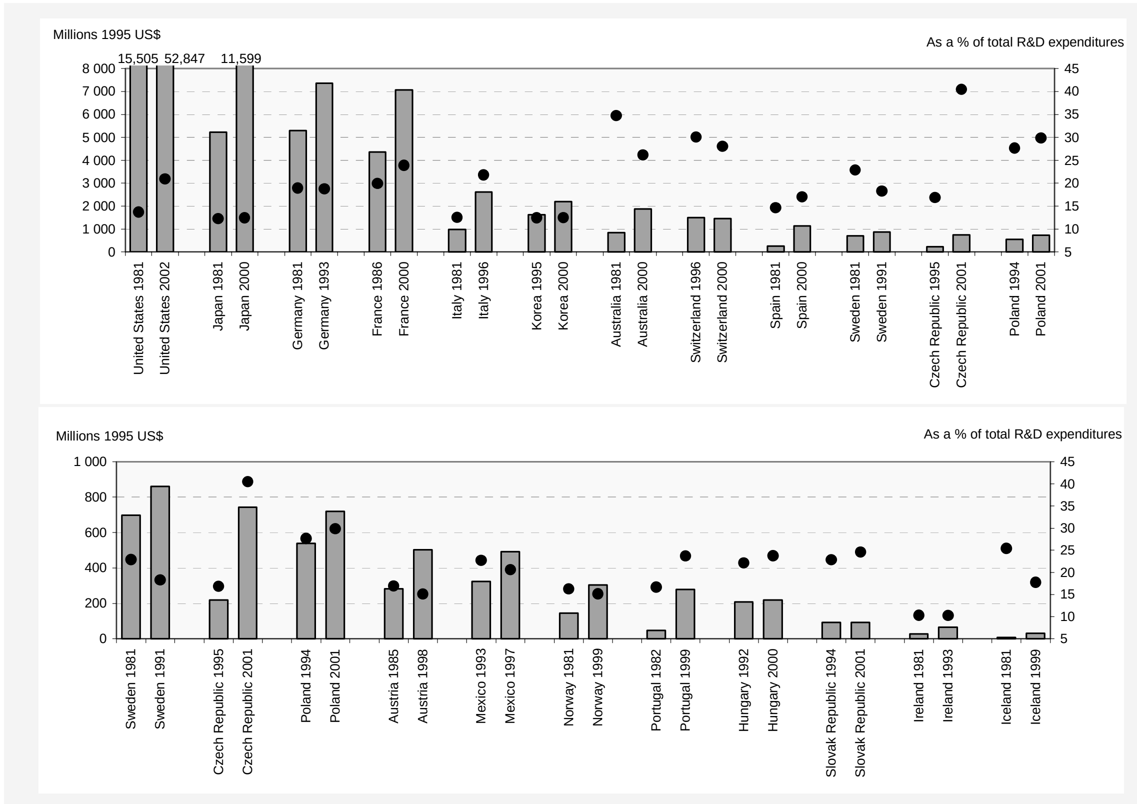
5. OECD *Frascati Manual* definition: "basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts without any particular application in view".

6. Workshop on "Policy-relevant Definitions and Measurement of Basic Research", Oslo, Norway, 29-30 October 2001. Proceedings available at www.oecd.org/sti/stpolicy.

Figure 4.5. Basic research in the OECD area, 1981-2001

In millions of 1995 USD and as a percentage of total R&D expenditures



Source: OECD, S&T Databases, May 2002.

It is quite clear to countries that they have to maintain strong support for basic research in order not to lose, or even still to establish a strong science base. This support can take very different forms. Most OECD countries provide this support as institutional funding to institutions of higher education or to special institutions for fundamental long-term research (*e.g.* CNRS in France, institutions of the academies of sciences in the countries in transition, or the institutions of the Max Planck Society in Germany). In this case, the institutions are totally autonomous in managing such funds. Others provide contract-based funding for such research which comes without strings attached. Some countries have introduced programmes which encourage industry to engage in science-industry relations (*e.g.* the Netherlands, with its funding for leading technological institutes). An overall trend is that institutions dedicated to basic research are increasingly looking for partnerships with industry and are more and more committed to a rapid transfer of research results to application.

Box 4.4. The Max Planck example

Germany's Max Planck Society for the Advancement of Sciences (MPG) is a good practice example for the funding of basic research outside the higher education sector. Its research institutes carry out basic research in all fields of science. The MPG focuses on new and promising research that universities have difficulties accommodating sufficiently, either due to the fact that the interdisciplinary character of such research does not fit into the universities' organisational framework or because the costs for personnel and facilities go beyond the universities' resources. Other research is performed in joint projects between the Max Planck Society and universities. Such co-operation will be intensified in the future.

95% of the MPG's funding comes from the public sector and only 5% from other sources (members' contributions, donations, own income). Public money comes without any strings attached. The Society is completely autonomous in choosing its research priorities, managing its staff ,*etc.*

A good example of a modern MPG institute that responds to the demand for more societal and economic relevance and interaction with other players in the science system is the Max Planck Institute for Biochemistry in Martinsried. Working in the field of biotechnology, the institute has gone beyond purely basic research and is now also engaging in medical-oriented work. The institute co-operates in this area with the pharmaceutical industry at national and international level. By 2002 it had concluded 27 such co-operation contracts.

Other indicators for close co-operation with the private sector and for a rapid transfer of research results to innovation: Until May 2002, 15 spin-off companies were established by staff of the institute. Between 1997 and 2002, 32 new licensing contracts for inventions patented at the institute were concluded; a total of 76 such licensing contracts presently exist.

The institute also closely co-operates with universities. It engages in researcher training, has an extensive programme for graduates and has established special research groups for young scientists (MPG, 2002).

The increasing demand for greater relevance of research makes it more difficult for research funders and performers to balance mere knowledge generation with contributions of research for solving societal problems. Increased funding of public research from industry and – alongside this – an increasing influence of industry on research agendas, calls for more economic relevance of research activities. Also, increases in competitive funding levels relative to institutional funding can affect institutions' capacity to conduct basic research as well as their science infrastructure investments. Such effects could be negative if public funding did not take account of the full costs incurred.

The UK example

In the United Kingdom competitive funding of university research relative to institutional funding has increased rapidly in recent years. This trend is giving rise to major concerns. Funding from the Higher Education Funding Councils (HEFC) enables higher education institutions (HEI) to conduct research that is *not* supported by others. As the proportion of "project" funding increases, research work funded with such funds consumes the staff time and infrastructure funded by HEFCs. The situation is aggravated in research areas where the proportion of HEFC funds accounts for a much smaller portion of total research, notably in biomedicine in the United Kingdom. There are indications that in this area the widening distortion between "project" and "institutional" funding is resulting in "squeezing out" of some forms of long-term basic research. Although research councils do fund basic research through the "responsive" mode funding, this cannot necessarily replace HEFC funding since the RC funding through this mode may fail to support research at the cutting edge, as there may be time lag for RC peer review committees to be responsive to research needs at the real frontier. Also, different types of funding may induce different behaviours on the part of the researchers, *i.e.* the basic research that researchers undertake with RC funding and with HEFC funding could well be different.

Another concern is that the relatively diminishing funding through the HEFC stream of the dual funding system and the increasing grant funding has resulted in inadequate funding of university research infrastructure. Research Council (RC) funding, as well as charities and industry funding of university research only covers the direct costs of research. It is assessed that remedial investments are needed in generic institutional infrastructure (buildings, plant and services, IT networks and libraries), the minimum level of research equipment and facilities to attract external funding (the "well found laboratory"), and improvements in advanced scientific equipment to maintain infrastructure for world-class science. In response, the UK government has decided to allocate a major part of the annual science budget increase to boost university infrastructure. It recently announced that it will institute a dedicated earmarked capital stream for university science research infrastructure (HM Treasury 2002). Also, the UK research-funding bodies (government, RCs and HEFCs) agree that grant funding of university research should move toward covering the full costs of research. The HEFCs, with the encouragement of their sponsoring bodies, are working to help HEIs develop a standardised methodology for assessing the full costs of research, which is needed to move toward covering full research costs by the grant funders (see also country report on the United Kingdom).

Evaluation and assessment

The intention to implement major changes in their approach to funding R&D has incited some countries to review either their science system as such, or a whole area of the science system such as universities or public labs before introducing new schemes. In many countries certain research areas, disciplines or institutions have been evaluated or are regularly evaluated. Traditional evaluation procedures such as ex ante peer reviews for grants and projects are used in nearly all countries. Some countries have introduced ongoing measurements of performance, sometimes in the form of periodic assessment reviews. Ex post evaluation of projects is less frequent.

Table 4.4. Evaluation procedures related to funding

Ex ante	Ongoing and ex post	Ad hoc procedures	Sophisticated procedures (for whole programmes or institutions) in place or under development
Australia	Australia	Belgium	Australia
Austria	Canada,	Hungary	Austria
Belgium	Czech Republic	United Kingdom	Canada
Canada	Finland		Czech Republic
Czech Republic	Franc		Denmark
Denmark	Germany		Finland
Finland	Hungary		France
France	Iceland		Germany
Germany	Italy		Mexico
Hungary	Korea		Netherlands
Iceland	Netherlands		Norway
Italy	Norway		Sweden
Japan	Portugal		Switzerland
Korea			United Kingdom
Mexico			
Netherlands			
Norway			
Portugal			
Sweden			
Switzerland			
United Kingdom			
United States			

It is difficult to get a clear picture of the criteria on which evaluations are based. Scientific excellence still seems to be the most important criteria using the "classical" indicators such as the number of publications, citations, patents, prizes and awards. This might evoke the question of measuring productivity vs. quality. Public-private partnerships, networking and mobility of researchers so far are not well integrated into a set of criteria. However, there are attempts to change this: the Czech Republic reports that meeting socio-economic demand has been included as a criterion in its evaluations, and Germany is asking for an ex ante "utilisation plan of research results" for its project funding. New evaluation schemes still have to be defined for new funding schemes to fit their objectives.

Examples for evaluation and assessment

In Canada evaluation is used to provide periodic assessment of programme effectiveness, impacts (intended and unintended), and alternative ways of achieving expected results. Depending on the need, evaluation studies can be conducted soon after the initial implementation of a programme to assist in making adjustments to programme delivery, or later in the life-cycle of the programme where the focus is on demonstrating the accomplishments and results of the programme. Basic programme evaluation issues (the criteria upon which programmes are evaluated) include the following:

- Continued relevance: to what extent are the objectives and mandate of the programme still relevant?
- Programme results.
- Achievement of objectives: to what extent were they met as a result of the programme?
- Impacts and effects: what outcomes, both intended and unintended, resulted?
- Cost effectiveness: are there more cost-effective ways of carrying out the programme, are there more cost-effective alternative programmes that might achieve the objectives and intended results?

In addition to periodic evaluations, NSERC also engages in performance measurement activities. Performance measurement is the ongoing monitoring of the results of a programme; it differs from evaluation in that measurements of key indicators of performance are collected on an ongoing basis. Performance measurement activities feed into the evaluation process by providing the historical data upon which conclusions relating to programme performance and effectiveness in evaluations are based. NSERC tracks information on a variety of indicators relating to, for example, the excellence of its grantees and the technological and economic impact of NSERC-funded research. Specific examples of a few of the key indicators that NSERC tracks for performance in these areas include the following:

- Awards and prizes.
- Membership on editorial boards of journals and boards of professional societies.
- Funds leveraged from other sources.
- Patents.
- Publications (number and impact).
- Start-up companies.

The evaluation activities of the *Australian Research Council* (ARC) are quite comprehensive, as outlined below:

- Measuring its performance each year in its annual report against key performance indicators identified in its strategic plan.
- Monitoring the outcomes of individual research projects based on final reports provided by the researchers involved. Researchers with ARC funding are required to provide a final report within six months of project completion. The report includes information on the benefits expected to arise from the work as well as the results of the work and the outputs (*e.g.* publications).
- Monitoring the efficiency and effectiveness of the ARC's programmes in achieving their objectives. Activities in this category are currently under review, but in the past they have included evaluation of individual programmes as well as across programme evaluations, for example, an evaluation of biological science research funded by all ARC research programmes.
- Monitoring the status of or developments in the national research effort, for example, through discipline research strategies and other benchmarking studies. The conduct of discipline research studies has enabled research communities to commission or develop research strategies for their disciplines. The aim of these studies is to enable all stakeholders in a discipline, including those who use research and research training graduates to participate in developing longer-term goals for the discipline and a strategy for achieving the identified

goals. Benchmarking studies enable the comparison of Australia's performance against relevant indicators with international achievements. In 2000, for example, the ARC and CSIRO published the results of a study they had commissioned to investigate the linkages between public science (as represented by university and government research institute published papers) and private industrial technology (as represented by patents). The ARC completed a benchmarking study of research commercialisation activities in Australian universities in 2002.

Box 4.5. The UK Research Assessment Exercise

The Research Assessment Exercise[7] aims to improve research performance of HEIs by assessing and rating the research performance of university departments and institutes and selectively funding those that perform the best. It is conducted jointly by the four HEFCs on a UK-wide basis. The most recent exercise took place in 2001.

In the exercise, HEIs are invited to submit their research activity for assessment. The submitted information goes through peer review assessment of research quality by specialist panels who base their judgment in accordance to specified criteria and working methods. The scope of research activities subject to assessment is broad. Basic, strategic and applied research is given equal weight, and all forms of research output are treated on equitable basis. The assessment gives rating of one to five stars to each academic unit, with 5* being the highest. The HEFCs all allocate research funding on the basis of these ratings, using slightly differing allocation methods. In all cases, the allocation of funding is highly selective, although the precise degree of selectivity varies between the HEFCs. In England, for example, the highest rating of 5* attracts four times as much money as the lowest rating, and in 2001-02, 75% of HEFCE research funds were allocated to 25 higher education institutions.

