Investing in Innovation

A strategy for science, engineering and technology

July 2002

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PREFACE

In an increasingly knowledge-driven global economy invention and innovation are critical to Britain's long-term competitiveness. This requires a virtuous circle of innovation: from the very best research in science, engineering and technology in universities and science labs to the successful exploitation of new ideas, new science and new technologies by businesses.

The 2002 Spending Review announced the largest sustained growth in science expenditure for a decade – £1.25 billion extra a year by 2005–06. This document – building on the commitments we made in the Science and Innovation white paper of 2000, *Excellence and Opportunity: A science and innovation policy for the 21st century* – sets out the strategy we will adopt to ensure that our science and engineering base grows and flourishes and makes an increasing contribution to national prosperity. Specifically, we will:

- Establish a substantial and dedicated stream of capital for universities, worth £500 million per year by 2004–05, to develop their science research infrastructure and to allow them to plan for the future with certainty;
- Provide substantial new resources to the Research Councils from 2005-06 to enable them to make a more realistic contribution to the full costs of the research that they sponsor in universities;
- Increase the money available to the Higher Education Funding Council for England for the research component of university block grants;
- Boost the volume of basic research through sustained real annual growth of 5 per cent in funding for Research Council programmes and equipment;
- Expand the Higher Education Innovation Fund, with funding to stimulate enterprise from research across the regions, to over £90 million per year by 2005–06;
- Invest an additional £50 million per year by 2005–06 to support collaborative research and development on key emerging and pervasive technologies such as nanotechnology; and
- Improve the pay and training of scientific postgraduate researchers, and enhance technology, mathematics and science education in our schools, colleges and universities.

And the Government, as a major user of research and scientific advice, will take action to ensure science in government departments is of the highest possible standard and is used effectively in the delivery of policy and public services.

For far too long British science has been denied the opportunity to develop. We now have the chance to turn this around: to make more British inventions become British manufactured products, creating jobs and prosperity for all.

The Rt Hon Gordon Brown, MP | The Rt Hon Patricia Hewitt, MP | The Rt Hon Estelle Morris, MP

EXECUTIVE SUMMARY

Science into innovation: realising the potential

0.1 Innovation is at the heart of productivity growth and social gain. Science makes an important contribution to providing the raw material for innovation – new knowledge and ways of understanding our world, new problem solving techniques, new technology and businesses, but above all highly educated people. Together, the generation and exploitation of science enable us to do more and to do it better: to deliver economic growth and enrich the quality of life, to widen choices for industry and individuals and improve the way we meet our current and future needs. Startling advances in communications, information, health and basic technologies are now converging to magnify the pace of scientific and technological change and the productivity of scientific research. Now more than ever before, investment in science accompanied by matching investments in technology and innovation offers the prospect of sustained social and economic dividends.

0.2 The potential of scientific and technological discoveries will only be realised, though, if they can be effectively translated into innovation – new products, processes, services and systems. A vibrant innovation system is the key to reaping the gains from research, connecting science and technology with developments in market demand and social needs. The individual entrepreneurs, businesses, and investors are the essential catalysts who convert science and technology into new ways of meeting economic and social needs. They translate ideas into commercial reality. Success in innovation can in turn provide the motivation for focused research, attract talented people and inspire public confidence in science and technology as well as providing the extra value added which can resource future increases in scientific research and business R&D. It is only through innovation that science and technology can benefit our economy and society.

0.3 The UK has a long tradition of scientific excellence and technological invention but has been much less successful in capitalising on earlier waves of scientific and technological breakthroughs. We must not allow this opportunity to elude us now. In previous decades, weak links throughout the innovation process have held back delivery of economic benefits. Excellence in scientific research had been insufficiently funded, weaknesses in education and training meant that many firms lacked people who could interface with the science base and exploit new technology. Too often, senior management failed to appreciate the importance of science and technology to their businesses. Firms were insufficiently committed to innovation and the exploitation of new markets, partly because the competitive spur to innovate was not as sharp as it should have been. Industry's own investment in technology and innovation was undermined by the instability of the economy as a whole, which damaged investment incentives. Early innovation gains were not diffused through the economy as rapidly as in other countries, contributing to the UK's relative productivity decline.

0.4 Investment in innovation is now embedded in a wider strategy for raising the sustainable growth rate of the economy through productivity gains. We have laid strong foundations of macroeconomic and structural reform. Improvements in the investment climate, the opportunities for enterprise, and the acquisition of skills provide a more supportive environment for the exploitation of science, the development of new technology and subsequent investment in innovation, which in turn will boost productivity growth. This document sets out how the science, engineering and technology research strategy is intimately connected to the Government's economic goals.

Investing in science capital and capacity

0.5 This strategy addresses the two key challenges facing UK science and technology: renewing, in a sustained manner, the physical and human capital stock which underpins our growing research endeavour; and investing in capacity to exploit the burgeoning opportunities for new science. It also addresses the way Government departments obtain and use research and scientific advice.

0.6 Because the benefits from innovation spread right across the economy and society, investment in this arena needs a collective input from all the major research funders: Government, business and research charities. The Government has the primary responsibility as lead investor in basic scientific research, and in sustaining the science education and training infrastructure. For this partnership to work well, there must also be greater clarity about the respective roles and contributions of companies and charities to research funding.

0.7 **The Government will therefore take the lead in providing a new dedicated capital stream and enhanced research funding to enable the science and engineering base to restore, maintain and grow the infrastructure for research.** Universities will be able to invest with greater certainty for the long term, but will at the same time have sharper responsibility to ensure that their research is sustainably funded. **The Government will establish clear principles on the contribution of public, private and charitable funding to maintaining the science infrastructure.** In return, universities will improve the transparency and accountability of their increasingly diverse funding streams, demonstrating clearly that, over time, the full economic costs of their research activities are covered.

0.8 The opportunities from investing in innovation are matched by imperatives to do so. Business and R&D are conducted in a global market, in which other countries are boosting their investment in science and technology. Without the body of highly educated and skilled manpower and the knowledge gained from past investments in R&D and innovation, business will not be able to exploit R&D and innovations generated elsewhere. The UK starts from a strong position of excellence in many areas, backed by good science education and training. But in key disciplines we are living off the human capital acquired in previous decades. The Government's strategy, therefore, responds positively to the findings and recommendations of Sir Gareth

Roberts' review of science skills[1]. We need to ensure that our scientific talent is continually refreshed and rejuvenated, and that the UK is an increasingly attractive location for individuals and business to engage in research.

0.9 **The Government will invest a further £100 million per year by 2005-06, through the Office of Science and Technology (OST) to improve the development of the UK's science and technology skills base. It will increase the basic support for Research Council funded PhD students to an average of over £13,000 per year, with the increases focused on subjects with recruitment difficulties. Training and career paths for researchers will be opened up. Universities will be able to invest in pay flexibility to meet skill shortages in key disciplines. Schools will gain resources to attract science graduates into the classroom, and the Government will fund science training to revitalise skills throughout teaching careers. This will include a partnership with the Wellcome Trust to deliver a National Centre for Excellence in Science Teaching. Schools and universities will also be given resources to modernise and upgrade their science engineering and technology laboratories.**

0.10 These reforms and funding should set the science and engineering base on course towards renewal over the coming decade. At the same time, the Government will boost the resources available for expansion of research, both to maintain the vibrancy of the UK's best research programmes and to enable growth in new priority areas. **By investing an extra £400 million per year by 2005-06 in science and engineering research programmes, and an additional £100 million per year by 2005-06 in equipment and capital infrastructure, the Government will fund real annual growth in research programmes of 5 per cent. This will finance the expansion of world class basic research – the life blood of scientific innovation – and allow a start to be made on new priority areas of research to tackle social challenges such as: brain science, regenerative medicine, proteomics (building on the foundation of genome sequencing in which the UK has played a key role), sustainable energy, and rural land use.**

0.11 **To complement these measures for the science base, the Government will also take steps to strengthen the use of science and management of research by Government departments.** This will help ensure that science priorities are carefully considered and given proper weight alongside other priorities in spending decisions. Arrangements for knowledge transfer will be enhanced. The Government's Chief Scientific Adviser, accountable for the quality of science in Government, will lead a new rolling programme of external scrutiny and benchmarking to reinforce best practice and high standards across departments. Improving the competence of departments to act as an intelligent customer for, and manager of, research and scientific advice, will be driven by a Chief Scientific Adviser in each of the major Government departments which perform or commission research.

[1] ***SET for success:*** The supply of people with science, technology, engineering and mathematics skills.

Closing the innovation gap

0.12 Science and technology manifests itself in our lives through products and services, medical treatments and communications networks. The drive for this innovation must come from business. A key goal of the Government is increasing the productivity of industry and manufacturing in particular. If UK manufacturers matched the productivity levels of France, Germany and the US, and all else remained the same, the economy would be £70 billion per year better off, creating prosperity for all. Investment in innovation not only helps manufacturers retain a competitive edge in the face of growing global competition, but it is also a key driver of productivity improvements. The Government's strategy for manufacturing[2] provides a comprehensive framework for taking forward the manufacturing agenda in partnership with key stakeholders. This will be achieved, not least, by joining up Government activities and polices which underpin manufacturing success. The Government has now put in place the necessary framework of macroeconomic stability and structural reforms to create a better climate for investment. Of itself, this should encourage R&D investment by business, which by the late 1990s had shown the first signs of reversing several decades of relative decline.

0.13 The UK's strongest innovative industries are global leaders, but too many of our sectors are significantly lagging behind international investment levels in R&D. In 2000, the Government started to tackle this, through introducing tax incentives for R&D among smaller technology-based firms. This year, the Government has widened these fiscal reforms to encompass all UK-based business R&D. The Government is now investing through the tax system around £500 million per year across the full range of British manufacturing and services to underpin more than £11 billion of business R&D.

0.14 Industry's own efforts to exploit the ideas and skills emerging from the UK science base will be buttressed by continued and growing investment by the Government in knowledge transfer from the science base. Government resources will be sharply focussed on identified gaps in the transfer of scientific knowledge to industry, enabling collaboration between business and universities and forward-looking investment in future 'disruptive' technologies.