RAE has stimulated HEIs to improve their research performance. In the most recent exercise, the percentage of higher ranking units (rating of 4 or above) across the United Kingdom as a whole increased from 43% in 1996 to 65% in 2001, and lower-rated units (rated 1 or 2) decreased from 24% to 6%. Also, 55% of research active staff in UK HEIs now worked in the highest-ranking units (5 and 5*) compared to 31% in 1996.

The funding councils now view that the exercise has fulfilled its original mission of improving the research performance of the HEIs to a desirable level. It was even "too" successful in doing so, since undertaken in the context of slowly increasing funds for research, HEFCE in particular, it was found that the funding levels for higher performing institutions could no longer be sustained.

For the HEIs, the exercise has become an increasingly resource intensive process, in taking up staff resources as well as long-range planning and strategies. Compared to the amount of effort that needs to be put into the process, with the slow increase in the absolute funding levels, some observers assess that RAE has come to the point of "diminishing returns" (Geuna and Martin, forthcoming).

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7. Details of the Research Assessment Exercise are provided on the Higher Education and Research Opportunities (HERO) Web site: www.hero.ac.uk/rae

Conclusions

R&D funding is one of the major instruments to steer the science system and many OECD governments have embarked on reforms of their funding system to respond to the new demands and challenges highlighted above.

All countries have enhanced *strategic thinking* in the development of their funding policies and mechanisms in the sense that increased attention is paid to the broader social and economic environment in which research policies are designed, and to the evolving patterns of relationships between stakeholders involved in the funding and performing of research.

Each OECD country has a tradition of its own with regard to R&D funding. However, there are some trends and approaches common to all countries, and reforms in general go in the same direction.

The first of such trends concerns *the volume of R&D funding*. This is generally increasing in OECD countries. Overall, R&D public funding is increasing to a much lesser extent than private funding. For public sector research, this trend is not so obvious in all countries, although business funding of public research is also increasing, giving rise to new relationships between funding sources and research performers. In this context it is particularly important that funding measures are being designed which lead to public and private funding complementing each other in a way that ensures increasing returns on public investments for both sectors. New funding from public sources is usually attached to specific priorities, new interdisciplinary research programmes, or new funding schemes such as centres of excellence or public funds and foundations.

In order to broaden the base of their financial resources public research institutes are also increasingly looking for new sources of funding, including private charitable foundations, university tuition fees in some countries, and the attempt to include overhead costs for research funded with grants and contracts.

A second important reform approach relates to *changes in the allocation of funds*. The proportion of funds distributed through competitive grant schemes is increasing relative to institutional funding in the public sector. Also, the use of institutional funds by government research institutions and even universities is increasingly evaluated with measurable performance indicators.

In designing new funding schemes the *involvement of stakeholders* beyond the directly concerned research funders and performers is of increasing importance. Independent advisory bodies or research councils with representatives from government, the scientific community, business and society at large play an increasing role in the decision processes relating to the funding of public sector research (*cf.* Chapter 2).

More flexibility, more accountability and – in particular – the relative decrease in institutional funding and increase of funding based on competitive approaches as well as the increased role of business funding for the public sector may give rise to some concerns about support for long-term and fundamental research as well as about support for some research areas not high on the priority lists of policy makers (*e.g.* humanities). Countries will have to address these questions when shaping policy responses for R&D funding.

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Chapter 5

MANAGEMENT OF HUMAN RESOURCES IN R&D

Abstract. This chapter focuses on three major challenges facing human resources in science and technology: *i)* feeding the supply "pipeline", *ii)* adapting graduate education to changing demands from stakeholders and; iii) renewing the public research sector.

Introduction

The education, training and deployment of human capital in science and technology remain critical to scientific discovery and the advancement of knowledge. In modern times, investment in scientific human capital has been a cornerstone of the economic development policies of OECD countries as well as for emerging economies seeking to climb the development ladder. Ensuring an adequate scientific workforce, however, is not solely dependent on demographic numbers or investment in early education, but it is closely linked to how the science and education system of a country is structured, how research priorities are set and how and what research is funded.

As discussed in Chapter 1, the science systems in OECD countries are being challenged by a number of developments: private funding for research is outpacing public research investments; in many countries, research (and hence researchers) in public research organisations rely more and more on external and competitive funding. Research institutions face additional challenges in relation to human resources such as a diminished interest in science among primary and secondary school students in several OECD countries; an ageing research population in some fields; a weakened capacity of the public sector to expand employment or to provide long-term employment coupled with the need to make the public research sector more flexible and responsive to co-operation with industry; and the commercialisation of research. Taken together, these developments are forcing changes in the way scientific education is delivered and how researchers are trained and work.

This chapter explores the recent trends, challenges and policy responses related to human resources in the science system of OECD countries. The information contained in this chapter is based on responses to the Ad Hoc Group on Steering and Funding of Research Institutions' questionnaire as well as OECD data and additional information collected from member countries.

Challenges to increasing or maintaining an adequate supply of S&T personnel

Human resources in science and technology (HRST) are one of the driving forces that fuel research capacity and contribute to growth in the knowledge-based economy. However, the competition for talent and funds as well as the competition of interests has increased in recent years. Ensuring the long-term development of HRST has thus become an increasingly complex challenge for policy makers. The report focuses on three major challenges that have been identified during the project: *i)* feeding the S&T pipeline, *ii)* adapting graduate education to changing demands from various stakeholders and *iii)* renewing the public research sector.

To understand how OECD countries are meeting these challenges, the survey[1] carried out by the Ad Hoc Working Group on Steering and Funding of Research Institutions included six sets of questions concerning human resource policies. These can be summarised as follows:

- Training of masters, doctoral and postdoctoral students in S&T.
- Changing structure of employment for research staff in universities and other public sector research organisations.
- Mobility of researchers between public institutions and between industry and the public research sector.
- International mobility of S&T personnel and students.
- Ageing of research workforce and policy responses.
- Women in S&T education and employment.

1. Participating countries: Austria, Australia, Belgium, Denmark, Canada, Czech Republic, Finland, France, Germany, Hungary, Iceland, Italy, Japan, Korea, Netherlands, Norway, Portugal, Sweden, Switzerland, United Kingdom, United States. Countries responding to the questionnaire did not provide answers to all of the questions and sub-questions.

Feeding the S&T pipeline to ensure an adequate supply of S&T personnel

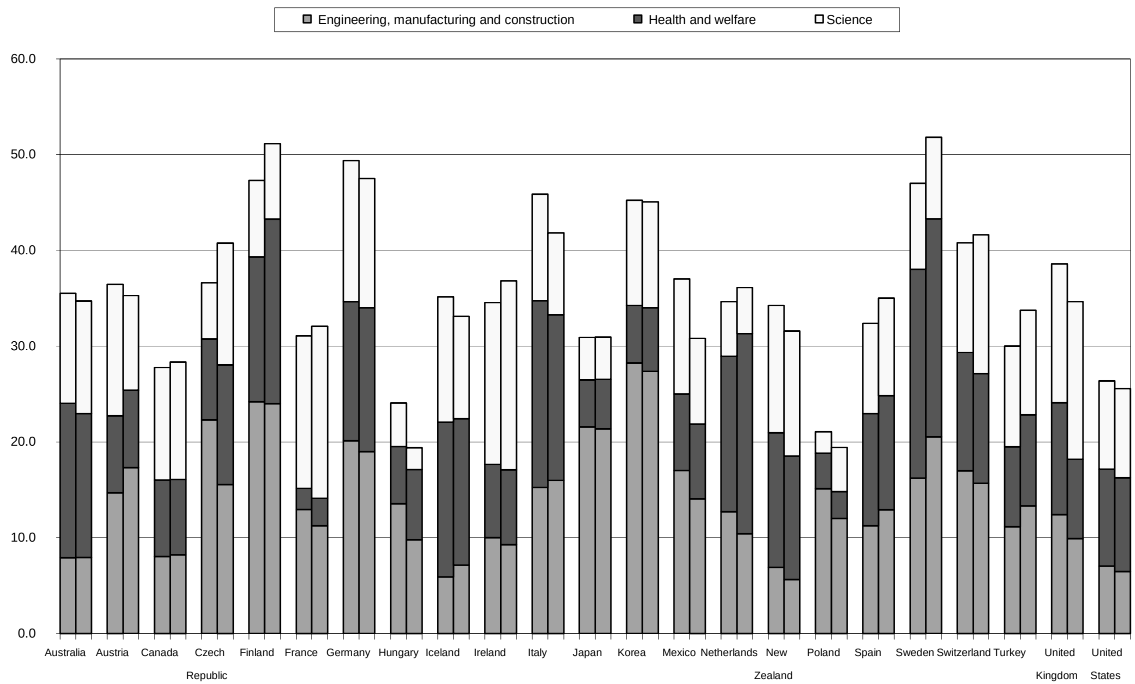
Before discussing the responses to the questionnaire, it is helpful to review some of the recent statistical evidence on trends in supply and demand for human resources in the public research sector in order to contrast concerns expressed by countries and internationally comparable data.

Just as OECD countries differ in the way they fund research and the scale of funding, they also differ in the quantity and quality of human capital in science and technology that is produced and deployed in the economy. The number of new S&T graduates provides an indicator of the potential labour pool for S&T employment. In 2000, Korea, Germany, Finland, Switzerland and France led the OECD area in the production of university level graduates in natural sciences and engineering as a share of total graduates (Figure 5.1). Korea and Japan, reflecting the strong specialisation in manufacturing technologies produce more university graduates in engineering than in science-related disciplines.

Although time series data are unavailable due to changes in survey methods, data on science and engineering (S&E) graduates over the period 1998-2000 nevertheless provide some indication of recent developments. Over that period, the number of S&E university degrees awarded in Iceland, Sweden, Switzerland and Ireland increased significantly with Sweden registering a 32% increase. At the same time, Norway and the Netherlands witnessed a decrease of 23% in the number of new university degrees awarded in S&E. Although Germany experienced a steep increase in student enrolment in computer sciences, which more than tripled between 1995 and 2001, the overall number of S&E university degrees awarded between 1998 and 2000 decreased by almost 11%. The production of S&E graduates in France and the United Kingdom remained stable or increased slightly during that period but both countries have more new science and engineering graduates as a percentage of 25-35 year olds than any other G7 country.

Figure 5.1. University graduates[1] in science[2], engineering[3] and health[4], 1998-2000[(*)]

As a share of total graduates



*The first column for each country is always 1998 and the second one 2000.

1. Tertiary-A and advanced research programmes (ISCED 1997). 2. Science includes life sciences (42), physical sciences (44), mathematics and statistics (46) and computing (48). 3. Engineering includes engineering and engineering trades (52), manufacturing and processing (54) and architecture and building (58). 4. Health and welfare.

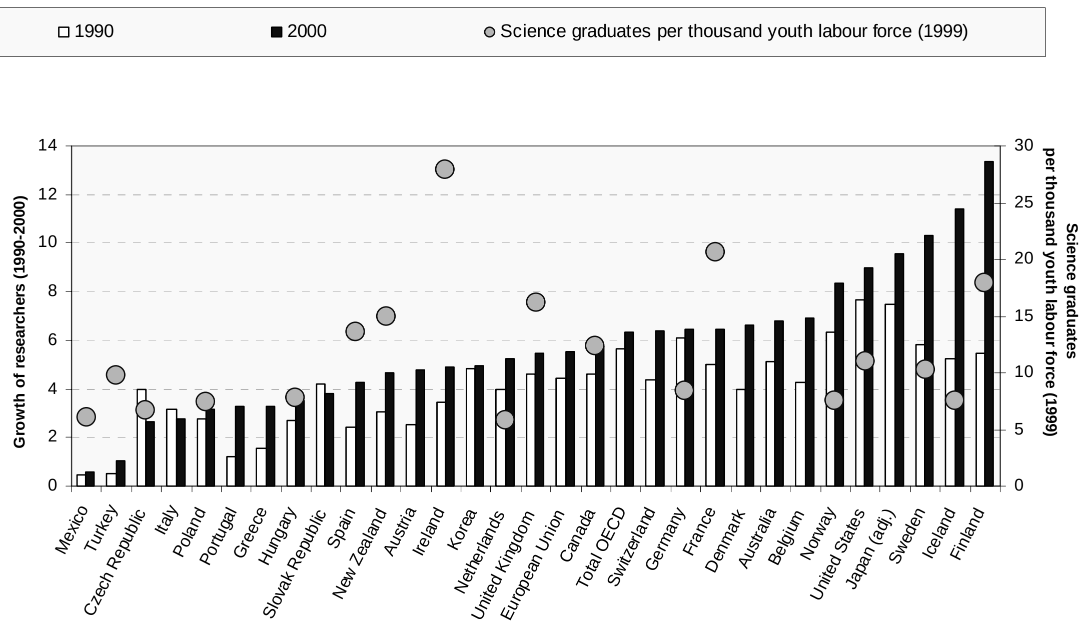
Source: OECD, Education Database, June 2003.

If one considers the number of "researchers" (the demand side) in the government, business and higher education sectors combined, it becomes apparent that with a few exceptions the leading OECD countries in terms of researchers also have a comparatively high number of new science graduates entering the labour force (Figure 5.2). Finland, Japan, Sweden and the United States lead the OECD area in terms of number of researchers relative to the population. Sweden and Finland as well as Spain and Ireland have seen strong growth in the number of researchers, although for the latter countries, their numbers are still below the OECD average. In contrast, despite a strong specialisation in science among graduates in Italy, the researcher population has actually declined in line with a drop in demand from the public and private sectors and concerns about a "brain drain".

It is also noteworthy that Germany and the Netherlands, with a traditionally high share of R&D, have seen modest increases in researcher employment combined with, in comparison to other countries, a lower share of science graduates relative to the size of the youth labour force. Finally, despite the success of countries that are "catching up" in increasing the number of new science graduates (*e.g.* Spain and Ireland), demand for researchers has mainly come from the public sector due to low business R&D investment. While the high production of science graduates may benefit the economy overall, there is a risk that underinvestment in R&D could result in few employment opportunities for researchers, emigration (brain drain) or out-of-field employment as graduates take up position in areas removed from their field of study.

Figure 5.2. Comparison of growth of researchers in OECD countries (1990-2000) and number of science graduates

Per thousand youth

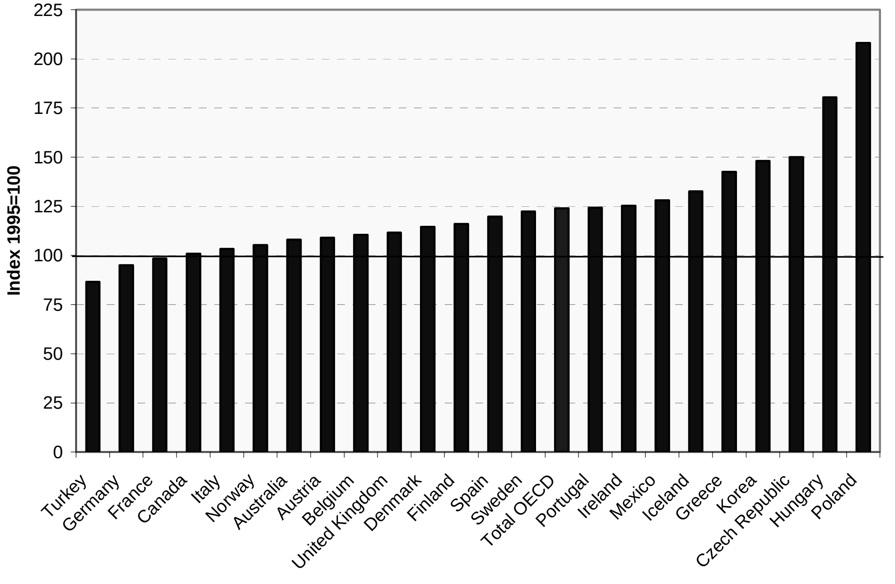


Source: OECD, *Main Science and Technology Indicators*, May 2003, and *Education at a Glance*, 2002.

Enrolment in tertiary education and S&T

The supply of researchers strongly depends on new entrants into higher education. Across the OECD, more people than ever are attaining a tertiary education (Figure 5.3). International data on enrolments by field of study (*i.e.* in S&T) are at present unavailable. Nevertheless, it is clear that with already high enrolment rates and smaller youth cohorts, the challenge of increasing university enrolment rates in advanced OECD countries is in some ways greater than for less advanced countries.

Figure 5.3. Changes in total tertiary enrolment between 1995 and 2000

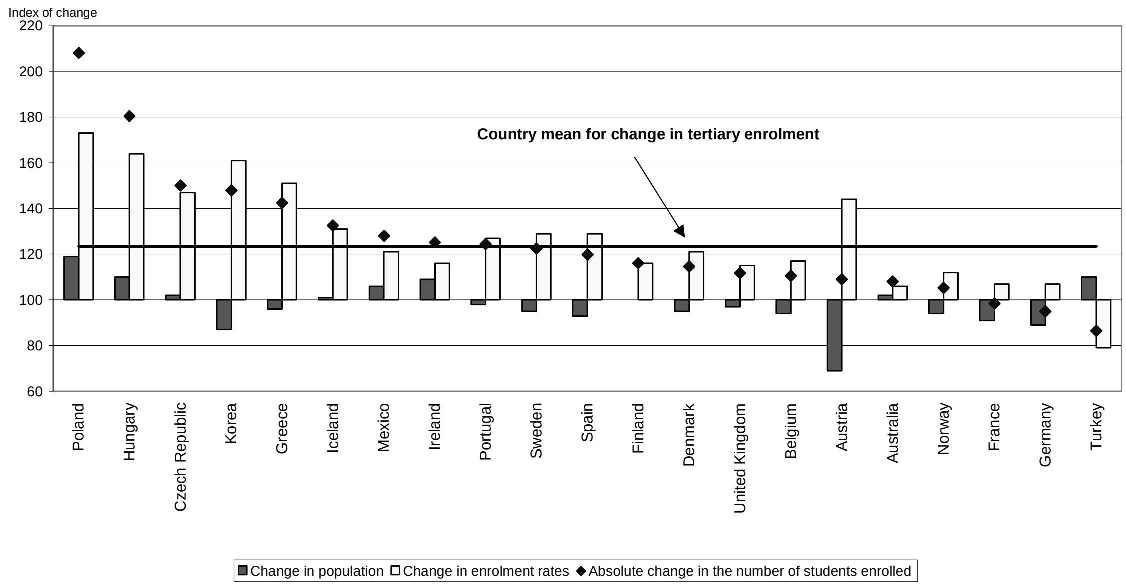


Source: OECD, *Education at a Glance*, 2002.

Figure 5.4 shows that the increase in enrolment in some of the latter countries was due in part to changes in the population. In countries with decreasing population cohorts such as Austria, Korea or Spain, however, overall enrolments nevertheless increased between 1995 and 2000 due in part to greater efforts in education policy.

Figure 5.4. Change in the number of tertiary students in relation to changing enrolment rates and demography (2000)*

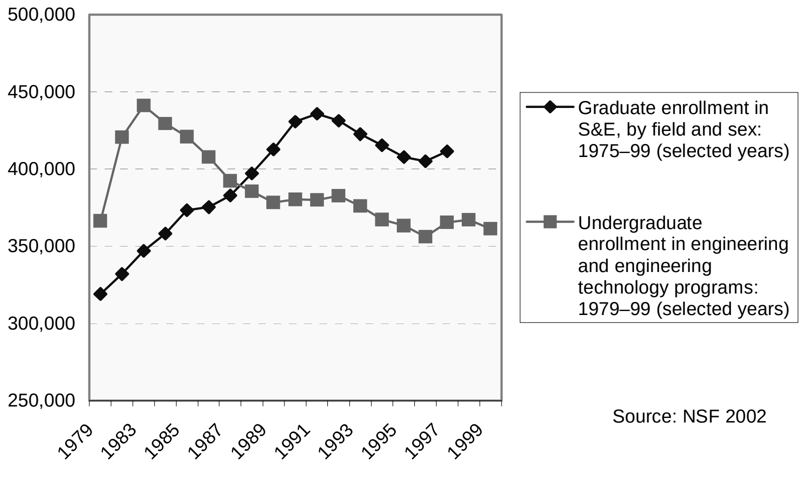
Index of change in the number of students between 1995 and 2000 and relative contribution of demographic changes and changing enrolment rates (1995 = 100)



*The change in total tertiary enrolment is expressed as an index, the base year of which is 1995 (100). The number of tertiary students in 2000 is therefore expressed as a percentage of the number of tertiary students in 1995. The impact of demographic change on total enrolment is calculated by applying the enrolment rates measured in 1995 to the population data for 2000: population change was taken into account while enrolment rates by single year of age were kept constant at the 1995 level. The impact of changing enrolment rates is calculated by applying the enrolment rates measured in 2000 to the population data for 1995, *i.e.* the enrolment rates by single year of age for 2000 are multiplied by the population by single year of age for 1995 to obtain the total number of students that could be expected if the population had been constant since 1995. *Source:* OECD. Data from OECD, *Education at a Glance*, 2002.

In the United States, graduate enrolment in science and engineering has continued to rise, due in part to a large supply of foreign students in S&T (Figure 5.5) although undergraduate enrolment in engineering has fallen since the 1980s. In Canada, PhD enrolment in the natural sciences and engineering (NSE) peaked in 1993-94 and in the subsequent five years declined by 12%. At university level, however, Canada has witnessed an increased enrolment of young people in science-related subjects in recent years, which may be partly due to increased government action in this area and labour market signals. Between 1995 and 2000, enrolments rates increased most in countries such as Poland, Hungary, Czech Republic and Korea and Greece. In Hungary, PhD enrolment has been continuously increasing since the mid-1990s. In the 1999-2000 academic year, there were 4 302 full-time PhD students at the Hungarian doctoral schools compared to 1 527 in 1993. In Australia, a continuing growth trend in doctoral completions can be observed, from 2 905 in 1996 to 3 664 in 1999.

Figure 5.5. Graduate and undergraduate enrolment in science and engineering, United States, 1979-1999



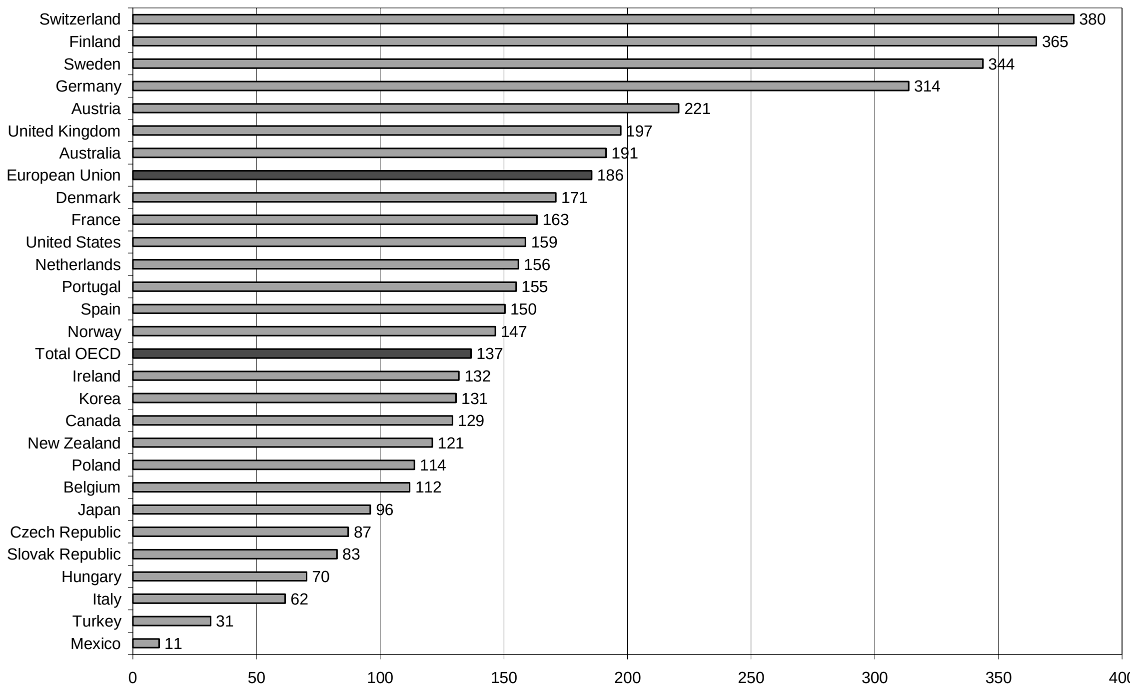
Source: NSF 2002

Trends in PhD graduates

The scope for increasing numbers of PhD graduates is less dependent on demographic factors than on the quality of secondary education and university graduation, access and quality of PhD training and, increasingly, student immigration policies. While the increase in enrolments in post-secondary education have provided a larger pool from which to raise the number of PhDs, further growth will depend on new cohorts entering higher education as well as greater participation by women. However, in a few countries (*e.g.* Finland) women already make up half or more of enrolment in tertiary higher education and increasingly enter PhD programmes. National data and information from the OECD questionnaire show that countries have implemented measures to increase the number of PhDs and strengthen PhD training. In Germany, for example, an increase in the number of graduate schools and new programmes has helped increase the supply of young scientists at doctoral and postdoctoral level in recent years.

OECD data do not allow for comparing the growth in PhD graduates over a significant period due to changes in survey methods in 1997 (*i.e.* new ISCED definitions). Nevertheless, Figure 5.6 provides data on the relative share of PhD graduates per million population in OECD countries with Switzerland, Finland, Sweden and Germany all having shares far above the OECD average of 137 per million inhabitants. As regards trend data, country data show suggest there is a steady increase in the supply of PhD graduates but a levelling off in some countries. France witnessed an increase in the number of PhD graduates from 6 000 each year at the end of the 1980s to more than 10 000 by 1994. However, this number has been in slight decline since the 1998. In Australia, doctoral completions rose from 2 905 in 1996 to 3 664 in 1999 (with non-overseas PhDs rising from 2 326 in 1996 to 3 018 in 1999). In 2001, just as in 2000, the number of Polish doctorates conferred was 4400; the largest ever number of doctorates conferred - about 3 times as high as in 1991 when the lowest ever number of doctorates conferred was recorded. Foreign students are also are important to the production of PhDs especially in Belgium, Switzerland, Germany, the United Kingdom and the United States.

Figure 5.6. Total PhD graduates per million population, 2000



Source: OECD, Education and MSTI databases, May 2003.

Detailed data from the National Science Foundation show that the number of graduates at PhD level in physics fell by 22% between 1994 and 2000, partly as a result in the decrease in foreign students in that field. A drop of 15% was observed in the number of PhD graduates in engineering between 1996-2000 also due in large part to the decline in the number of foreign graduates (NSF, 2002). Assessing whether such declines have resulted in shortages in the academic and R&D labour markets at the very least requires data on wages as well as employment patterns of such graduates, but this is outside the scope of this report.