0.15 To complement this, the universities and publicly-funded research establishments need to build on their recent progress in linking with business to create value for the regional and national economy. **The Government will consolidate the Higher Education Innovation Fund (HEIF) as a permanent third stream of funding for universities, with investment rising to £90 million per year by 2005-06.** This will provide pump-priming resources for technology transfer, entrepreneurship training, corporate spin-outs and seed venture funding. The **Regional Development Agencies** will play an enhanced role in helping to direct resources from HEIF and other knowledge transfer programmes, so that they contribute most effectively to regional growth strategies.

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[2] DTI (May 2002), The Government's Manufacturing Strategy.

Science and innovation in the Devolved Countries and English regions

This science strategy covers policy areas that are reserved to the UK Government such as science funding by the OST and tax credits, and those areas where policies are devolved such as higher education funding. In areas which are reserved to the UK Government, the coverage of this science strategy, and increases in funding associated with it, are UK wide. In areas that are devolved it will be for the devolved administrations to decide what policies they wish to implement; they will receive their share of increases in comparable programmes in the spending review in the normal way.

The Government intends to work closely with the devolved administrations in implementing this science strategy to ensure that the partnership between the Government and the devolved administrations delivers improved prosperity and productivity across the UK.

The Government will similarly work closely with the RDAs to strengthen the science base in the English regions, with the aim of strengthening innovation as a key driver of improved regional productivity.

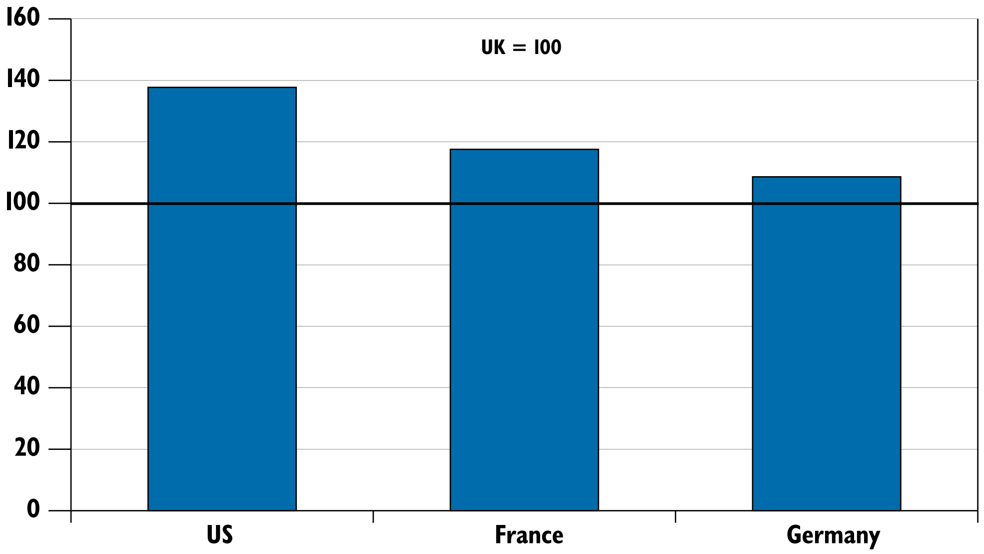
1 THE VALUE OF SCIENCE AND INNOVATION

Introduction

1.1 The Government's central economic objective is to achieve high and sustainable levels of growth and employment. To succeed, the Government is committed to increasing productivity in the UK[3].

1.2 The UK currently has a substantial productivity gap with other major industrialised economies. This gap exists with France, Germany and particularly the US, however productivity is measured. Chart 1.1 below shows that the gap, expressed as output per worker, is just under 40 per cent with the US, and that there is also a significant gap with France and Germany.

Chart 1.1: Output per worker, 2000



Source: ONS

1.3 The Government has made it clear that improving economic performance over the long term requires action across a range of areas: competition, enterprise, innovation, skills and investment. A strategy for science, engineering and technology focuses inevitably on the role of innovation. But innovation depends on enterprising companies and individuals, the supply of skills, and the opportunities and pressures created by a competitive environment. These factors are linked, and what is proposed here needs to be seen in the context of the Government's comprehensive approach to productivity enhancement.

[3] See, for example, HM Treasury (2000), Productivity in UK: the evidence and the Government's approach.

1.4 Innovation has been shown to be one of the most significant explanations of differences in GDP across countries and over time. Evidence shows that innovating companies sustain a higher performance, grow faster than non-innovators, and are much more profitable[4,5]. An economy's ability to undertake and exploit innovation is therefore central to its prospects for improving standards of living and prosperity. Despite the advances in electronic communications, research and development (R&D) activity is often concentrated in particular locations and regions, benefiting from the range of interactions which occur in and around research clusters. Business R&D is similarly drawn to specific locations, partly to benefit from regional pools of skilled labour. So national capacity for innovation matters.

1.5 To reap the economic benefits of innovation, it is therefore necessary for Government and business to invest fully in the necessary infrastructure: simply borrowing the fruits of overseas research is unlikely to be a successful long term strategy. Conversely, by creating a favourable climate for research and innovation, the UK can attract internationally mobile science and technology personnel and financial capital to this country, bringing wider productivity benefits. Encouraging scientific research and innovations flowing from them must play a major role in the Government's strategy for raising productivity.

1.6 The Government's approach to increasing innovation recognises the complexity of the environment in which firms operate and the incentives they face. It sees successful innovation as a system operating across the economy. This requires a constant stream of new ideas arising at the interface between science and technology and economic and social needs, and in which the knowledge arising from basic scientific research plays a major role. Firms must have the knowledge base, highly trained personnel and the incentives to develop these ideas into commercially successful innovations. Firms must also be able to access and absorb relevant science and technology from all sources, academic and industrial, domestic and international, in order to benefit from them. UK universities play an important role both as the primary source of scientific knowledge and as intermediaries between UK firms and science and technology worldwide. This interactive process requires sustained investment by business, but also by Government, as funder of the science base and user of research for public policy and service delivery.

The value of innovation

What is innovation?

1.7 Innovation is the generic term for the successful exploitation of new ideas. Although innovation is often viewed as, and quantified by, R&D activity, it is much more than that. Innovation can result from new science and technology, from changes in skills or business processes, or from the exploitation of new markets. Typically all or most of these are involved. New technology can

[4] Geroski and Machin (1993), The Profitability of Innovating Firms, RAND Journal of Economics.

[5] Cameron (1998), Innovation and Growth: a survey of the empirical evidence, Mimeo Nuffield College; Cameron (2000), R&D and Growth at the Industry level, Nuffield College, Discussion Paper. No 2000-W4; OECD (2000), The impact of Public R&D on Business R&D.

result from scientific research (particularly in science-based sectors), from R&D carried out by the firm concerned, from customers, suppliers and competitors, from engineering development, and from 'learning by doing'. Although attention tends to focus on the initial introduction of a new product, process or system, it is its subsequent diffusion through the economy which yields the benefits to productivity and economic and social well-being. This may take decades and usually involves the innovation being improved out of all recognition from its original appearance.

1.8 Innovation itself can take many different forms including: process innovations, product innovations and innovations in business processes and models. One type of innovation often needs to be linked with others if it is to be successful. For example, a manufacturer may generate a product innovation, which then becomes an input into a process innovation. Organisational innovation will often accompany the new process in order for the user to maximise the benefit from the technological change.

1.9 Historically, the bulk of R&D has been carried out by the industrial sector. In the face of growing global competition, the most successful industrial companies invest in continuous innovation in order to add value in production and customer services and to ensure that, in product and service development, they can remain ahead of what will often be lower cost competition from overseas.

1.10 Industry's contribution to the UK's R&D activity remains vital, particularly in leading edge product innovations in high-tech sectors. But it is no longer enough to encourage R&D in manufacturing and industry alone. As the service sector has expanded in industrial economies, improving overall economic performance means more widespread increased attention to technology. This may not require such firms to spend heavily on R&D to increase innovation. Rather, the emphasis may be on firms having the ability to absorb, adopt and adapt technological improvements and to organise their processes and functions more innovatively to make productivity gains.

1.11 Increasing innovation therefore requires a multi-faceted approach that recognises the different circumstances of different firms and sectors, appreciates the regional dimension, and recognises that firms do not innovate in isolation. Interaction with different institutions and the incentives created by the microeconomic climate are crucial to a country's innovation performance.

The importance of R&D and innovation to economic growth

1.12 Work by the OECD and others has demonstrated that R&D carried out by businesses across different sectors has had a large impact on productivity[6,7]. Estimates of the contribution of a firms' own R&D effort to productivity

[6] E.g. OECD (2000), Knowledge technology and economic growth: recent evidence from OECD countries; OECD (2001), R&D and productivity growth: a panel data analysis of 16 OECD countries.

[7] E.g. Coe and Helpman (1993), International R&D Spillovers; Englander and Gurney (1994), OECD Productivity Growth: Medium Term Trends.

growth are typically high – estimates of private annual rates of return to R&D tend to be around 10 to 15 per cent, although some studies have estimated them to be as high as 30 per cent[8]. Further recent analysis of returns in the UK puts this figure at between 10 and 20 per cent. To set this in context, the average net rate of return on capital employed for UK manufacturers over the period 1970 to 2001 was 5.7 per cent per year.

1.13 Furthermore, there are also significant positive spillover effects from private R&D activity, which increase the benefit of the R&D to the economy as a whole (the social return). Spillovers can occur through a number of sources, for example through the transmission of knowledge through scientific journals, via engineering understanding of the product itself and the movement of skilled workers between firms. These can create difficulties in capturing the full economic benefits of innovation via the price of a product or service. Spillovers are generally largest between firms in the same industry, although sizeable spillovers may occur across industries and across countries.

1.14 The effect of these spillovers is seen in estimates for social rates of return, which are consistently found to be higher than private returns. Research indicates the private rate of return may constitute as little as a quarter of the social returns to R&D as a result of technology spillovers. This means that society as a whole would benefit from firms undertaking more R&D than they would individually choose to do. This divergence between private returns and social returns implies that firms left to their own devices will generally face insufficient incentives to invest in R&D from society's point of view[9].

1.15 The end result is that, left to itself, the private market will tend to under-invest in R&D. This provides a clear rationale for Government intervention to create incentives for firms to increase the level of privately funded R&D to the optimal level by capturing more of the benefits associated with spillovers, which firms are unable to appropriate directly. Basic scientific research is likely to be particularly subject to under-provision, owing to its broad nature and the high-risks associated with investment.