Table 5.1. US doctorates awarded in physics and engineering, 1993-2000

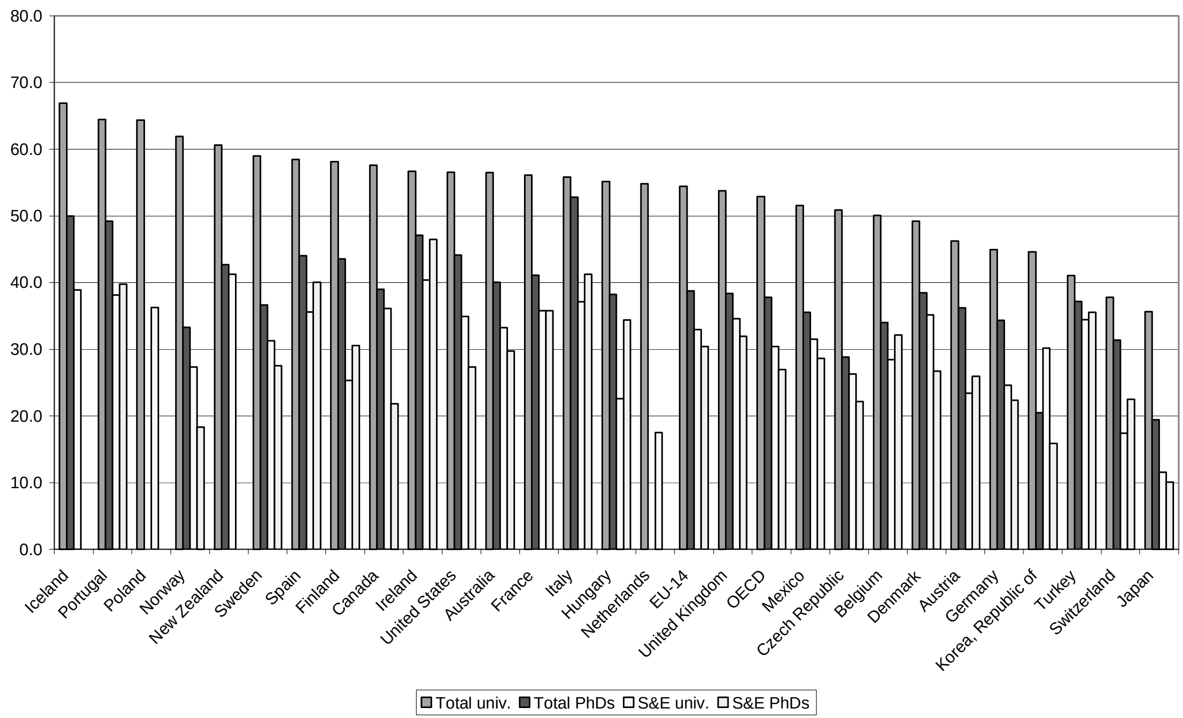
Academic year	Physics	Engineering
1993	1 399	5 698
1994	1 548	5 822
1995	1 479	6 008
1996	1 484	6 305
1997	1 401	6 114
1998	1 377	5 927
1999	1 270	5 328
2000	1 205	5 330

Source: National Science Foundation/Division of Science Resources Statistics, Science and Engineering Doctorate Awards: 2000, Detailed Statistical Tables, NSF 02-305 (Arlington, Virginia, 2001).

Women in science and technology

Although the proportion of women in higher education has continued to increase over the past decades, even to the point of surpassing the share of men completing tertiary higher education in Norway, Sweden and France, women still remain under-represented in science and technology, especially in Japan, Korea, the Netherlands, Norway, Germany and Switzerland. In the US survey, data show that the share of US women PhDs in science and engineering has doubled since the late 1980s. Ireland, Spain, Portugal and Italy had the highest shares of women among S&E PhDs in 2000. Finland has one of the highest shares of women among PhDs graduates, about 40% (Figure 5.7).

Figure 5.7. Proportion of university degrees awarded to women, 2000



Source: OECD. Data from OECD Education Database, November 2002.

While the participation of women in academic and research employment has increased in some countries such as France, they also remain concentrated in the natural, medical sciences and social sciences (OECD, 2000) and few women enter engineering and computer science. In general, the share of women graduates in S&T falls as the degree level rises, especially above senior lecturer. Australia might be cited as a notable exception in this respect: over the three-year period 1998-2000 the number of women employed at universities at lecturer level or below remained relatively constant while the number of women above senior lecturer rose steadily. In the United States, the growth in academic doctoral employment is largely due to the hiring of women and minority PhDs: women constituted 27% of all doctoral scientists and engineers in academia, 24% of full-time faculty (higher percentage in lower ranks, signalling the more recent increases in their numbers), and more than one-third among other full-time and postdoctoral positions by 1995. In France, there is almost parity between men and women researchers under the age of 35 in the fields of life sciences (50.3%) and medicine (49.2%) with the overall share of women in researchers in this age bracket being 30%.

With women having increased their share in education, there is great attention to their conditions of labour market entry and employment in the public research sector. Making sure women stay in S&T jobs may thus be as important as persuading young women to pursue such careers in the first place. To do this, policy makers will have to address the barriers female researchers often face such as the difficulty in balancing career and family lives and lower starting salaries compared to men.

Feeding the S&T pipeline: main policy responses in OECD countries

Overall, there is growing pool of university graduates due to an increase in tertiary enrolment and graduates. Despite the larger pool, however, a number of countries have expressed concern about the slow growth or reduction in the share of S&T graduates, especially among the heavy R&D spending countries. “Catching-up” countries such as Ireland and Spain, on the other hand, witnessed a significant increase in S&T graduates, including at PhD level. However, even with an increased production rate, the long-term ability of countries to fill the S&T pipeline given evidence of the waning interest in science-related subjects among primary and secondary students remains a concern.

Making S&T education more attractive

According to data from the European Commission and the NSF, the waning interest in science among youth, reflected in a decreasing proportion of students who take up scientific subjects, especially at secondary level, remains a problem in many OECD countries. The so-called "hard" sciences such as mathematics, physics and chemistry seem to be the most seriously affected with the proportion of students remaining in these subjects having dropped by almost a third in countries such as Germany, the Netherlands and the United Kingdom. The reasons for this waning interest seem to be manifold: unattractive curricula, a lack of talented and trained teachers and the low status of scientists in society. In order to address these deficiencies and to attract young people into science-related subjects, several OECD countries such as Belgium, Finland and Portugal have redesigned curricula, increased the resources dedicated to schools and launched science exhibitions or established new science centres. Some initiatives also aim at updating teacher skills in various scientific fields. Although a full evaluation of the impact of these initiatives seems to be premature at this point, the initiatives undertaken by Finland have been regarded as quite successful and may serve as one example of good practice.

Box 5.1. Finnish LUMA programme to improve teacher training

In 1996, the Finnish National Board of Education launched a national development programme called LUMA, which aims at improving mathematical and science knowledge among teachers and raising it to an international level. Within the framework of LUMA (an acronym of the Finnish words meaning natural sciences and mathematics), mathematical and science teachers of all educational levels may participate in additional training free of fees. The LUMA project group has also developed special material teachers may use in the classroom, for instance a book to assist physics teaching in primary school or a publication dealing with scientific experiments in class.

A definite evaluation of the programmes is not available yet, but the Finnish Ministry of education has already drawn a positive conclusion. The feedback from teachers was highly positive, co-operation between teachers has increased and the connections between schools and with partners outside the schools have become stronger than before. Many of the 270 educational institutions that participated in the nation-wide project have introduced classes that specialise in mathematics and science. Public appreciation of mathematics and science has risen as well with teachers placing a higher value on their profession. Further information on the LUMA programme is available at http://www.minedu.fi/minedu/education/luma/finn_knowhow.html.

Increased funding for PhDs

Funding is critical to the supply of new PhDs and for post-doctorates. In 1999, overall expenditures per student for tertiary education were highest in the United States and Switzerland, followed by Canada and Sweden. Most graduate funding comes in the form of fellowships funded through institutional (core) and agency funding or grants. More than 72% of French PhD graduates (having defended their doctoral thesis) received financial support. Around 10% of those receiving financial support did so in the context of a salaried position in higher education institutions and to a lesser extent in industry. In addition, the French government has increased research funding for student researchers by 5.5% as well as the number of "CIFRE" agreements for training through research for doctoral level student researchers and has committed to creating 1 000 new posts in S&T by 2004. In the United States, PhD training includes paid employment as teaching assistants as part of financial support.

The Australian government has committed to doubling the number of Australian postdoctoral fellowships in an attempt to attract young researchers. In Canada, the Natural Sciences and Engineering Research Council (NSERC) has increased the number and dollar value of postgraduate scholarships: the 2003 budget provides for 4 000 new graduate fellowships, half of which are at PhD level. Portugal has one of the highest increases in new PhDs due in part to active funding. In Sweden, the government and the research councils have set aside EUR 12 million to establish additional positions for new recruits and to support outstanding young researchers. In Hungary the NRSF Postdoctoral Programme and Magyary Scholarship, and secondly, the reorganised Békesy Postdoctoral Programme and Bolyai Research Programme support mainly young researchers who have already obtained PhD degree. Professors can also apply for individual grants, which ensure high monthly salaries (*e.g.* Széchenyi and Szilárd Scholarships, and the newly founded Szentgyörgyi Scholarships). The Hungarian government has also increased funding for doctoral schools and granted universities the right to train and award PhDs. These policies seem to have had a significant impact: between 1993 and 2001, the number of doctorates tripled.

Attracting women and under-represented minorities

The overview has shown that there are still gender imbalances in research, which are greater at higher degree levels. However, increased participation of women may help to enlarge the pool of researchers for the public S&T sector. Therefore, a major challenge for policy makers might consist in tapping the potential of women (and minority groups in the United States and the United Kingdom) who are still under-represented in the S&T workforce. Several OECD countries have undertaken considerable efforts to address this problem and to improve the representation of women among S&T graduates and researchers. Box 5.2 provides an overview of recent policy measures.

Box 5.2. What is being done to improve the role of women in academia and research?

Canada. The goal of the "Chairs for Women in Science and Engineering" programme created by the NSERC is to increase the participation of women in S&E and to provide role models for women considering careers in these fields. NSERC funding is matched by cash contributions from corporate sponsors. In addition, the University Faculty Awards (UFA) programme assists universities in hiring 25 women faculty members in the NSE each year by providing a salary supplement of CAD 40 000 per year per chair holder for up to five years.

Finland. Specific long-term measures (since the 1980s) have steadily increased the number of women in research making Finland one of the countries with the highest share of women in research at all levels: in 2000, about 32% of research personnel in general and 43% of university research personnel were women. Since 1998 all Academy of Finland calls for funding applications have encouraged women in particular to apply. In 2000, the Academy adopted an equality plan to promote gender equality in the science community: where applicants are equally qualified for the post, preference is given to women.

Germany. The BMBF has set up a "women in education and research" division. The division's responsibilities include establishing gender mainstreaming in the BMBF itself with the aid of a separate budget item entitled "strategies for achieving equal opportunities for women in education and research". Non-university research organisations have created career track posts to attract more female researchers to science and technical areas.

Iceland. In recent years there has been a move towards improving the conditions for women to participate in the labour market. The Icelandic Parliament (Althing) has passed laws enabling longer parental leaves for both parents; companies have introduced flexible working times and methods such as remote work stations for women at home. Day care centres have been a limiting factor in some communities.

Netherlands. The Aspasia programme run by the Research Council NWO with financial participation of NWO, the Ministry of Education, Culture and Science and the universities aims to promote women assistant professors (UD) to associate professors (UHD).

Sweden. Positive discrimination is expected in the recruitment process for posts in the higher education sector.

United Kingdom. The ATHENA project, funded by OST and the UK higher education funding councils, is working to tackle the issue of women's under-representation in higher education employment. It has been in existence for two years and a further two years are planned before a full review. The government has also set up a Web site on women in S&T to provide statistical data on women in S&T with a view to informing policy: www.set4women.gov.uk.

United States. The NSF's Advance Program focuses on advancing the early academic careers of women in postdoctoral or equivalent positions.

Source: OECD (2002) Ad Hoc Group on Steering and Funding of Research Institutions questionnaire results.

Attracting talent from abroad

In certain fields, shortages of S&T workers may appear because market changes occur faster than supply can adjust. Canada, the UK and the US have traditionally met part of their demand through the immigration of foreign nationals at several points of the S&T pipeline. In 1999, the number of individuals with a masters or doctoral degree in NSE immigrating to Canada equalled the national production. Both the United Kingdom and the United States have a large percentage of foreign students in their S&E doctoral programmes: in the UK, 33% of all PhD doctorates in science and engineering-related subjects in 1999-2000 were awarded to students from outside the UK. According to a recent study, 51% of those who received their doctorate degree in 1994-95 were still working in the United States in 1999, with 63% for the field of computer sciences.

The propensity of PhD graduates and researchers to immigrate/emigrate is partly influenced by the quality of the research environment. Although countries are not establishing centres of excellence with the explicit goal of attracting foreign talent, up-to-date research facilities provide an additional incentive for foreign graduates. In Australia, the government has provided additional funds for the establishment of centres of excellence in ICT. In 2000, Italy, too, has set up a network of 45 centres of excellence, *e.g.* in the fields of biotechnology, ICT and innovative technologies. In addition to a high-quality research environment, salaries that can compete with those on offer in the private sector and abroad are important incentives. Better stipends at the training level and career opportunities thereafter are important for enlarging the science base "at home" as well as attracting foreign scientists. In Italy, for example, poor funding of PhD training in recent years seems to have driven away young S&T graduates (American Association for the Advancement of Science, 2001).

In addition, the interplay of administrative and fiscal incentives can influence the decision of foreign researchers to work in a certain country. In Sweden, changes in immigration policies have led to an enlargement of the pool of researchers. In Australia, in response to shortages in the ICT and engineering sectors, the skill base will be enlarged through new immigration arrangements granting permanent residence to additional 2 500 Australian-educated overseas students. In the United States, regulations favouring the immigration of scientists in areas of high demand have long been in place. Also, the creation of special visa programmes has favourably influenced the propensity of foreign scientists to stay in the US. Some countries are also using fiscal incentives to recruit foreign talent, at least on a temporary basis. In 2001, Sweden, emulating similar initiatives in other countries, passed a law to alleviate the tax burden on highly skilled foreign workers residing in the country for less than five years.

As indicated above, shortfalls at different points of the S&T supply chain may have a negative impact on the overall flow of scientists and ultimately, the delivery of a sufficient number (in qualitative as well as qualitative terms) of researchers to fuel the knowledge-based society. The overview has also shown that the effective functioning of the S&T pipeline is markedly influenced by a variety of supply-side policies, from higher education funding to PhD funding and immigration policy. Demand-side labour market policies also matter. Measures that facilitate mobility of graduates and young researchers as well as labour market signals for young people to invest in S&T education are equally important in addressing supply shortages or mismatches.