The innovation system

1.16 This strategy sets out in detail how the UK can encourage increased innovation to help drive up productivity through investment in R&D. Successful technological innovation needs to be seen as a system operating across the economy. A variety of conditions need to be met for such a system to work effectively. In some, Government's role is direct and obvious – the funding, for example, of education to generate a skilled workforce. In others, the role is indirect, but still important. Tax policy, for example, can help to strengthen the incentives for innovation by increasing post-tax returns to investment. Competition policy can create incentives for innovation by encouraging the entry of new providers and new services. Striking the right balance in these

[8] Hall (1996), The Private and Social Returns to Research and Development, in [eds] B Smith and C Barfield, Technology, R&D and the Economy, Brooking Institution and American Enterprise Institute: Washington DC.

[9] Griliches (1992), The Search for R&D Spillovers, Scandinavian Journal of Economics, Vol. 94.

relationships can be complex. Intellectual property rights, for example, restrict competition, but are essential to give innovators the incentives they need to take risks.

1.17 National policies provide the framework within which the innovation system operates at a local and regional level. The collaborative and interactive nature of much research and its exploitation in the economy roots much of this activity in specific locations, based on localised linkages between researchers, institutions and business. This human and social dimension provides the drive towards the clustering of innovation and the persistence of activity in specific regions over time.

1.18 Clustering is a well-known phenomenon: Silicon Valley, Cambridge and the Thames Valley are familiar examples for the 'new economy'; recent studies[10] have identified many other innovation-based clusters across the UK. The main drivers behind such concentration include 'thick' labour markets, particularly in highly skilled personnel with technical and commercial expertise. Universities can be a major source of supply into these labour markets – particularly of the highest-quality graduates and academics. Supply linkages between firms can also be important, and also between firms, university departments and other research organisations. Another element seen in many innovation clusters is the supply of high-quality professional and financial services. Local access to capital can be particularly important, especially when firms are too small to access national and international markets. Financing of technology firms is a specialist activity, and brings not just financial capital but access to networks and expertise in building businesses and markets.

1.19 Persistence effects can be seen in innovation performance at both the level of individual firms and regions. Once a firm or region has established itself on a successful trajectory, it is more likely to stay there. A firm that has assembled the resources needed to fund and manage successful innovation – the access to intellectual and financial capital, the expertise to undertake R&D and the management skills involved in commercialising technology successfully – is more likely to be able to continue attracting these resources, whether by recruiting good quality graduates or extra financial capital.

1.20 This said, innovation is not a smooth or linear process. Much innovation is characterised by incremental change. But other changes can be more dramatic – like the emergence of wholly new technologies which disrupt existing products and processes. Firms will have different capabilities to adopt and implement different types of change. But the larger the technological change, the more radical the change that is likely to be required in organisational form. This may mean the rise of wholly new markets and industries, populated by new entrant firms, or the transformation of existing firms so that they have a different character. Science, technology and customer needs influence one another in the innovation process.

[10] For example, DTI (2001), UK Business clusters in the UK.

1.21 These characteristics of innovation have implications for policy. They stress the importance of building on success at the regional and national level, to strengthen conditions for growth. They also point to creating an environment that supports the widest variety of innovations across firms and technologies, and to reducing barriers to entry to new enterprises. Creating such a system will require action in many areas.

1.22 Successful innovation requires a continual stream of new scientific, technological and business ideas on which entrepreneurs and firms can draw to develop new and commercially successful innovations. These in turn require:

- strong basic research capability to provide the new knowledge and research methods;
- strong technological capability within firms to undertake R&D and other forms of technology development and to seek out, absorb and adapt science and technology from elsewhere;
- business capabilities to adapt new technology to the needs of customers, to produce, market and service products successfully and to manage the innovation process generally; and
- sufficient supply of high level skills in scientists and engineers and trained managers to support the above.

1.23 The UK has produced high volumes of high quality basic scientific research for many years. Much of this is performed in university science and engineering departments. Since 1997, the Government has consistently invested in university research because it produces successful outcomes. In the 1998 Spending Review, the Science Budget was increased by 15 per cent in real terms between 1999-2000 and 2001-02. Following the 2000 Spending Review, it has been increasing at 7 per cent per year in real terms. Combined annual DTI and DfES spending on science research now stands at some £3 billion. Chapter 3 deals with the detailed issues that need to be addressed to ensure that universities can continue to provide world-class research on a sustainable basis in the face of increased global competition for talent and ideas.

1.24 To understand better the supply of scientists and engineers to the UK economy, in the 2001 Budget the Government commissioned Sir Gareth Roberts, President of Wolfson College Oxford, to carry out a review of this issue. The review published its findings in April 2002, and has set out recommendations for ensuring that the UK has adequate scientific skills in the economy[11]. The Government's formal response to the Roberts report is included at Annex A. Chapter 4 of this strategy sets out how the Government will act to ensure that the UK trains and develops enough highly skilled scientists and technologists to support a vibrant innovation system.

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[11] ***SET for success:*** The supply of people with science, technology, engineering and mathematics skills.

1.25 Addressing these areas will help to ensure that the UK has the capacity to produce, absorb and develop new ideas and inventions. To encourage their dissemination throughout the economy, the Government can help to reduce barriers to knowledge transfer between higher education and public sector research establishments and firms, and between different firms. The same spillover rationale behind Government support for university and business R&D research also supports many knowledge transfer activities. Well-targeted Government action can therefore help to improve incentives for this activity, by:

- encouraging strong links between the private sector and universities and other research establishments; and
- reducing informational and other barriers that reduce knowledge transfer between firms.

1.26 Chapter 5 looks in detail at what the Government can do to increase activity in knowledge transfer.

1.27 Business innovation requires the private sector to invest in R&D and to develop the capacity to absorb new technologies. This in turn needs a supportive economic environment to provide the incentives for them to do so, through:

- stable macroeconomic climate in which firms can invest for the future;
- strongly competitive regime to provide incentives for firms to innovate and reduce the costs and barriers to new entrants to markets;
- reduced barriers to entrepreneurship to encourage new innovative businesses to emerge, thus increasing competitive pressures on incumbents;
- incentives, via tax measures and patent protection, to encourage private sector investment in R&D and skills; and
- efficient and sophisticated capital markets that are attuned to the needs of research-intensive companies.

1.28 Chapter 6 sets out the Government's approach to creating the right framework conditions to support investment across the UK economy as a whole. In particular, it highlights the measures taken to foster the demand for innovation investment among firms, and the supply of the finance necessary to fund this, most notably through the introduction of new tax credits on R&D spending by all businesses.

1.29 Action in all these areas will produce an environment that is conducive to increasing innovation and encouraging technological progress. The Government has an important role to play and is committed to doing so. Ultimately, however, the challenge is to firms to respond to that environment and to make best use of the opportunities presented to improve their performance.

The challenge to industry

1.30 The need to adapt and stay ahead of competitors both domestically and internationally drives innovation at the firm level – continually seeking new products, services, processes and markets that will lead to sustained profitability. Innovation surveys for 12 European countries indicate that, on average, more than 30 per cent of annual revenues in the manufacturing sector derive from new or improved products i.e. the result of innovation[12]. In the UK this figure is 23 per cent.

1.31 At the firm level, spending on R&D can be an important determinant of growth. Furthermore, firms tend to spend more on R&D when several of the factors in the system described above come together. For example, there is evidence that there are strong complementarities between the rate at which firms adopt new technologies, higher levels of capital investment and workforce skills[13]. There is a strong persistence effect. Firms that have been successful innovators in the past tend to build on that success and outperform competitors.

1.32 Notwithstanding the positive benefits from R&D investment, UK business performance in this area declined over much of the 1990s. UK business R&D declined from 1.5 per cent of GDP in 1990 to 1.2 per cent by 1997. Since then, there have been signs of a gradual improvement in investment levels. But as a share of overall economic activity, R&D spending in the UK remains below most other industrialised economies. At the same time, other countries have increasingly recognised the importance of R&D and innovation to growth and have seen increases in investment in the private sector.

1.33 The challenge is therefore clear. Firms need, themselves, to invest to maximise their productive potential through innovation. This requires management to make such choices. Failing to invest in R&D and the skills needed to exploit innovation through improved products or services reduces a firm's ability to grow, succeed and perhaps survive. In an increasingly competitive global economy, the ability to keep on innovating becomes increasingly important to a firm's long term health and viability.

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[12] DTI (2001), Competitiveness Indicators, Second Edition.

[13] HM Treasury (2000), Productivity in the UK: The evidence and the Government's approach.

Box 1.1: Innovation in Europe and internationally

The Lisbon agenda: Enhancing R&D and innovation across the European Union

The Government recognises that the innovation potential of the UK is closely linked to the research and innovation capacity of the rest of Europe. It strongly supports the strategy adopted at Lisbon European Council in March 2000, which aims to enhance Europe's capacity in this area as a means to becoming 'the most competitive and dynamic knowledge-based economy in the world by 2010'.

Since Lisbon, the UK has been at the forefront of calls for the reforms needed to raise the level of European performance. Currently European businesses spend less on R&D and take out less intellectual property protection than those in the US. In particular, many European countries fail to fully translate a relatively strong research base into the inventions and innovations which yield tangible economic outcomes: the so-called 'European paradox'.

The Government played a key role in drawing up a report on R&D and innovation which was agreed by EU economic and finance ministers (ECOFIN Council) in January 2002[14]. This report emphasises the importance of getting the broad economic framework conditions right if innovation is to thrive. Focusing on the importance of the intricate links and feedback loops within innovation systems, the report also identifies several key barriers to innovation in EU countries, for example:

- ineffective intellectual property regimes (including the need for an affordable EU patent system);
- weak science-industry links;
- a lack of risk capital; and
- the effectiveness of public research spending.

This was followed up by a joint letter from the Prime Minister and his Dutch counterpart to the Spanish Prime Minister, ahead of the Barcelona Spring Council in March 2002[15]. This letter reiterated the UK's support for the recommendations of the report agreed at ECOFIN.

The Barcelona Council conclusions themselves reflect this renewed importance placed on R&D and innovation. The Council called on the European Commission to come forward (by Spring 2003) with proposals on how to integrate innovation into a 'European Knowledge Area', which would encompass both education and research policies. A core part of these proposals will look in detail at the European weaknesses identified in the ECOFIN report.

In addition, the Barcelona Council set an ambition for the EU to increase spending on R&D to 3 per cent of GDP by 2010, with two-thirds of this investment coming from the private sector. This is triggering further analysis of the ways that the EU can best improve both the amount of R&D undertaken, but also the effectiveness of that spending. The Government welcomes an extensive exchange of best practice between EU Member States on this issue.