Adapting graduate education to changing demands

Today, graduate education is under pressure to respond to the demands of various stakeholders in the science system, *e.g.* industry, the research community and society. In the past, there were clearly separate roles in the division of labour for knowledge production between universities, applied research institutes and industry. These dividing lines, however, seem to have been blurred. The challenge policy makers may now face consists of finding a balance that allows being responsive to various stakeholders without thwarting the long-term education and research missions of universities.

Industry involvement in PhD training is increasing

In many countries, industry involvement in training traditionally takes place on an ad hoc basis or in the context of vocational education, specialised education such as IT training and first university degree programmes. However, even at the PhD level, industry involvement in training is growing. This is driven in part by the need to improve the labour market entry of graduates as well as to provide industry with the right skills in applied as well as basic research. In Japan it is claimed that many postdoctoral students lack some skills needed by industry, a phenomenon that may challenge traditional PhD training. In Canada, industry has pointed to a lack of practical skills of highly skilled researchers in the area of communication, management and strategic thinking. To remedy this, the NSERC fosters industry involvement in student training at undergraduate, graduate and post-doc levels by co-funding various industrial research fellowships and scholarship programmes. In the United States, the National Academy of Sciences' Committee on Science, Engineering, and Public Policy has put forth recommendations to reshape doctoral education to facilitate the labour market entry of PhDs in industry. Industry is also increasingly locating small research laboratories on campuses where they have access to world-class research as well as to new graduates. In Sweden, strong demand from the telecommunications industry provided an incentive for government and universities to focus funding on particular areas of ICT research. US companies such as Microsoft or Sun Microsystems have long been involved in the provision of ICT-related education.

Industry involvement in training may also be related to the increase in industry funding for higher education institutions. While the amount of industry funding in higher education remains low in most OECD countries, its share has increased dramatically and this is likely to affect training as much as research. Governments are also funding or subsidising industry training for PhDs. The CIFRE PhD programmes in France, which have increased in number, allow PhD candidates to carry out research for their thesis in an industrial setting. However, with increased industry involvement, one may question whether the burden of financing PhD training should be solely concentrated in the public hands as industry funding does usually not cover the overhead costs resulting from research.

Emphasis on networking and multidisciplinarity

Greater involvement by industry in education coincides with an increased emphasis on networking and multidisciplinarity in PhD training. Policy makers in OECD countries have undertaken efforts to adapt graduate education to these changing demands. In France and Sweden, a closer collaboration between industry and higher education has been fostered through the introduction of industrial PhD programmes. The German Federal Ministry for Education and Research (BMBF) has selected eight universities as pilot interdisciplinary clinical research centres and funded them for eight years in order to provide qualified scientific training conditions for young researchers. However, as new scientific industries and fields emerge, there is greater pressure on training systems to balance multidisciplinarity with the need for specialisation. Priority of research education and training in general follows priority areas for research. Funding for fields such as bioinformatics has led to the development of new multidisciplinary curricula and degree programmes in countries such as the United States and Switzerland.

Since the 1990s, countries have stimulated multidisciplinarity in research and training via the emergence of “centres of excellence”. These centres help to foster multidisciplinary research, allow for faculty to teach at multiple sites and contribute to greater networking among students and professors. Their unique funding structures also allow for greater flexibility in faculty and researcher movements. In Italy, a network of centres of excellence was set up in 2000 by different advanced schools operating in various fields and linking three older traditional research institutions and three new establishments. In the Dutch system, special “graduate schools” were established in the early 1990s to foster high-quality research in one particular field or in a multidisciplinary context. There is currently a debate about strengthening the training component of the AIO and OIO posts in order to keep graduates interested in science careers. In 1995, a new system of graduate schools was also established in Finland, organised around networks that include students from several universities. At present there are some 100 graduate schools in different disciplines financed by the Finnish Ministry of Education and the Academy of Finland. Box 5.3 provides an overview over the initiatives governments have undertaken to adapt researcher training to changing demands.

Society as a stakeholder

In recent years, an increasing demand for societal accountability of research has been noticeable. However, the impact of training programmes and shifts in priorities are often only felt in the long term. Therefore, societal demands for a rapid economic payback of investments in research and research training might, in the short run, be neither feasible nor desirable if they shift training and research too far in one direction. Shifts in priority areas, for example, must be backed by a sufficient number of PhDs in this area, which may take a decade or more to be "generated". Also, a rapid economic payback of investment in research may be incompatible with the pursuit of scientific excellence.

Renewing the public research sector

In several OECD countries, the public sector is no longer the main source of employment opportunities for researchers. It should be noted that Australia and some European countries including Italy and Spain are exceptions in this respect as researcher employment has traditionally been greater in the public research sector than in industry since the mid-1980s. At the global level, the share of employment of researchers in industry has increased relative to the share in higher education and government. Most researchers in Japan, the United Kingdom, Germany and the United States are employed in the business sector, which has continued to increase since the mid-1980s. Employment in the French business and higher education sectors expanded in absolute numbers, but the overall distribution has remained broadly stable with slightly more researchers in business followed by the higher education and government sectors. In absolute terms, however, employment of R&D staff in higher education increased sharply between the mid-1980s and the mid-1990s in Australia, Austria, Denmark, Germany, Ireland, Norway and Portugal. Finland and Ireland, for example, have doubled the amount of R&D staff in higher education. It is noteworthy that in many countries the increase in public sector research employment has been greater in the higher education sector than in the government sector (Table 5.2).

Box 5.3. National and institutional developments in graduate degree programmes

Over the past ten years, many OECD countries have made efforts to reform graduate education. There has been a general move away from the apprenticeship model in the United Kingdom, Italy and more recently Germany towards research training programmes focused on quality, efficiency and control that include coursework, joint supervision and monitoring of progress by a research committee. Some countries have sought to shorten PhD programmes or develop new ones. Many countries have also developed programmes to fund younger researchers in order to keep them in the research system.

Australia. The new Research Training Scheme (RTS) replaces the research training component of the operating grant and makes funding for research training places performance-based. It provides federally funded higher degree by research (HDR) students with an entitlement to a higher education contribution scheme exempt place for the duration of an accredited HDR course, up to a maximum period of four years full-time equivalent study for a doctorate by research and two years full-time equivalent study for a masters by research. The scheme was introduced to address some persistent concerns identified by students, institutions and employers about the poor quality of some students' research training environment and mismatches between the research priorities. The performance-based funding formula for the RTS takes into account research student completions, research income and research publications and introduces some measure of public accountability for funding of research training for the first time. In order to be eligible for funding, a university must publish an acceptable research and research training management report setting out, among other requirements, objectives and future directions for research training, and information about the quality of its research training environment.

Finland. A new graduate school system was introduced in 1995. At present there are some 100 graduate schools in different disciplines financed by the Ministry of Education and the Academy of Finland. The Academy of Finland has also launched a programme for postdoctoral researchers aimed at promoting the professional development of doctoral graduates opting for a career in research. A programme especially for education and training intended for information industry and digital communications professionals has been adopted.

Netherlands. A bachelor-master structure (with new curricula) is being introduced in order to better meet demands of the labour market in the private and public sectors. The general aim of this measure is to stimulate flexibility and openness of Dutch higher education. The new bachelor-master structure includes research-oriented masters courses as preparation for PhD training. This means that new curricula will be developed, with disciplinary as well as multidisciplinary courses.

Sweden. Labour market demands for IT and management skills led to the development of interdisciplinary programmes to combine engineering and economics/law and environment, etc. The Research Council has an industrial PhD programme. Engineering schools also collaborate with industry in PhD programme design.

United States. Among NSF programmes, IGERT, the Integrative Graduate Education and Research Training Program, focuses on interdisciplinary education, innovative approaches to graduate education, and broadening the participation of under-represented groups. Much of the graduate education reform effort is in fact driven and supported by private sources, most notably the Keck and Sloan Foundations which have extensive programmes in place.

Source: OECD (2002) Ad Hoc Group on Steering and Funding of Research Institutions questionnaire results.

Table 5.2. R&D personnel in the public sector and researchers by gender, mid-1980s to early 2000s

		R&D personnel of the public sector						Researchers by gender, 2000			
		Total public sector		Higher education		Government		Higher education		Government	
		(FTE)		*(As a % of public R&D personnel)*				*(% of total researcher population)*			
		Mid-1980s	Early 2000s	Mid-1980s	Early 2000s	Mid-1980s	Early 2000s	Male	Female	Male	Female
Australia	(1985-2000)	37 662	64 694	53.5	71.5	46.5	28.5	-	-	-	-
Austria	(1985-1998)	7 125	10 775	75.0	80.5	25.0	19.5	74.3	25.7	68.1	31.9
Belgium	(1985-1999)	12 452	18 101	88.7	87.7	11.3	12.3	-	-	-	-
Canada	(1985-1999)	55 980	60 650	64.7	72.8	35.3	27.2	-	-	-	-
Czech Republic	(1991-2002)	27 460	13 198	10.2	44.3	89.8	55.7	68.4	31.6	68.5	31.5
Denmark	(1985-2000)	8 791	13 673	52.2	58.2	47.8	41.8	72.0	28.0	65.2	34.8
Finland	(1985-2001)	11 383	22 884	51.7	68.2	48.3	31.8	58.5	41.5	62.5	37.5
France	(1985-2000)	127 762	143 439	46.2	62.8	53.8	37.2	67.8	32.3	69.3	30.8
Germany	(1985-2001)	120 748	173 048	57.1	58.9	42.9	41.1	-	-	-	-
Greece	(1987-1999)	6 075	21 725	24.9	79.6	75.1	20.4	55.7	44.3	62.5	37.5
Hungary	(1990-2001)	17 953	16 163	49.3	52.0	50.7	48.0	65.5	34.6	64.4	35.6
Iceland	(1985-2002)	679.2	1 513	41.7	50.5	58.3	49.5	64.2	35.9	69.6	30.4

Table 5.2. R&D personnel in the public sector and researchers by gender, mid-1980s to early 2000s *(continued)*

		R&D personnel of the public sector						Researchers by gender, 2000			
		Total public sector		Higher education		Government		Higher education		Government	
		(FTE)		*(As a % of public R&D personnel)*				*(% of total researcher population)*			
		Mid-1980s	Early 2000s	Mid-1980s	Early 2000s	Mid-1980s	Early 2000s	Male	Female	Male	Female
Ireland	(1985-2000)	3 113	4 037	40.4	64.4	59.6	35.6	-	-	-	-
Italy	(1985-2000)	61 665	86 068	60.0	63.7	40.0	36.3	71.2	28.8	59.8	40.2
Japan	(1985-2001)	290 686	312 984	81.6	79.9	18.4	20.1	80.6	19.4	88.7	11.3
Korea	(1995-2001)	53 367	47 241	59.0	68.7	41.0	31.3	84.7	15.3	89.7	10.3
Mexico	(1993-1999)	24 823	31 745	44.3	44.6	55.7	55.4	-	-	-	-
Netherlands	(1985-2000)	29 940	40 122	54.0	66.6	46.0	33.4	-	-	-	-
New Zealand	(1989-1999)	6 322	9 798	36.8	64.8	63.2	35.2	-	-	77.0	23.0
Norway	(1985-2001)	8 480	12 246	62.0	61.1	38.0	38.9	64.3	35.7	65.3	34.7
Poland	(1994-2001)	53 709	60 688	61.0	71.2	39.0	28.8	61.1	39.0	57.1	42.9
Portugal	(1986-2002)	8 153	16 676	46.6	61.9	53.4	38.1	55.3	44.7	45.5	54.5
Slovak Republic	(1994-2001)	11 561	9 666	37.1	58.8	62.9	41.2	-	-	-	-

Table 5.2. R&D personnel in the public sector and researchers by gender, mid-1980s to early 2000s *(continued)*

		R&D personnel of the public sector						Researchers by gender, 2000			
		Total public sector		Higher education		Government		Higher education		Government	
		(FTE)		*(As a % of public R&D personnel)*				*(% of total researcher population)*			
		Mid-1980s	Early 2000s	Mid-1980s	Early 2000s	Mid-1980s	Early 2000s	Male	Female	Male	Female
Spain	(1989-2001)	37 106	78 090	60.6	69.9	39.4	30.1	62.5	37.5	58.8	41.2
Sweden	(1985-2001)	16 423	22 654	82.8	87.6	17.2	12.4	56.7	43.3	72.8	27.2
Switzerland	(1986-2000)	10 000	16 040	71.0	94.4	29.0	5.6	73.4	26.6	80.5	19.5
Turkey	(1997-2000)	-	-	-	-	-	-	64.8	35.2	69.1	30.9
United Kingdom	(1985-1993)	104 000	100 000	50.0	66.0	50.0	34.0	-	-	68.2	31.8
European Union	(1985-1999)	545 120	760 370	54.7	66.6	45.3	33.4	-	-	-	-

Source: OECD, S&T Databases, June 2003.

Data on US higher education R&D spending show that funding rose by 23% and the number of researchers employed in the higher education sector grew by 34% during the 1990s. The European Union as whole saw funding for higher education R&D rise by 27% and research population grow by 30% during the 1990s. In Japan, the higher education R&D expenditures fell by 4% and the number of higher education researchers fell by 15%.

A large share of R&D funds is spent on labour, but spending on R&D is not always positively correlated with employment since a large part of the remainder is allocated to equipment and services. Data on R&D expenditure per researcher in the higher education, government and business sectors are presented in Figures 5.8c to 5.8e. In 2000, the United States appears to have spent more R&D per researcher in the higher education and government sectors, and this has increased since 1995. Business R&D spending per researcher appears greater in EU area than in the United States and Japan. This may reflect differences in the structure and functioning of labour markets (*e.g.* higher social charges on labour in the EU).