[14] http://europa.eu.int/comm/economy_finance/epc_en.htm

[15] http://www.number-10.gov.uk/output/page4481.asp

At the same time, the EU is currently finalising negotiations on the 6th Research Framework Programme, which has a total budget of 17.5bn over four years. This latest Framework Programme aims to focus down on key areas of European research excellence, consolidate and add value to existing research projects, and enhance researcher mobility.

Promoting UK science and technology on the global stage

The Government recognises that there are many advantages to the UK from engaging fully and actively in international research collaboration beyond Europe. The UK has many strengths to offer as a partner in international research endeavours: the top rated research excellence generated by many UK institutions, the successful track record of multilateral programmes, and the ease of communicating (via English and the UK's global transport links) with UK-based researchers. These assets are to be more vigorously promoted with increased support overseas for wealth creation by UK industry and research community, through the expansion of the networks of Foreign and Commonwealth Office science attachés and DTI International Technology Promoters.

Conclusions

1.34 R&D and innovation are important to increasing economic growth and productivity. However, raising the UK's innovation performance requires an approach that recognises the complexity of the forces that contribute to technological progress.

1.35 Chapter 2 looks at the UK's past record on R&D and innovation to provide a context for this strategy. It shows that over the last 20 years, businesses in the UK have invested less in R&D than our major competitors and that our innovation performance is relatively weak.

1.36 The remainder of the strategy explains what the Government and others need to do to develop a technological innovation system in the UK to improve this record. A strong scientific research system has a vital role to play in this. In the UK, the bulk of basic scientific research is carried out in universities; and chapter 3 explores the issues that must be addressed to ensure that universities can sustain their current output in the long-term and move into new areas of research.

1.37 Chapter 4 then analyses the current supply of highly skilled scientists into the economy and shows that the UK is facing potential problems. It sets out how the Government, universities and business together can prevent these occurring.

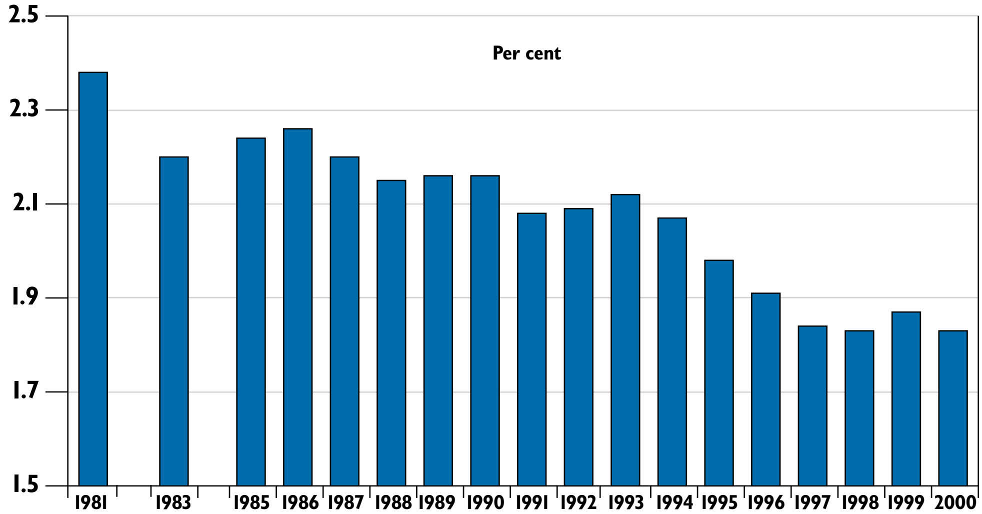
1.38 Chapter 5 then covers knowledge transfer, before chapter 6 looks in more detail at the wider innovation system and the challenge to business to increase investment in innovation. Chapter 7 sets out how the Government intends to strengthen its own research effort to improve the delivery of public services.

2 THE UK'S RECORD ON R&D AND INNOVATION

2.1 This chapter sets out the context for the Government's strategy for increasing R&D and innovation in the economy. It examines the evidence on the UK's record over the last 20 years. It draws on the available data describing the quantity of research inputs by business, Government and higher education, as well as the more limited evidence on the quality and quantity of the innovation outputs from these activities.

2.2 Chart 2.1 presents total UK R&D expenditure as a percentage of GDP over the 1980s and 1990s. It shows clearly the progressive trend decline in R&D spending as a share of GDP in the UK. UK gross R&D spending has in fact fallen from 2.38 per cent to 1.83 per cent of GDP between 1981 and 2000 – a fall of 23 per cent. There are, however, some signs that this downward trend has been arrested and may be starting to reverse.

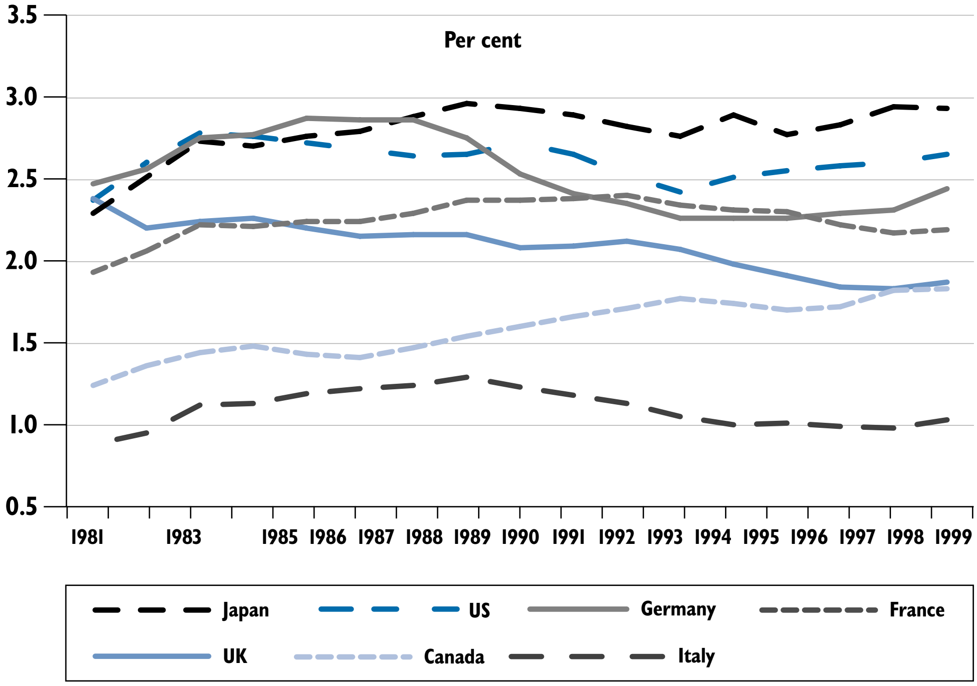
Chart 2.1: UK R&D spending as a share of GDP



Source: OECD

2.3 Chart 2.2 shows total R&D spending as a proportion of GDP for the G7 countries over the same period, placing the declining level of investment in the UK in the context of international trends. This demonstrates that, while the UK invested more than the rest of the G7 except Germany in 1981, by 1999 the US, France, Germany and Japan all spent more on R&D as a percentage of GDP. Part of the UK's absolute decline can be accounted for by a sharp downturn in defence R&D over the 1990s, from 0.5 per cent of GDP in 1989 to 0.2 per cent in 1999. Although similar falls in defence spending were also experienced in most other G7 countries, in nearly all the proportion spent on civil R&D increased, more than offsetting the fall in defence R&D expenditure. Large increases in the level of investment will now be required for the UK to catch up and converge with the leaders, whose investment levels are also rising.

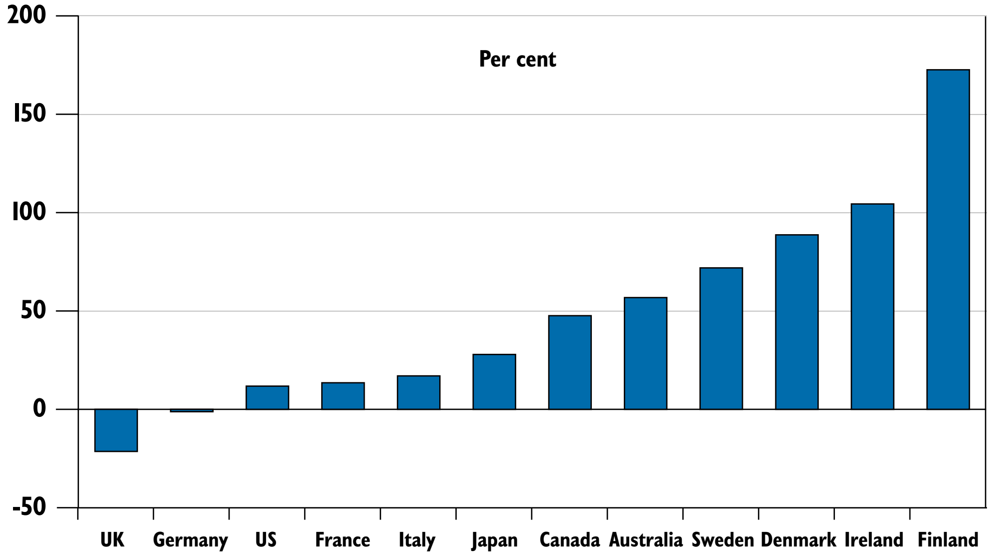
Chart 2.2: R&D expenditure as a proportion of GDP in G7 countries



Source: OECD

2.4 Furthermore, as chart 2.3 shows, the UK was the only country to experience a significant decline in total R&D spending as a share of GDP compared with its competitors.

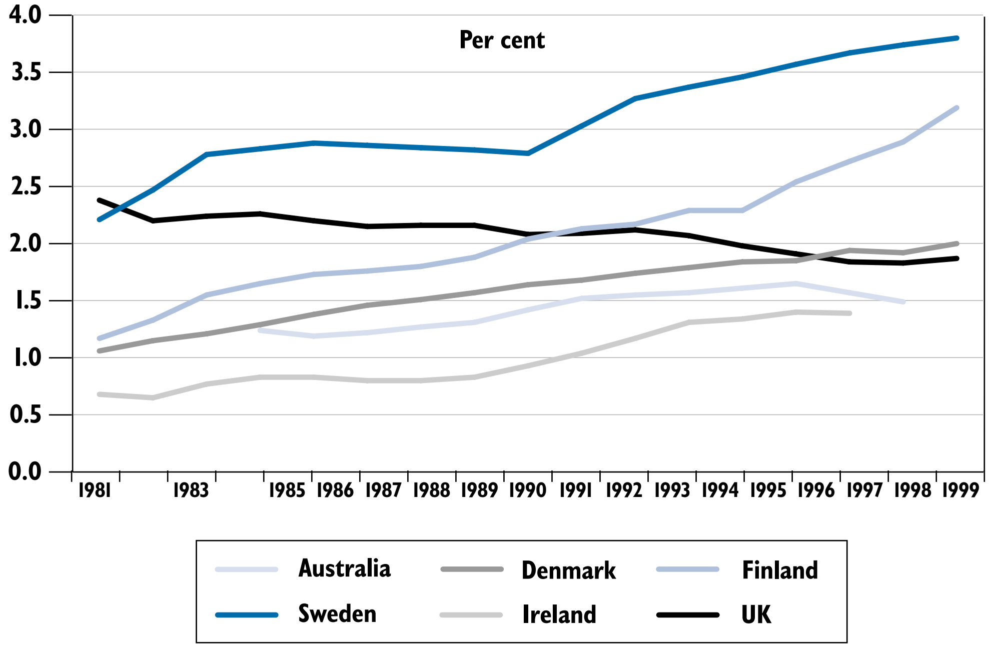
Chart 2.3: Growth in R&D spending as a share of GDP, 1981 to 1999



Source: OECD

2.5 Chart 2.4 shows that many smaller economies have significantly increased spending on R&D. For example, Sweden, Finland, Denmark and Ireland have accelerated spending as a share of output in the last twenty years by 72 per cent, 172 per cent, 88 per cent and 104 per cent respectively. As a result, the UK now invests a lower percentage of GDP in R&D than many OECD countries. The high levels of investment in R&D by many smaller nations suggest that there is a widespread acceptance that it is not enough for economies to 'free ride' on R&D investment by others. There is some evidence that in smaller economies, R&D investment primarily facilitates technology transfer from other economies, while in large economies it directly increases the rate of innovation[16]. Nevertheless, these high investment levels by even small, open economies support the view that spillovers often occur within countries. This suggests that all economies benefit directly from their own R&D investment.

Chart 2.4: R&D expenditure as a proportion of GDP

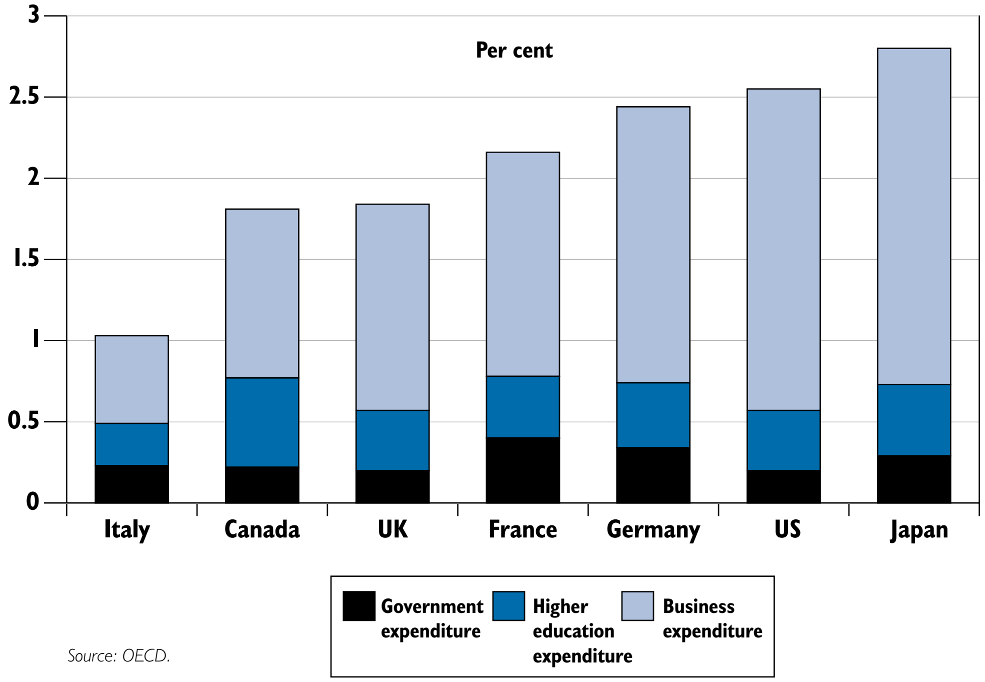


Source: OECD.

2.6 In all countries, the largest component of R&D investment is that performed by business – accounting for between 52 per cent and 77 per cent among the G7 in 1999. This is shown in chart 2.5. Given the prominence of business R&D within the total, variability in this element will have a significant impact on the R&D investment levels of a country as a whole.

[16] OECD (2000), A New Economy? – The role of innovation and information technology in recent OECD economic growth.

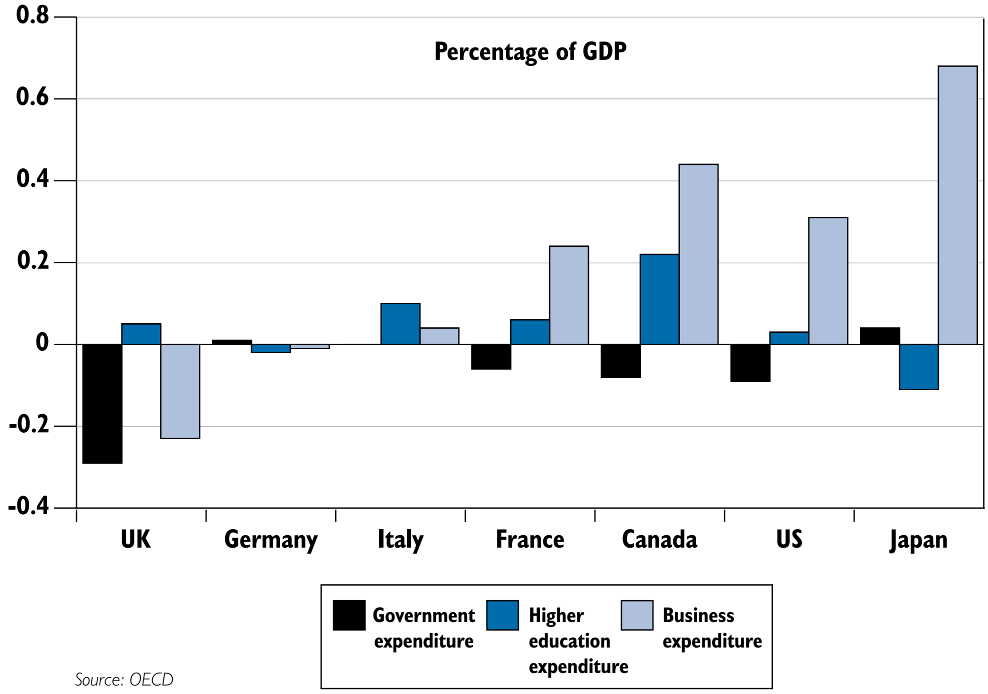
Chart 2.5: R&D expenditure by principal performer as a proportion of GDP, 1999



Source: OECD.

2.7 Chart 2.6 shows the impact of changes in components of R&D. The decline in spending in the UK relative to other countries between 1981 and 1999 can be mainly accounted for by a reduction in spending by business. Although R&D performed by government in the UK decreased in the period by more than other G7 countries, business R&D as a percentage of GDP also declined here while in other countries it mainly rose – and often substantially.

Chart 2.6: Change in composition of R&D expenditure, 1981 to 1999



Source: OECD

Sectoral patterns of innovation

2.8 The UK excels in innovation and R&D in some sectors, giving it world-leading industries. In others, though, the UK's research intensive sectors fall some way short of international benchmarks in R&D investment. Chapter 6 explores the sectoral patterns of UK business R&D and sets out the Government's approach to improving the climate for business investment in innovation.

Indicators of innovation

2.9 This analysis has reviewed comparative performance in terms of R&D expenditure. While useful as a measure of the UK's commitment to innovation, it is only an input to the innovation process and does not show the effectiveness of the spending[17]. Critical to the success of R&D research is the ability of firms to transform research initiatives into commercially viable new processes and products.

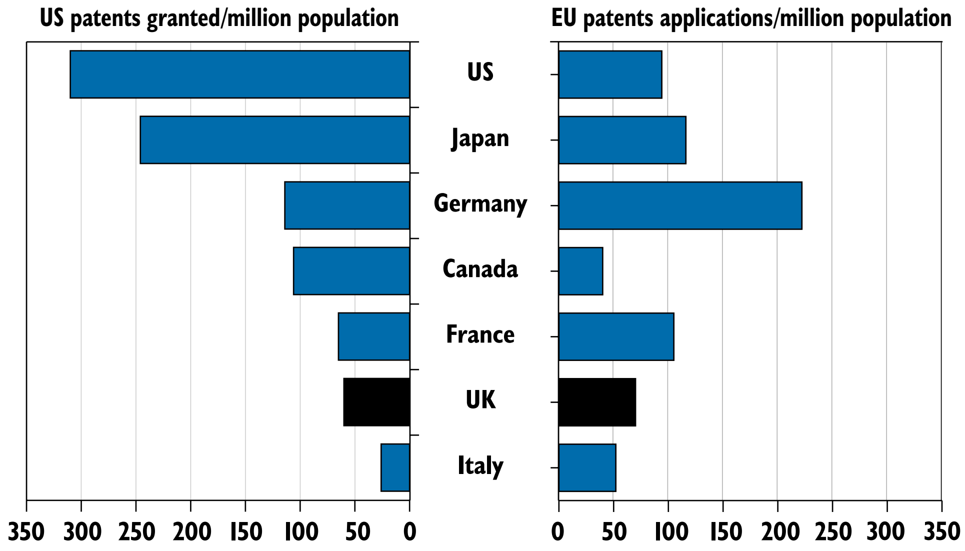
2.10 International comparison of patents applied for or granted to firms can be used as a proxy indicator of success in converting knowledge spending into new products or processes (although there are limitations to such comparisons). Problems include the fact that firms follow different policies for patenting products. Some inventions are not patented as firms find other ways of protecting them. Equally, not all patented products become a commercial success. Differences between countries' patenting systems also cause difficulties. For example, some countries and regions tend to focus on patenting finished products; others tend to patent all the intermediate stages and a number of variations of the final product. Nevertheless, patents are a useful indicator of innovation potential and capacity.