While public sector employment has increased in a few countries, it is also becoming more tied to project funding and hence to temporary appointments. Much of the federal money spent for research projects in the German university and non-university public sector is dedicated to employ researchers (doctoral and postdoctoral level) on a temporary basis. As in other countries, the number of temporary positions slightly increased in many German institutions, but general figures are not available. Academic employment of PhD holders in science and engineering in the United States has seen a decrease in the share of full-time tenured faculty positions and an increase in non-faculty full-time contract positions (*i.e.* they can be terminated when "soft money" funds are unavailable) and postdoctoral appointments. Faculty positions dropped from 82% to 75% of doctoral academic employment (1991-99) (79% to 75% 1995-99). At universities the share of tenured positions has fallen in the United Kingdom. Tenured positions for researchers in Norwegian universities and university colleges deceased only slightly between 1983 and 1999. In France, there has also been an increase in temporary posts among PhD entering the labour market.

Figure 5.8a. Higher education R&D expenditures in the G7 countries, 1990-2000

Billions of 1995 USD using PPPs

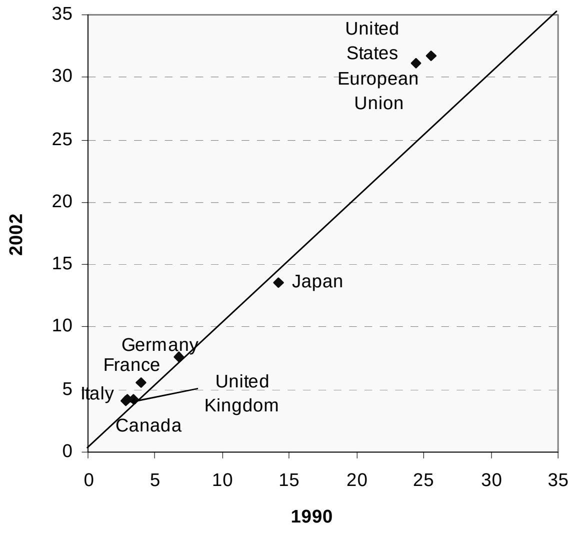
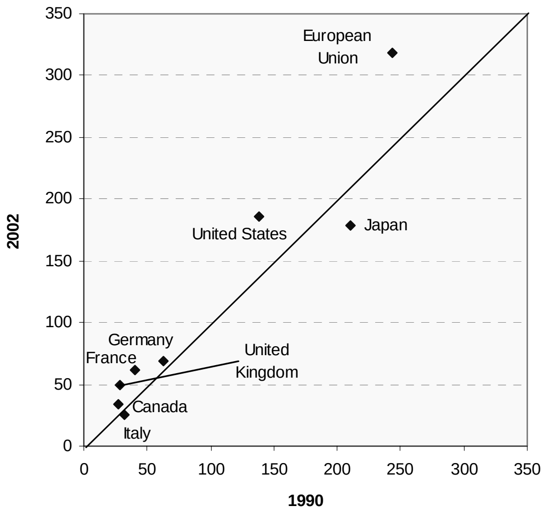


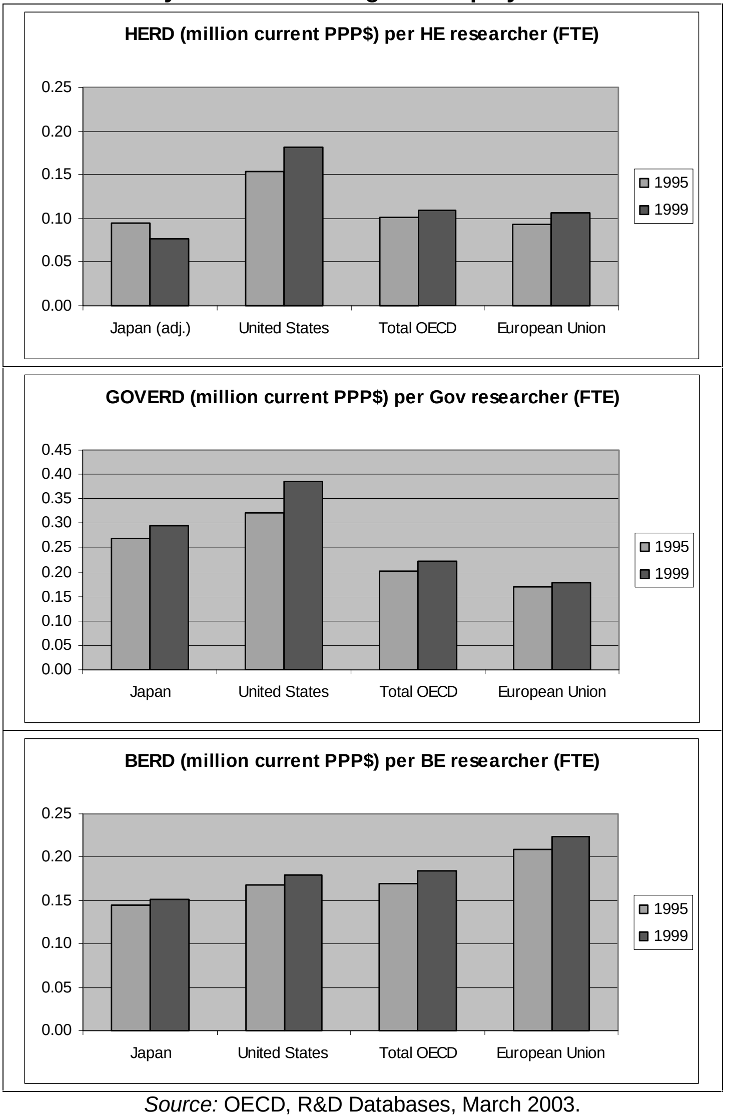
Figure 5.8b. Researchers in the higher education sector in the G7 countries, 1990-2000

Thousand FTE



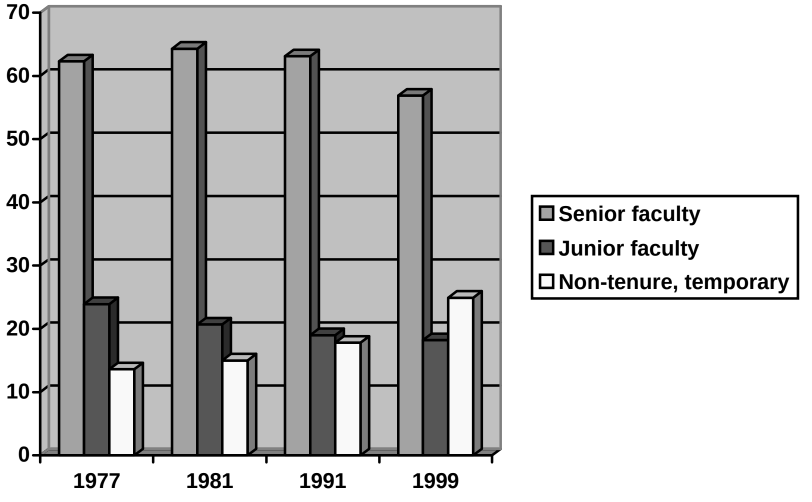
Source: OECD, R&D Databases, March 2003.

Figures 5.8c, 5.8d, 5.8e. Share of R&D expenditures per researcher by sector of funding and employment



Source: OECD, R&D Databases, March 2003.

Figure 5.9. Share of PhD scientists and engineers in permanent and non-tenured, temporary employment, United States, 1997-1999



Note: Senior faculty defined as full and associate professors. Junior faculty defined as assistant professors and instructors. Non-tenure, temporary includes all post-doctorates, part-time instructors and other full-time faculty.
Source: NSF Science and Engineering Indicators, 2002.

A similar trend is observed in Australia where the share of temporary or casual positions for research only, and research and teaching staff, in the higher education sector increased between 1995 and 1999.

Table 5.3. Employment in Australian higher education research, 1995 to 1999

Year	Function						Total		
	Research only			Teaching and research					
	Full-time	Fractional full-time	Actual casual	Full-time	Fractional full-time	Actual casual	Full-time	Fractional full-time	Actual casual
1995	6 545	1 065	457	22 752	1 509	144	29 297	2 575	601
1996	6 664	1 093	489	23 312	1 592	141	29 976	2 685	630
1997	6 696	1 154	617	22 357	1 649	107	29 053	2 802	725
1998	6 504	1 115	631	21 940	1 817	157	28 444	2 933	788
1999	6 623	1 133	711	21 722	1 644	391	28 345	2 777	1 102

Source: Selected Higher Education Statistics Database, Department of Education, Training and Youth Affairs, Canberra, 2001.

The rising costs of employment at individual universities, as well as the slow career paths of researchers, have also increased the reliance on temporary posts to perform research. In Italy, the number and share of temporary researchers/professors has increased in recent years. Temporary researchers/ professors at universities represented 30.6% of employment during the academic year 1998-1999. However, an increasing share of temporary posts also implies a growing uncertainty for researchers concerning the future of their careers. In the National Research Council (CNR), the largest Italian public research institution, the share of temporary researchers vs. full time permanent posts was 21.6% vs. 78.4% in 2000. Data for 1999 show an even greater share of fixed-term posts among new hires, accounting for 394 of 506 new positions. The situation changed in 2001-02 when a recruiting plan was introduced and some 1 000 new positions opened; in many cases these positions were filled by former temporary contract holders. The following table shows the breakdown of CNR personnel by contract typology and gender.

Table 5.4. Temporary and permanent employees in Italian National Research Council (CNR) by activity and gender, 2001

Type of contract	Men	%	Women	%	Total	%
Payroll researchers	2 606	95.0	1 479	93.8	4 085	94.6
Term contract researchers	136	5.0	98	6.2	234	5.4
Total researchers	2 742	100	1 577	100	4 319	100
Payroll technicians	1 911	97.5	587	86.0	2 520	95.3
Term contract technicians	49	2.5	56	14	105	4.7
Total technicians	1 960	100	683	100	2 643	100

Source: CNR, 2003.

Mobility: a challenge among senior researchers and in public research institutes

Mobility stimulates a better match between supply and demand and contributes to increase the diffusion of scientific knowledge. There is also some evidence that the greater mobility of workers correlates with multifactor productivity growth. Mobility is a high priority in countries where there is a perception of low movement and where public employment systems are less flexible. Addressing mobility, however, is a question of both incentives and regulatory conditions. Competitive funding for research in the United Kingdom is used to foster mobility of scientists at universities. Flexible employment arrangements at "centres of excellence" are seen as one way to foster researcher mobility in Italy: temporary staff is jointly recruited by participating institutions. In 1997 Japan also introduced a fixed-term system in employment at universities and the national testing and research institutes which, while presenting other challenges, also fosters mobility.

In the Netherlands, encouraging mobility is a new objective of universities where, as a result of decentralisation, they have been given greater control of human resource management. The scope for fostering mobility differs between research institutions and universities. Support for mobility has traditionally been strong at the Dutch Foundation for Fundamental Research on Matter institutes and the TNO institutes. Mobility is also lower or higher depending on scientific discipline; data on Dutch mobility show that researcher mobility is lower in the humanities and the social sciences. As mobility generally concerns younger researchers, promoting mobility of older researchers is another challenge.

Ageing of researchers in the public sector

Ageing of researchers in the public sector poses an additional challenge for policy makers. Ageing is defined here as a change in the age distribution within the research community in higher education and public research institutions characterised by stronger growth among older cohorts. An ageing research population may hamper research and innovation. The transfer of knowledge from educational institutions to working life or academia might be also hampered if fewer and smaller cohorts of young people choose scientific careers.

According to the findings of the OECD questionnaire, the age structure of the research community in the public sector seems to be of concern in Australia, Italy, the Netherlands and to a certain extent Norway and Sweden, but to varying degrees and limited to specific sectors and areas. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia’s largest scientific research agency finds it increasingly difficult to attract bright young scientists into ICT and engineering fields. In Italy, the concerns are poignant given the concentration of R&D in the government and higher education sectors. It is also of some concern in the Czech Republic and Hungary as a result of outward migration and the economic transformation of those economies. In Canada and Germany the retirement of a significant number of researchers in the next decades is considered as an opportunity for renewal and re-orientation of the existing structures and institutions rather than a cause for concern. In France, the United Kingdom and the United States, a rather balanced age structure of the science workforce in the public sector seems to prevail.

Countries where the ageing of researchers is viewed as a problem

In Australia, the share of researchers (full-time equivalent academic classifications) aged over 50 significantly increased in only two years: accounting for 33.2% of the overall academic workforce in 1998, this figure rose to 36.6% in the year 2000. In the same time, the proportion of university staff aged 45 or more rose from 36% to 47%. In contrast, only about 6% of staff was aged less than 30 years in 2000.

A similar pattern can be observed in Italy, where ageing of the S&T workforce in the public sector is aggravated by the fact that more researchers are employed in the public research sector than in the private one. Approximately a quarter of researchers in the Italian public sector is age 50 or older and the age classes 30-39 and 40-49 are becoming the leading classes in the public R&D sector while the number of employees younger than 25 is steadily shrinking. Whereas the situation at the largest public R&D centres has improved due to an increased pace of hiring after several years of very poor recruitment activity, the situation in higher education seems to be more preoccupying. The share of staff in higher education over the age of 50 has increased from 23% in 1991 to 35% in 1999, a similar percentage to Australia. In one year (from 1998-99 to 1999-2000), the average age of academic members in Italy rose from 50.5 by 0.8. The age profile of full professors (all disciplines) indicates that approximately 70% are over 50. A substantial share of professors is thus expected to retire in the next years.

The age distribution of researchers in the public sector is of concern both in the Czech Republic and Hungary. According to recent studies, the average age of professors in Czech higher education is over 60 and only about 5% of professors are younger than 50. With regard to associate professors, the situation is slightly better with approximately a quarter younger than 50 and a third over 60. The majority of researchers-in-chief in the Czech Republic are in the 44 to 61 age bracket with a peak at the age of 57. A similar situation can be observed in Hungary where 35% of researchers were over 50 in 1998.

In 2001, the average age of research staff in national universities and colleges in Japan was 45.8 years, with an average of 54.9 years for university professors and 44.2 years for assistant professors. Almost 80% of all professors in national universities are over 50 years old, whereas professors aged 45 and under amount to 5%. In the Netherlands in 1998, academic research staff of 50 years and older were over-represented, with 68% of professors and 57% of associate professors pertaining to this age bracket. As is the case in Australia and Italy, a large share of these researchers will reach retirement age in the next years. In contrast to Australia, however, where shortages are expected to be concentrated in certain areas, extrapolation of recent changes in academic staff in the Netherlands indicates shortages in all disciplines and positions, amounting to 12% of the current staff positions by 2008.

In Swedish higher education, almost 75% of professors are over age 50, with a majority in the 55 to 59 age bracket. A considerable proportion of current holders of research degrees is over 55. In broad terms, half of all professors and 30% of senior lecturers are expected to retire in the next decade. In addition to these retirements, increasing numbers of students as well as increasing resources allocated to research might create the need for additional recruitment of teachers and researchers. A 2000 Swedish government bill therefore stated that there was "an increased need for trained researchers". In contrast to other countries, the ageing of researchers in the Swedish public S&T sector is of concern only to a certain extent because a large share of PhD graduates – approximately 45% in 1999 – stays in higher education institutions and a quarter usually takes up a position in the public sector.

Countries where the ageing of researchers is viewed as a "manageable" problem

According to the OECD questionnaire, the ageing of the S&T workforce in the public sector is a concern in Canada and Germany but one that is manageable. In Canada, it is estimated that 5 000 ageing S&T faculty will have to be replaced over the next five years. In some research institutions in Germany, up to 40% of the researchers are expected to retire in the next decade and a similar situation can be observed in higher education: between 2001 and 2005 the share of retirements of university professors in mathematics, natural sciences and engineering in overall retirement may amount to 38%. Figure 9 shows that the share of research scientists in the 50-59 year age bracket as a share of researchers increased significantly between 1991 and 1999 while at the same time, the share of 30-39 year-olds and researchers under 30 decreased significantly. In Germany, the average age of professors was 52.6 in 2000. In Canada, additional researchers will also be needed as a result of increasing enrolment. A recent report by the Council of Science and Technology Advisors pointed out that in addition to the replacement of ageing faculty, a highly skilled workforce in biotechnology and electronic business needed to be educated in order to meet future demand. In Germany, shortages seem to occur above all in disciplines such as ICT or biotechnology and in 2000, the *Deutsche Forschungsgemeinschaft* (DFG) observed emerging difficulties filling the vacancies for doctoral training as well as research positions in engineering and the natural sciences. Furthermore, with the increased hiring of highly skilled young researchers by universities in the years to come, increased competition between the private and the public sector is expected.

Countries where ageing of researchers does not currently seem to be a problem

In France, the United Kingdom and the United States, the ageing of the science workforce does not seem to be a pervasive problem today, with the exception of the disciplines of mathematics and physical sciences in the United Kingdom. Whereas an overall 16% of academic staff across science-related disciplines in the UK is older than 55, the percentage aged 55 and over in mathematics has risen from 18% to 25% between 1994-95 and 1999-2000 and in physical sciences over one quarter of academic staff is older than 55. Recent years have seen some weakening in the demand for places in these disciplines, with implications for the quantity or quality of supply.

In France, the average age of researchers in the public sector has slightly decreased in recent years with 46.5 in 1998 compared to 46.7 in 1996. The discipline with the highest average age (50.3) is medicine, whereas the youngest researchers can be found in mathematics (44.7 years) and engineering (43.2 years) due to increased hiring in the 1990s. In higher education where 74% of the research personnel are employed, the average age of researchers constantly decreased from 47.3 in 1993 to 46.7 in 1999. In the United States, the mean age of full-time faculty decreased by more than a year from 44.7 in 1981 to 46.5 in 1999. The greatest density of full-time doctoral S&E faculty in the US occurs between ages 45 and 54. In 1999, approximately 23% of full-time academic doctoral S&E faculty were 55 or older compared to 12% in the overall S&E workforce. However, PhD holders generally enter academic faculty later and a long-term shift toward greater use of non-faculty appointments, both as post-doctorates and in other positions can be identified.

What are the reasons behind the ageing of the public research workforce?

Some of the factors contributing to the ageing of the public research labour force are demographic shifts, decreases in recruitment of new faculty and a declining interest in scientific careers as well as the attractiveness of non-academic employment opportunities. In some cases, cuts in institutional funding have led to a situation where tenured positions are often not advertised for replacement. As a result, the share in tenured positions held by younger scientists is decreasing. Ageing patterns may also be aggravated by rigid or hierarchical organisational structures of universities and public research institutions, which might pose barriers to the promotion of young researchers and the renewal of faculty.

Demographic trends coupled with the retirement of the baby boom generation

The age structure of the science workforce is influenced by the demographic structure of the overall population as countries with relatively young populations will generate a relatively larger supply of S&T graduates. Population trends seem to indicate a major demographic shift with sharpest rises in the overall age of the population to occur in Australia, Czech Republic, Italy and Japan. The overall demographic shift might result in staffing problems in the public sector in the next two decades. Its rapid expansion from the 1960s on contributed to a substantial rise in the number of older researchers – in academia as well as public research institutions – which are expected to retire in the next two decades, leading to ageing scientific workforce in the public sector. In Sweden, the full replacement of retiring government employees (all levels) might absorb up to two-thirds of new labour force entrants from 2005 to 2015. In France, the retirement of researchers in the public sector will gain momentum from 2004 on: between 2004 and 2016, approximately 4.2% of the staff is likely to retire per year, a significant increase compared to the 2.5% for the period 1999-2004. 2011 and 2012 are considered peak years with 5% of researchers to be replaced yearly. However, attributing the constantly increasing age of researchers in some OECD countries to the demographic framework conditions may be too limited a view. In fact, the demographic downturn may be partially offset by an increased participation rate of young people in higher education, including science-related subjects, observed in recent years. France, Germany, and the United Kingdom have almost doubled their S&E doctoral degree production in the past two decades. In the United States, overall academic employment of doctoral scientists and engineers was quite robust in recent years – hiring in non-faculty ranks increased by 62% and by 6% in full-time faculty – and seems set to continue in the future.

Promotion structure in the higher education sector

Rigid hierarchical structures in the public sector might contribute to an ageing workforce. In Italy, the preoccupying age structure of researchers in academia seems to be partly due to a strict implementation of a rule prohibiting the recruitment of researchers who do not hold a five-year university degree. In Germany, the average age of professors is 52.6, which is partly due to the long elaboration phase of the “habilitation”, a postdoctoral dissertation required to obtain professorship. The average age for conferment of the “habilitation” in 1999 was 39.8. In the Czech Republic as well, the rank of professor is only awarded after the successful completion of a “habilitation”, thus delaying the entrance of young researchers in scientific academic careers. The age structure in the Japanese public sector might be influenced by the fact that promotions are still decided on the basis of seniority rather than performance.

Competition with the private sector and brain drain towards other countries

In the Czech Republic, ageing of the science workforce in academia may be due to the fact that university teachers aged 60 or over in the humanities who reassumed their duties after political rehabilitation account for a large share of the university staff. In addition, many researchers have left Czech Republic in the years after the political restructuring to pursue opportunities abroad. Recent surveys indicate that the major source of motivation in the Czech Republic seems to consist in the economic yields associated with a scientific career, which still seem to be more advantageous in the private sector or abroad. The brain drain of researchers in Hungary is rather oriented towards the private sector, where better salaries and research environments are offered. The decline in the supply of researchers in the 1980s and 1990s has aggravated the increase in the average age of R&D personnel.

Lack of investment in research infrastructure and funding of PhDs

The propensity of young graduates in S&T to stay in the public sector is influenced by the availability of funding and access to PhD training. In most OECD countries, PhD degrees are preconditions for employment in higher education. Without funding, attempts to increase the number of doctorates in S&T may only result in higher drop out rates.

Renewing the public research sector: main policy responses in OECD countries

In order to maintain current levels of research staff in the public sector and to attenuate the effects of an ageing scientific workforce witnessed in several OECD countries, a sufficient inflow of highly skilled researchers in key areas will be required. Thus, attracting young scientists to a career in the public sector by improving the attractiveness of the public sector is a challenge for policy makers. Salary levels and the quality of the research infrastructure are important incentives for researchers to pursue a career in the public sector. In addition, the availability of PhD places and funding for doctorates have a significant influence on the decision of young researchers to enter a career in the public S&T sector. Initiatives for renewal of the public sector have been undertaken in many OECD countries: graduate education has been reformed, funding for PhD training has been increased and reforms in the overall structure of the public sector, *e.g.* changes in the tenure structure, have been undertaken.

Increasing the supply of highly skilled researchers

In order to increase the supply of young graduates in scientific areas, the Australian government has provided AUD 151 million over five years for an additional 2 000 university places each year with a priority in biotechnology and ICT to address shortages in these areas. In the United Kingdom, the government and research councils have increased funding for PhD studentships and committed to providing further resources for higher education to recruit and retain academic staff in science and engineering. The Dutch government has launched a special programme, the so-called "Renewal Impulse", which aims at retaining more young researchers in the public science system. In the period 2000-2010, 1 000 researchers will be selected for this programme. Furthermore, foreign students will be targeted for science-related careers in the Netherlands. In Germany, reforms aimed at shortening the doctoral programmes have been launched. Additional measures include a strengthening of the positions of junior staff in German universities and increased funding for research in high demand areas. In Sweden, during the "Promotion Reform" launched in 1999, 1 100 lecturers in higher education were promoted to the rank of professor. The Czech government in their National Research and Development Policy committed to improving the material situation of young R&D workers and to increasing the funding for talented young researchers. In order to attract graduates into public research the Hungarian government increased the salaries of public sector researchers, especially for young graduates, in 2001.

Improving the attractiveness of the public sector

Salaries and research conditions are key incentives for young researchers to pursue employment in the public sector. They are also important in preventing an internal as well as an international "brain drain". The quality of graduate education is seen as one of the reasons for the attractiveness of the US system: the existence of a dense network of high-quality research facilities allows young researchers to pursue high-quality research close to their degree field. The introduction of Integrative Graduate Education and Research Traineeship (IGERT) programmes offering stipend support to graduate students to engage in research in emerging multidisciplinary areas in S&E have contributed to this development. In Hungary, closer co-operation with industry, *e.g.* the establishment of R&D labs in universities, aims at improving the research environment of young researchers.

Increasing the contribution of older researchers

The experience of older researchers is important for transferring knowledge and know-how to new researchers. The challenge for policy makers is to attract a sufficient number of young researchers while offering flexible work arrangements for older researchers. Reforms aimed at lengthening work life for older researchers (*i.e*. in the 55 to 64 age group) might lead to a further increase in the share of scientists in this age group, but would also contribute to an increase in the total number of researchers in the public sector. In most OECD countries, strong incentives for early retirement exist. Increased flexibility with regard to the work time or retirement schemes of older researchers might have positive effects on both the age distribution of the overall scientific workforce in the public sector and the knowledge diffusion between generations. Part-time work of older scientists might lead to better career prospects for young scientists. In areas where a growing demand for scientists is forecasted and the supply of sufficient numbers of new researchers is not yet assured, such flexible arrangements might contribute to a smooth adjustment of research systems.

Repatriation schemes: mobility with strings attached

Promoting mobility without endangering the national scientific base (*i.e.* a brain drain) is a key goal of policy makers. Support for international mobility has traditionally been focused on supporting the temporary outward mobility of post-docs and researchers, but there is new emphasis on attracting foreign researchers in order to increase supply and access specialist skills. Most OECD countries maintain schemes to help students and post-doctorates to study/work abroad on a temporary basis. At the EU level, the European Commission schemes such as ERASMUS (for students) and Marie Curie fellowships for researchers aim to increase intra-European mobility. As part of the ongoing reform of Norwegian higher education, students are encouraged to spend at least one term of their course studies at a foreign institution. The home institution facilitates such mobility and receives financial rewards for the international exchange of students.

Large immigration countries such as Australia, Canada and the United States have long relied on foreign students and researchers to meet demand in the national science system and to supplement innovative capacity. Especially in the 1990s, US academic institutions and the US S&E workforce as a whole have relied on foreign-born (often US-educated) persons; in some engineering and computer science fields, they exceed one-third of the total. In addition, a number of visa classes (in addition to the H1B temporary visa for highly skilled professionals) facilitate the temporary move to the US of highly educated personnel, and there is discussion in the US Congress about liberalising spousal work permit rules. In the past two years, however, Germany and the United Kingdom, and to a lesser extent France, have also made the attraction of top foreign students and researchers a priority (see Box 5.4).

Box 5.4. Science and technology policies to retain and attract scientific talent

Attracting foreign and expatriate talent. The UK government, jointly with the Wolfson Foundation, is funding a Research Merit Award scheme run by the Royal Society and worth GBP 20 million over five years. This offers institutions additional funds to increase the salaries of researchers whom they wish to retain or recruit from industry or overseas. In Germany, the Humboldt Foundation and the German Federal Ministry for Education sponsor a EUR 22 million Research Award the "Sofja Kovalevskaja-Preis" to help young scientists from overseas as well as expatriate German scientists carry out research in Germany for a period of three years. A single award can be as much as EUR 1.2 million. France has long supported the temporary stay of foreign researchers but a new initiative launched in 1999 aims to attract some 200 young researchers each year, in particular from emerging economies such as Brazil, China, Mexico and South Africa.