2.11 Chart 2.7 provides information on European Patent Office (EPO) and United States Patent and Trademark Office (USPTO) patents[18]. The data suggest that the UK lags behind the US, France, Japan, and Germany in both the EU and US markets. The predominance of US firms in holding US patents reflects a home advantage as it is generally more expensive to patent abroad. However, the US records a relatively strong performance in the EU market as well. When a comparison is made within the EU, the UK record on patent numbers is nearly a third the level of Germany, and less than France, Japan and the US.

[17] DTI (2000), UK Competitiveness Indicators: Second Edition

[18] The USPTO only publish data on patents granted, whereas the EPO only publish data on patent applications

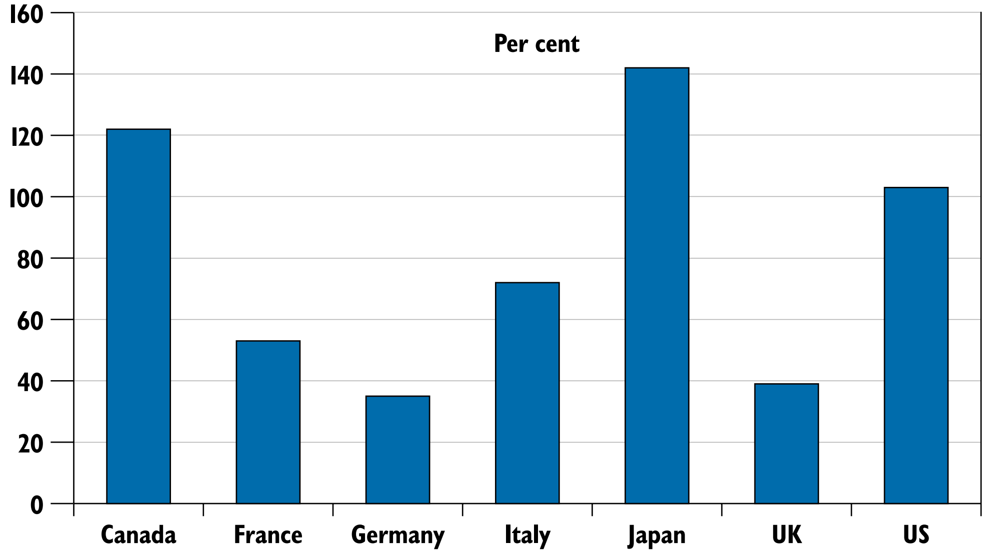
Chart 2.7: Patents granted and applications, 1999



Source: US Patent and Trademark Office; European Patent Office.

2.12 This therefore suggests that the UK has some way to go to catch up with German, Japanese and US innovative capacity. Chart 2.8 shows the percentage change in US patent grants between 1985 and 1998 as a measure of the pace of change of UK performance versus our international peers. This indicates that the UK has experienced a slower increase in its innovative performance than most other G7 countries.

Chart 2.8: Change in US patents granted, 1985 to 1998



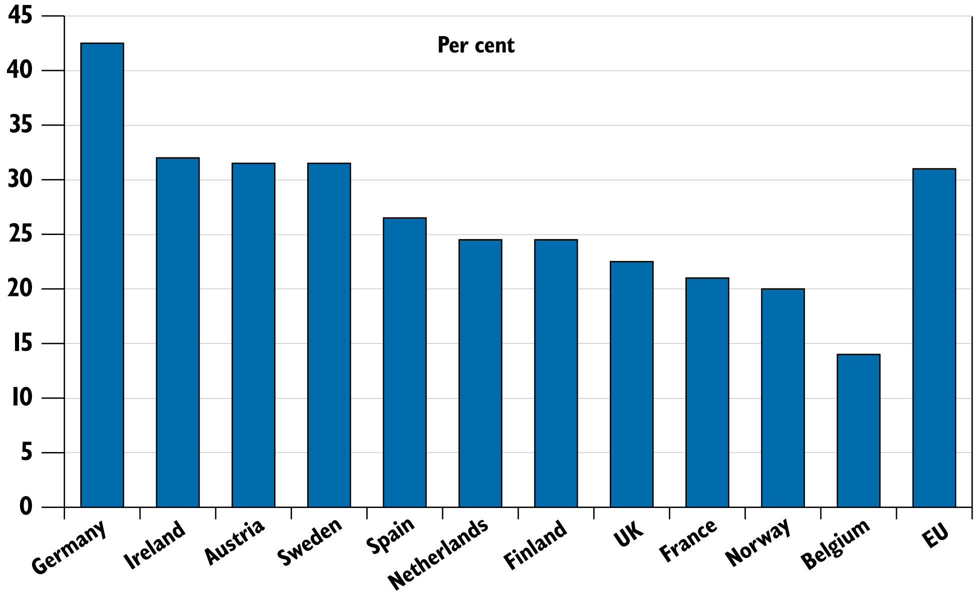
Source: OECD.

2.13 Comparison of the UK's performance on other output indicators of innovation show a similar pattern. For example, the revenue generated by firms from new or improved products is an indicator of the effectiveness of R&D spending, showing the commercial success or viability of new products, processes and services.

2.14 Chart 2.9 highlights that UK manufacturers are in the bottom half of the EU league in terms of revenue generated from new or improved products. Only 23 per cent of turnover is derived from new and improved products compared to an EU average of 31 per cent. This is consistent with the relative decline in investment levels in R&D in the UK.

2.15 This decline is largely a phenomenon of the last two decades. Even in 1981, the UK's total spend on R&D was the second highest in the G7 as a share of GDP, reflecting in part the combined focus of Government and business on defence research and product development. However, this investment did not translate into outstanding economic performance. As Chapter 1 argued, what is needed to link R&D with economic growth is an effective system for driving innovation through the economy, so that new ideas are turned successfully into new products. When UK businesses were investing heavily in R&D, the framework conditions, including a weak competition regime, an unstable macroeconomic climate, lack of commercial focus and poor access to risk capital, did not provide the right incentives to foster innovation.

Chart 2.9: Manufacturing revenues from new or improved products, 1996



Source: European Community Innovation Survey.

Conclusion

2.16 The UK's productivity performance has been weak over recent decades, allowing a considerable productivity gap to open up with other countries such as the US, France and Germany. One driver of improved productivity performance is innovation and technological progress, which is driven in part by investment in R&D. This chapter has shown that the UK's record on R&D is relatively weak and that, in contrast to other developed countries, the private sector has reduced R&D investment over the last 20 years.

2.17 This creates a challenge for industry to remain internationally competitive. But, as Chapter 1 argues, it also places the onus on Government to ensure that the innovation system is functioning well. This requires delivery of complementary policies. The Government will invest where it is best placed to do so in basic research, involving research partners in business and charities in sustainable financing for the long term. Chapter 3 sets out the Government's approach to ensuring that universities (which conduct the bulk of basic research in the UK) are able to produce sustainable high quality research output and to move into new areas of science. The Government will also work to ensure that the national and regional innovation systems operate well to diffuse ideas and skills generated in business and the science and engineering base. Chapters 4 and 5 set out the Government's approach to the creation and deployment of research and technology skills in the economy, and the transfer of knowledge across business and the science base.

3 STRENGTHENING UNIVERSITY RESEARCH

Introduction

3.1 Chapters 1 and 2 have shown that it is the private sector that drives much of the economic exploitation of science and innovation, but that there is much the Government can do to provide the incentives for businesses to invest in such activities. Underpinning the innovation system, though, and providing the feedstock of research outputs and skilled personnel, is the UK's science and engineering base. This chapter looks at how the Government can work with other partners to ensure that the UK has the capability to produce world-leading scientific ideas and inventions into the future.

University research

3.2 Scientific research is a diverse activity, producing outputs with a range of social and economic benefits. The closer these are to the commercial objectives of firms, on the one hand, or the policy objectives of Government departments and agencies, on the other, then the more those commissioning the research should themselves have the incentives and responsibility for funding this activity. Beyond this, there will remain a core of basic research activity, providing dispersed benefits throughout society and the economy as a whole, through both the ideas generated and the training of skilled personnel. The Government's responsibility is to ensure that this science and engineering research base (the universities along with the Research Council Institutes) is maintained and developed, so that it continues to deliver flows of new basic scientific research and associated skills to support the rest of the innovation system. At the same time, the research base for the arts and humanities, which also contributes to economic and social benefits, should continue to be supported.

3.3 UK universities perform well compared to institutions in other countries, producing relatively high volumes of top quality research. Although the UK only has 1 per cent of the world's population, it carries out 4.5 per cent of world science and produces 8 per cent of science papers. These papers receive 9 per cent of citations[19]. Furthermore, on average, UK scientists receive about 10 per cent of internationally recognised science prizes.

3.4 The overall research performance of universities is on an improving trend. In recent years, the outcomes from the Research Assessment Exercise (RAE) have shown the quantity of high quality research coming out of UK universities has increased substantially. At the same time, helped by Government initiatives such as the Higher Education Innovation Fund (HEIF), universities are building more and stronger relationships with business and other users of research. The numbers of spin-out companies created have reached record levels. All this has improved the prospects for publicly funded science being transferred into productive use.

[19] DTI (2000), Excellence and opportunity: a science and innovation policy for the 21st century

3.5 The Government has already invested significantly to support university research. Between 1996-97 and 1999-2000, research funding available to universities from the Funding and Research Councils has increased in real terms. This has enabled universities to increase the volume of research undertaken, to move into new areas of research, and to increase the quality of the outputs (as demonstrated by the 2001 Research Assessment Exercise (RAE)).

3.6 Overall, the story is one of growing success. However, for this to continue, three key issues must be addressed.

- First, the market for science and research has become increasingly global in recent years. UK universities have to compete with the USA, Europe and elsewhere for talent and research contracts if their departments are to maintain or improve their world ranking. This means universities - particularly those which are recognised leaders in their fields - being able to offer competitive salaries to potential staff, and having facilities and equipment conducive to top class research.

- Second, universities must be able to sustain and improve their current output. Past under-investment in universities has put at risk the current high levels of research output. Despite previous Government initiatives, there remains much to do to modernise university infrastructure. Furthermore, much research does not cover its costs let alone allow universities to compete in the international labour market.

- Third, universities must have the resources and dynamism to move into new areas of scientific research and to ensure their work remains at the cutting edge. This means universities being able to fund such investments but also having the institutional flexibility to cross traditional disciplinary boundaries.

3.7 This chapter describes how the Government intends to play its part in addressing these three issues through:

- a more sustainable system of university research funding, with the onus on universities to deliver change at the institutional level;

- improved mechanisms for universities to engage with all the users of the science base, including Government, the research charities and business; and

- resources to enable the science base to respond to the demands of new science.

3.8 While this chapter sets out the Government's intentions with respect to the first two of these and commits substantial new funding for the third, much of the detail will remain to be developed in due course. It is intended that a cross-departmental group will be established, reporting to the Minister for Science and Innovation, Lord Sainsbury, and convened by the Treasury, to co-ordinate the implementation of the package of measures proposed.

Ensuring scientific research is sustainable

3.9 There has been much public debate about research 'funding gaps'. However, increasing the resources provided by Government will not alone be sufficient to ensure that that the volume and quality of scientific research carried out in UK universities is sustainable in the long term. Rather, there are structural issues that need to be addressed by Government, the universities and other users of the science and engineering base together. They require all funders and users of the university research base to recognise a shared interest in its long term viability and to work in partnership to sustain it.

Funding of university research

3.10 University research is now resourced from a range of sources, including the Government, charities and industry. This diversity has increased in recent years as bodies outside Government have funded, and contracted with, universities to carry out greater volumes of research. The Government welcomes this diversity: it maximises the chances of fruitful outcomes given the uncertainty inherent in scientific research.

Dual support system

3.11 The Government itself provides two streams of funding known as the dual support system. The first stream from the Funding Councils[20] (known as Quality Related or QR funding) provides an underpinning research capability for universities. Support from the Funding Councils is intended to provide research departments with:

- the base from which permanent academic staff can make credible proposals for research project funding from the Research Council and other project funders;
- the costs of training new researchers;
- the resources to build research capabilities; and
- the freedom to pursue a certain amount of their own blue-skies research.

3.12 The Funding Councils reward excellence as measured by the RAE. Funding is skewed sharply towards the best rated departments, giving those most likely to produce results the resources to do so. This incentive structure has been successful both in driving up the quality of university research and in encouraging universities to focus on their strengths. The improvement in the quality of research assessed in the RAE has been dramatic. In 1992, 23 per cent of researchers were in a 5 or 5* rated department, the two highest ratings. That figure rose to 31 per cent in 1996 and in the 2001 RAE was 55 per cent. Nearly two thirds of all universities now have at least one 5 or 5* rated department.

[20] The Higher Education Funding Council for England (HEFCE), the Scottish Higher Education Funding Council (SHEFC), the Higher Education Funding Council for Wales (HEFCW) and the Department for Employment and Learning, Northern Ireland (DELNI)

3.13 HEFCE announced on 27 June 2002 that it would be conducting a review of the RAE in partnership with the other UK higher education funding bodies. The review will investigate different approaches to the definition and assessment of research quality, drawing on the lessons both of the recent RAE and of other models of research assessment, and will advise on the future of research assessment. Sir Gareth Roberts, President of Wolfson College, Oxford, will lead the review, which will begin in autumn 2002. There are concerns that the RAE does not give proper weight to applied research and favours basic research, which results in conventional research outputs, such as articles in peer reviewed journals. There are also concerns that the RAE, as a subject based exercise, does not give proper weight to inter-disciplinary research. Both these areas were given attention in the 2001 exercise. The review will need to consider, among other things, to what extent existing steps have been successful and what should be put in place to tackle these issues in future. From the Government's viewpoint, it also will be important to ensure that any modifications reinforce incentives for excellence – increasingly measured by world class standards – and maintain a dynamic research system by enabling newcomers to challenge research leaders. The review must also take account of developments in the dual support system set out in this strategy, and of the implications of these for the future allocation and management of QR funding within the dual support system.

3.14 The second Government funding stream is delivered by the Research Councils funded by the Office of Science and Technology (OST). It provides money for specific peer reviewed purposes. The Research Councils are listed in table 3.1 below. The Council for the Central Laboratory of the Research Councils (CCLRC) provides facilities and technical expertise in support of basic, strategic and applied research programmes for the Research Councils and other users. In total, the Research Councils are, at present, investing £1.6 billion per year in scientific research.

Table 3.1: Research Council budgets 2002-03

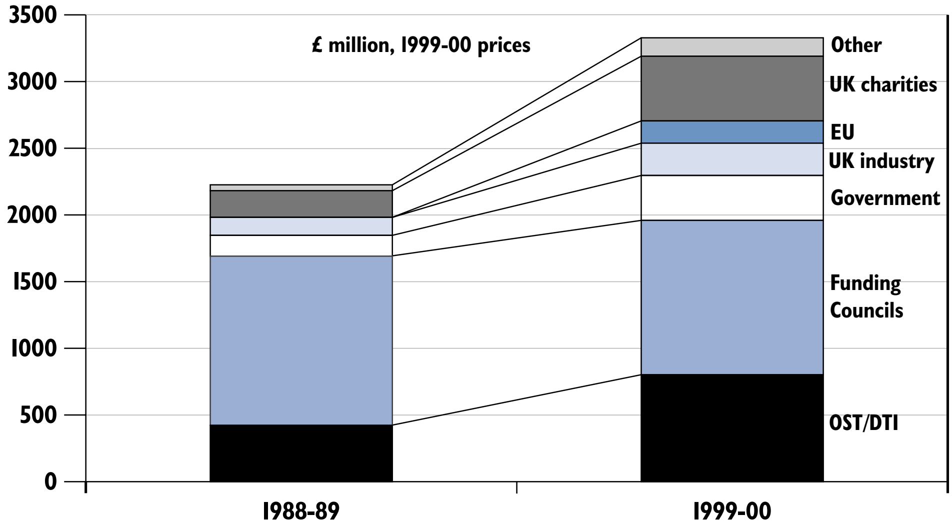
Research Council	Budget (£m) total
Medical Research Council (MRC)	374
Biotechnology and Biological Sciences Research Council (BBSRC)	239
Natural Environment Research Council (NERC)	203
Engineering and Physical Sciences Research Council (EPSRC)	498
Particle Physics and Astronomy Research Council (PPARC)	228
Economic and Social Research Council (ESRC)	84
Council for the Central Laboratory of the Research Councils (CCLRC)	11
Total	1,638

3.15 The Research Councils are not obliged to fund research and training in any particular type of institution, but are free to decide upon the best means to deliver their Royal Charter objectives, which include the need to promote and support high quality basic, strategic and applied research. In 1999-2000, 49 per cent of Research Council funding was spent in universities, with the remainder being spent largely in Research Council Institutes and on subscriptions to international facilities.

3.16 The Government continues to believe that the dual support system is the most effective way to fund university research. It sustains a dynamic balance in research funding which underpins the vitality of UK research. The precise mechanisms will need to adjust; this strategy itself proposes changes. But the principle remains valid and has become even more crucial as it now underpins an even more diverse – and potentially productive – system.

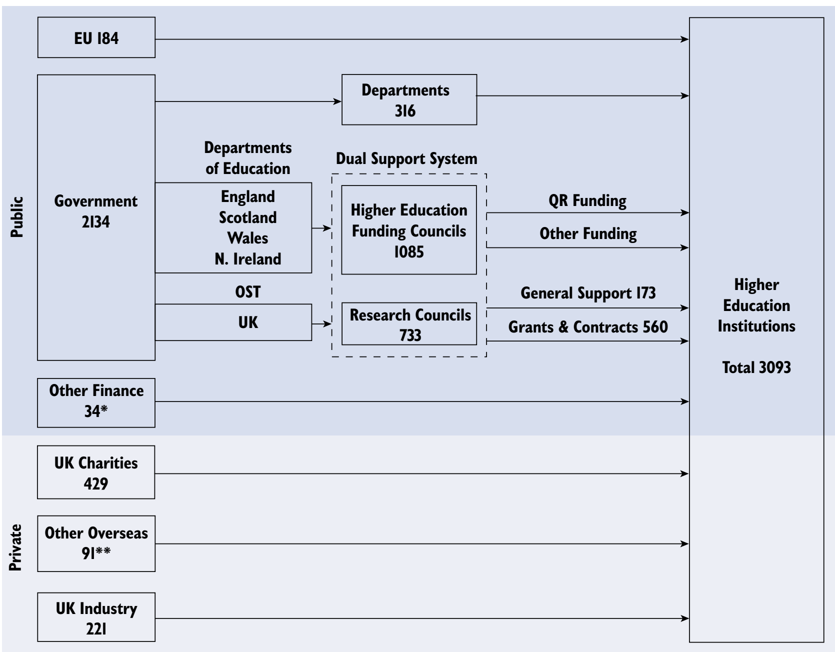
3.17 Chart 3.1 below shows that third parties now provide universities with over 40 per cent of their funding for research, compared to less than 25 per cent in 1988-89. It also shows that over little more than a decade total research income in universities has risen by around 50 per cent. This dramatic increase has been driven mainly by the growth of third party income, especially from research charities. Chart 3.2 shows how all the different funders of university research now contribute.

Chart 3.1: Sources of university research funding



Source: Office of Science and Technology.

Chart 3.2: How universities receive funds, 1998-99 (£million)



* *Universities own funding, other universities, local authorities* ***Non-EU funding including overseas charities and firms*

Charities

3.18 Research charities are now major funders of the UK science and engineering base, spending over £600 million a year on scientific research. In 1999-2000, the Wellcome Trust spent around £350 million on science research. Other medical research charities spent a further £288 million. In the last five years, medical research charities have contributed £2.7 billion to the science base. In particular, Cancer Research UK has an annual scientific spend of more than £130 million per year, and in 2001 the British Heart Foundation spent £40 million on research. Much of this money is effectively spent in partnership – with universities and the Government. For example, in addition to the research projects it funds through the universities, the Wellcome Trust provided £525 million towards the recent Joint Infrastructure Fund and the Science Research Infrastructure Fund in partnership with the Government. They have also, alongside the Medical Research Council and the Department of Health, provided an initial £45 million for the UK Biobank project – a study of genes, environment and health that will capitalise on the knowledge from the Human Genome Project. In addition, the Wellcome Trust has committed £110 million to the Diamond Synchrotron project, and £360 million over five years for genomic research at the Wellcome Trust Sanger Institute.