Providing tax incentives to encourage recruitment of foreign personnel. Denmark, the Netherlands and Belgium have passed laws to alleviate the tax burden on foreign experts and highly skilled workers. In Quebec, the government is offering five-year income tax holidays (credits) to attract foreign academics in IT, engineering, health science and finance to take employment in the provinces universities. In 2001, Sweden adopted similar policies for highly skilled workers who live in Sweden for less than five years.

Repatriation schemes for post-docs and scientists. The Academy of Finland has a programme to ease the return to Finland of Finnish researchers who have been abroad for a length of time. In Austria, the Schroedinger scholarships help returning Austrians integrate into scientific institutions. Germany's Ministry for Research and Education (BMBF) has also launched a new programme in 2001 to attract the return migration of German researchers overseas. In support of the repatriation of Canadian postdoctoral researchers, the Canadian Institutes for Health Research offers a supplementary year of funding to Canadians and permanent residents who are recipients of either the Japan Society for the Promotion of Science (JSPS) Postdoctoral Fellowships for Foreign Researchers or Wellcome Trust/CIHR Postdoctoral Fellowships. In order to be eligible for the "Canada Year" funding, training must take place in a Canadian laboratory. Italy has recently introduced the "Reverse Brain Drain Project", which is aimed both at attracting foreign professors and scientists and at facilitating the repatriation of Italian scholars abroad. In 2002, the Italian government provided EUR 20 million in additional funding for new positions. Over 100 foreign scholars have been employed in Italian universities, most of them in the fields of mathematics and physics (51%) and engineering. Also, 63 Italian scholars benefited from the project. The Italian government is continuing the project in 2003.

Leveraging immigrant and diaspora networks. Such networks do not only exist among emigrants from developing countries; Swiss scientists in the US have created an Internet network and directory (*Swiss-list.com*) to link Swiss scientists and post-doctorates working in the US to colleagues in Switzerland. The French foreign ministry sponsors meetings between French post-doctorates working in US research institutions and French companies.

Source: OECD, Ad Hoc Group on Steering and Funding of Research Institutions questionnaire results; *International Mobility of the Highly Skilled,* 2002.

Stimulating intersectoral mobility

Linkages between the research sectors exist at both formal and informal levels and may promote intersectoral mobility. Joint location of university and public institute sectors is common in some countries. In France, many of the laboratories of the *Centre National de Recherche Scientifique* (CNRS) are located on university campuses and consequently, staff from both sectors may exchange experiences in the workplace. With the exception of a few units, these are administratively "mixed" labs which are both part of the CNRS and the universities, with researchers paid by either institution. University staff must teach in addition to conducting research in the lab. Nearly all CNRS labs are staffed by a mix of university and permanent CNRS staff, whether located on university campus or not. In Germany, the Max Planck Society (MPG) has followed a policy of establishing an institute in proximity to a university with a focus on a similar research area, thus enabling researchers to undertake joint work, but from different bases. Recently, however, jointly located teams have been established within universities. Also, directors of institutes with major networks often hold additional posts at local universities. Research training is also a key area of collaboration between the sectors. Although only universities have the authority to award research degrees, many doctoral students who work in PRIs in Norway use institute staff as supervisors for their theses.

Reforms to public sector employment

Across OECD countries, universities and education systems are gaining in autonomy vis-à-vis education and research ministries. In federal countries, such as Canada, Germany and the United States, the trend toward autonomy is a natural consequence of decentralisation in policy making and funding. Universities and public research organisations have greater freedom with regard to human resources management including the hiring and setting of salaries. This freedom is relative however and is to some extent limited by the amount of core funds and employment agreements with the social partners. Shifts in funding also affect employment structure and priorities. The general increase in the reliance of institutions on external (non-intramural) research has increased the number of researchers whose funding depends on external funds.

Box 5.5. Promotion schemes for researcher mobility and co-operation with industry

Austria maintains mobility promotion schemes such as “scientists for the economy” and the mobility of junior researchers is promoted through the Industrial Promotion Fund. The Social Science Fund (FWF) has envisaged the creation of “Graduate Programme (WK)” centres for the education of highly skilled young scientists. They will be established in scientific areas where the productivity in Austria is exceptionally high.

Australia’s Linkage Projects scheme, which is administered by the ARC, supports collaborative research projects between higher education researchers and industry. Under this scheme, support can be provided by Australian Postdoctoral Fellowships Industry (APDI) for researchers with less than three years’ postdoctoral experience; and Australian Postgraduate Awards Industry (APAI) for postgraduate research students studying towards a masters or PhD.

Canada. The Natural Science and Engineering Research Council sponsors postgraduate training in industry through various schemes including scholarships for training masters and doctoral students in industry and fellowships for the hiring of a recent PhD graduates by firms.

France. The Ministry of Research fosters PhD training in a research company by subsidising up to half of the corresponding salary costs to the firm. Subsidies for post-doctoral positions in SMEs are available to young PhDs without industry experience.

Hungary. The knowledge flow and mobility between research institutes, higher education and industry will be promoted by the foundation of CRCs.

Japan’s latest Basic S&T Promotion Plan outlines a series of regulatory reforms to the labour market for public, sector research, aims to improve mobility between the public and private research sectors. The Centres for Co-operative Research in 56 national universities carry out joint industry-public research as well technical training of researchers from private companies. A main goal is to create critical mass by canalising individual researcher collaboration into institutional level linkages.

Korea. The Korean Institute of Science and Technology (KIST) has promotional schemes to grant temporary leave to researchers to undertake entrepreneurial activities.

The Netherlands’ KIM scheme, which promotes the movement of S&T personnel to SMEs, has been successful. Furthermore, under the WBSO Act to promote R&D, small firms are allowed a tax deduction for the labour costs of R&D staff.

Norway has set up special programmes to stimulate mobility from universities/ research institutes to the private sector and to make industry-relevant research more attractive, *e.g.* the FORNY programme, which is entering its third phase.

Portugal. The Ministry of Science and Technology runs a programme to help the placement of new PhDs in firms by subsidising salaries for two years.

Sweden. The NUTEK competence centres at universities promote collaboration between public researchers and those in firms which may help break down non-regulatory barriers to mobility.

Box 5.5. Promotion schemes for researcher mobility and co-operation with industry *(continued)*

United Kingdom. The Faraday Programme promotes a continuous flow of industrial technology and skilled people between industry, universities and intermediate research institutes. In 1999, it was expanded with a focus on entrepreneurial activities and research commercialisation. In addition, the long established Teaching Company Scheme finances an associate to work on project in a semi-academic or company environment for two years.

United States. The Grant Opportunities For Academic Liaison with Industry (GOALI) initiative of the National Science Foundation (NSF) funds: *1)* faculty, postdoctoral fellows and students to conduct research and gain experience with production processes in an industrial setting, *2)* industrial scientists and engineers to bring industry's perspective and integrative skills to academia and *3)* interdisciplinary university-industry teams to conduct long-term projects. There are no requirements for matching funds from firms for GOALI projects performed in universities. University-industry IPR agreements must be made up front and submitted for funding consideration.

Source: OECD Ad Hoc Group on Steering and Funding of Research Institutions questionnaire results, *Benchmarking Industry-Science Relationships*, 2002.

As universities have gained greater autonomy, they have been able to better determine their human resource needs and employment conditions. In Sweden and Finland, both countries where membership of academic staff in trade unions is high, the responsibility for pay scales and working conditions has shifted: the national government sets framework conditions while local bargaining between institutions and local branches of trade unions regulate further details of employment conditions. In Sweden, this is supplemented by individual bargaining concerning salaries and teaching loads. In Finland, additional research allowances can be paid depending on the professor's responsibilities for researcher training. In the Netherlands, responsibility for the terms of employment has been transferred to the universities and research organisations. While universities in Belgium (Flanders) have a large autonomy in selection of candidates and new post creation, the government sets the salary scales. Germany is moving to performance-pay systems for university researchers in order to gain more flexibility with regard to salaries for top researchers. In Australia, CSIRO has the responsibility and freedom to negotiate new posts and salaries, but the government does not fund salary increases, so any increases must be offset by lower staff numbers or outside revenues. In general, public institutions have less leverage than private institutions in increasing salaries to attract top professors and researchers. Competitive funding from research agencies or special grants from central governments and from industry thus becomes a source of leverage.

Box 5.6. Improving the attractiveness of the public research sector

Raising salaries and funding. The UK government plans to increase the salaries of post-doctorates by 25% and increase funding for the hiring of university professors. The Czech Republic has implemented schemes to provide additional financial support to young R&D workers up to 35 years of age. The European Commission has doubled the amount of funding devoted to human resources in the Sixth Research Framework Programme to EUR 1.8 billion in order to improve the attractiveness of the European research area. The Backing Australia's Ability initiatives include establishing prestigious Federation Fellowships worth AUD 225 000 a year each. These are aimed at attracting and retaining leading researchers in key positions, and up to 125 Federation Fellowships will be awarded with total funding of AUD 112.3 million over the next five years from 2002 to 2006. The Prime Minister announced the first fifteen Federation Fellowships on 25 September 2001. In addition, the number of Australian Postdoctoral Fellowships will be doubled from 55 to 110 and remuneration of these positions will be improved, with total funding of AUD 50.1 million from 2002 through 2006.

Employment reforms and post creations. Germany is launching the development of junior professorships, which are temporary posts to attract young researchers to university employment in some 30 universities. These junior professors will be tied to research departments rather than to professors, which is currently the case for new academics. In 2001, the BMBF provided EUR 6.1 million. Junior professors are granted three-year employment contracts, renewable once. In Austria, a major reform has taken place in the employment of the university system. As of January 2004, new university staff will not have civil servant status and employment contracts will be limited (four to six years) after which scientists/researchers will have to apply for new contracts, depending on the number of available posts. Tenure will only be granted to full professors. Currently 21-23% of total university staff are tenured professors. Norway aims to increase the number of doctorates by 60% by 2007 in order to secure recruitment to research in academia and industry, international recruitment and the recruitment of women. In France, the some 700 teaching-researcher posts were created between 1997 and 2001 to strengthen the public research sector and attract post-doctorates from overseas. The Dutch Ministry of Education, Culture and Science and the Ministry of Agriculture, Nature Management and Fisheries, together with the universities, have launched the Renewal Impulse scheme to retain bright young researchers in the public science system. The programme focuses on three stages of the scientific career up to professorship: young post-docs, experienced post-docs and top talent. In the first round (2000) NOW placed 43 candidates. The aim is to select over 1 000 researchers between 2000 and 2010.

Source: OECD (2002) Ad Hoc Group on Steering and Funding of Research Institutions questionnaire results.

Conclusions

Ensuring an adequate supply of human resources in science and technology remains a major policy goal of OECD countries. Despite an overall and sustained increase in tertiary level graduates, with greater participation of women, the relative share of graduates in sciences and engineering fields has fallen in several OECD countries although it has increased in others. In some countries, the decrease in the share of S&T graduates appears to be concentrated in fields such as physics, chemistry or mathematics. Women make up larger numbers of university graduates, even at PhD level, but remain under-represented in S&T fields and employment. Furthermore there are concerns, and some evidence, of a waning interest in science education among the youth. There is a need to collect evidence as to whether decreases in S&T graduates are resulting in shortages for researchers, but countries are nevertheless moving to make S&T education more attractive by redesigning curricula, increasing expenditures on higher education and enhancing the quality of science teachers.

This chapter has shown that trends in the education and employment of scientists and researchers that have been observed in larger OECD countries - such as the rise in temporary academic and researcher employment - are also taking place in smaller countries even if the limited data is not fully comparable on a cross-country basis. It has also shown that changes in funding, the growth in multidisciplinary research and increased interaction with industry are all exerting greater pressure for flexibility and changes in the training and employment of researchers. Partnerships with industry and higher education in training are increasing and this emerged from descriptions of PhD training programmes and postdoctoral employment. With regard to PhD training, most seems to be financed by scholarships and institutional funds, which in many countries are made available to foreign students, and several countries have recently implemented special programmes to increase funding.

Mobility among young researchers is to some degree institutionalised in training mechanisms, especially for PhDs and post-doctorates. In addition, in many countries limits on hiring of young graduates by their graduating institution foster involuntary mobility (*e.g.* graduates must look for work at other universities). It is well known that mobility decreases with age and little is known about the mobility (or lack of) among older researchers except insofar as low turnover among permanent staff and faculty mean fewer job opportunities for younger researchers in the absence of new positions. Although salaries and wages are important incentives that increase the attractiveness of academic and research employment, the lack of data on earnings by researcher occupation make it difficult to assess whether in fact S&T graduates are turning away from research careers because of low pay and/or poor working conditions.

The issue of ageing is likely to stay with us in the coming years as more faculty and researchers retire. In addition demand for replacements, the rapid expansion of ICT has created an additional demand for young scientists. The analysis has shown that in most OECD countries where ageing is a perceived as a problem, there seems to be no formal policy response to specifically address the ageing phenomenon. Policy responses vary between countries due to differences in the structure of their science systems, their overall educational and research policies and demographic composition. In France, for example, the increased participation of women in science disciplines seems to have had a favourable impact on the age distribution of researchers in the academic sector. The majority of policies aim to fill the supply pipeline with young, highly skilled researchers. Providing a high-quality research infrastructure, attractive salaries and access to funding seem essential. Mismatches in S&T workforce supply and demand in the next decades might also be offset by creating incentives for older members of the science workforce to stay on. This might also increase the flexibility of the workforce and contribute to better knowledge transfer from generation to generation.

Better quantitative and qualitative statistical information on human resources in science and technology is needed in order to detect potential mismatches in supply of and demand for S&T personnel and to verify whether decreases in enrolment or S&T graduates are actually resulting in labour market shortages. Data could also be used to anticipate potential aberrations in the age structure of the public research sector. However, many factors such as the size of budgets for scientific research and other policy decisions come into play here, making these forecasts difficult. As the lead times for training and developing highly skilled researchers are very long and inextricably intertwined with cost issues, the provision of this data could contribute to better re-allocation of resources, thus providing better framework conditions for the training and retention of human resources in science and technology.

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