3.19 Charities, in general, are increasingly making a distinctive contribution to research by supporting different types of partnerships. These have enabled charities to work with others to develop more focused, strategic and sustainable research programmes which meet the objectives of both the charity and the research institutions.

Industry

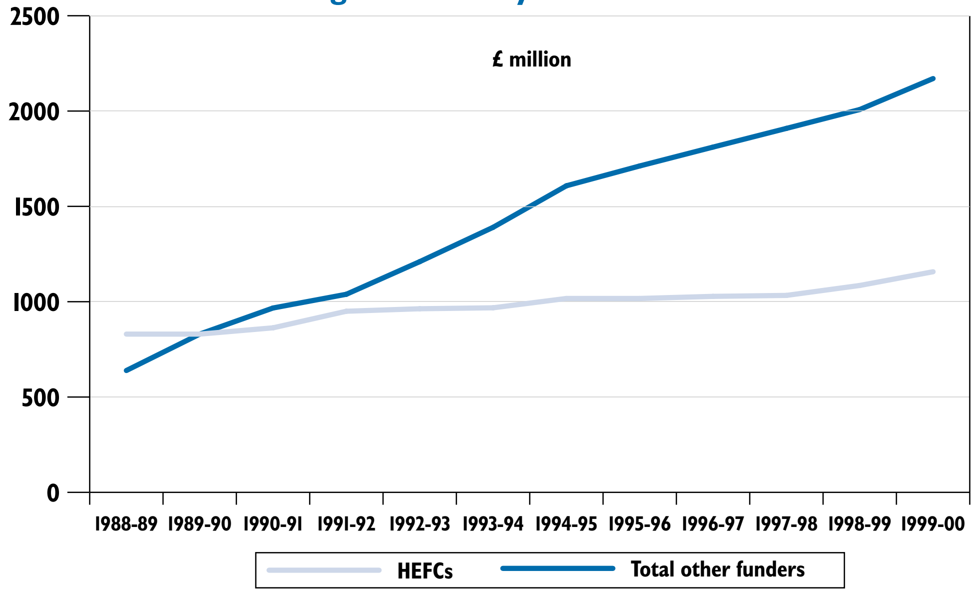
3.20 In parallel, industry collaboration with, and use of, university research has grown in real terms from £135 million to £242 million (in 1999-00 prices) between 1988-89 and 1999-2000. Building such relationships with business is crucial to successful scientific research relevant to the wider economy. The Government, through the Higher Education Innovation Fund and other measures, has encouraged this growth.

Government departments

3.21 Government Departments are also major users of university research, though their role is distinct from that of the Funding and Research Councils. Departments' concerns are usually with particular policy objectives, rather than more general scientific enquiry. The NHS, however, is an important funder of the science and engineering base, now spending more than £500 million per year in total on clinical and other health-related research in NHS Trusts, universities and research institutes. Its position is, therefore, closer to that of the Research Councils.

3.22 The differential growth rates of different funding streams have changed the balance of university research funding. From a position in the late 1980s where Funding Council resources were intended to complement Research Council grants and were basically in balance with all other sources of research funding, they are now dwarfed by the latter, as Chart 3.3 shows. As a result, Funding Council resources have been increasingly thinly spread.

Chart 3.3: Funding of university research



Source: Office of Science and Technology.

3.23 This situation has enormously increased the apparent productivity of the research base but in a way which now risks its sustainability. As a result, some key issues now need to be addressed to ensure the future of scientific research in UK universities. These are:

- a lack of clarity over what level of support (if any) Funding Council money is intended to provide to specific projects and programmes funded by others;
- the accumulated under-investment in the university research infrastructure;
- the incentives which exist at present for universities to take on increasing volumes of research without sufficient regard for their long term viability; and
- the need for universities to manage their research and finances to match the increased complexity and demands of diverse funding sources.

Principles for the public funding of research

3.24 The increased volume and diversity of university research funding makes it imperative that there is greater clarity about the purpose and scope of Funding Council support for research. **The Government is therefore proposing a set of principles to which universities should have regard when considering how to manage and price the research they take on.** These are set out in box 3.1 below. The basic proposition is that money from the Funding Councils should be used to support research which is intended to, or otherwise likely to generate, a public good.

3.25 These principles recognise that basic research is highly speculative and long term in nature. Many avenues of research will prove unfruitful, while others will unlock huge wealth-generating potential quite unexpectedly. It is therefore unlikely that industry, left to itself, would fund this form of research. Nevertheless, such research is clearly beneficial to the economy, to individuals and to society. Government therefore funds this research and, by doing so (and thereby lowering the risk), also leverages in research funds from others. Where research is near market and the rationale for it is directly related to the user's core business, universities should ensure that the price paid covers at least the full costs of the project.

3.26 In summary, there is a distinction between *funders* of the research base, motivated by the health of science and acquisition and diffusion of knowledge, and *users* of it who are motivated more by their own, more circumscribed, interests.

Box 3.1: Principles for using QR funding to support a research project

i. Research should demonstrably contribute to the enhancement of the UK Science and Engineering Base (SEB) or in some other way provide a net public good. An indicator of this may be that the results will be published openly in the academic literature and that any intellectual property generated by virtue of the research will vest in the university rather than with the commercial funder (so that revenues generated by licensing or spin-outs benefit the university). Charity funders may, with the agreement of the university, choose to hold and exploit intellectual property themselves, or allow the university to do so.

ii. The funder will have a research strategy, which, while recognising the advantages of having a plural funding system, nevertheless takes account of the strategy and priorities of other key funders, most notably the Research Councils and charities.

iii. Research supported will be only of the highest quality. Funders wishing to benefit from public support will need to be able to demonstrate that they have project appraisal systems in place which seek to ensure that only high quality research is funded

iv. Access to research funds should not systematically be restricted to any specific research performers or group of performers. In principle, anyone with an idea for excellent research and the means to carry it out should be eligible for funding.

3.27 The exercise of these principles will differentially impact different organisations who may in different situations be funders or users. The precise impact will need to be determined by individual universities in the light of their financial positions, the value to them of particular pieces of research, and the need to move their research activity towards long-term sustainability. But even where the research conducted demonstrably meets the principles for support there may need to be some greater contribution from funders. In recognition of this, **the Government has provided an additional £120 million per year from 2005-06 to increase the Research Councils' contribution in respect of existing levels of research**. The precise form this will take will need further discussion. But it is a very clear signal of the Government's intention to start to redress the imbalance identified and to put research financing on a long term sustainable basis. It will be looking to other partners similarly to recognise that the long run viability of the system is in the interests of all.

3.28 The future health of university research will be increasingly dependent on an open partnership between the major stakeholders. **The Government will set up a Science and Engineering Base funders' forum, to allow major research sponsors to share strategic information about research plans, to consider the financial impact of their plans on the system overall, and to make sure there is a shared understanding of how all the funding streams for research fit together.** Key partners include the charities, Government departments and industry.

3.29 The Government recognises the important role that charities play in UK research and the enormous value of the research they sponsor. The goal of the research charities – especially in the biomedical field – is clearly to generate knowledge that will benefit the public. This makes them funders rather than users of university research. They provide an independent stream of research funding which should complement that of the Research Councils and NHS. This argues for explicit recognition of what has up to now only been implicit – that in principle charity funding of research in universities is entitled to support from public funds provided by the Funding Councils. What this means in practice will need to be decided, case by case, by universities in discussion with charities, against the background that – taking all sources of funding together - research should be fully funded. But the Government believes that charities accept that they should at least pay the full directly attributable costs of the research they fund, looking to universities to provide supporting physical and human infrastructure. Beyond that, many charities have shown themselves willing and able to make specific investments in university buildings and equipment where they see the specific need, or wish, for example to exercise greater influence, for their own strategic purposes, over a research programme.

3.30 The Government welcomes the continuing development or such partnerships between charities and universities. It hopes that the explicit recognition of the national role that charities play in funding UK research will lay the foundations for a long term strategic partnership, under which there is a shared appreciation of a mutual interest in a financially healthy science and engineering base and a joint sharing of expenditure plans and research priorities. The publication by the Wellcome Trust of its five-year forward funding strategy, enshrined in its corporate plan, is a positive move down this road.

3.31 Government departments are major users of the research base. In 1999-2000, they accounted for around 10 per cent of university research income. They will need to recognise that the context in which they are using universities to procure evidence to support policy making is changing. They often commission research to meet their own objectives, rather than to advance the science and engineering base *per se*. In the light of the Government's principles, Government departments must therefore increasingly expect to pay nearer to the full costs of much of their research. And in common with other users who depend upon the existence of specialised infrastructure within which they can commission the applied work they need, they will need to be prepared to enter into strategic partnerships with universities, Research Councils and charities and other funders if they are to be sure of the continuing provision of this infrastructure.

3.32 The Government welcomes the increased interactions between industry and universities. It also recognises that these are complex, varying from near market applied research to basic, high risk research that can have significant knowledge spill-over benefits. Only universities can determine in discussion with industry what should be charged for individual projects, but in general the nearer to the market the research and the more focussed it is on financial benefit for business, the fuller the economic cost the customer should expect to pay. In return, industry should expect a high quality, timely service. The funding proposals contained in this strategy should also ensure a research base which is increasingly up to date, well equipped, able to attract the best talent and therefore more capable of responding to industry's demands.

Improving research infrastructure

3.33 The imbalance in university research funding has manifested itself in a growing and persistent failure to invest in research infrastructure. Two particular issues have exacerbated this:

- universities have been incentivised to increase volumes of research above other priorities such as investing in and maintaining their capital infrastructure; and
- resources from the Funding Councils have risen more slowly than Research Council grants.

3.34 The RAE provides a strong incentive for universities to take on increasing volumes of research as the funding they receive is based on a formula that rewards such behaviour. Equally, the RAE , as the driver of the Quality Related allocation formula, has provided the clearest route for universities to increase discretionary funding from Government in recent years.

3.35 The Research Councils' funding has grown substantially faster than that for the Funding Councils over the past decade. This has allowed the Research Councils to fund more projects than universities could support with money from the Funding Councils. Given, also, increased demands from charities and industry, Funding Council money has fallen short of providing sufficient infrastructure spending. These funding issues have been exacerbated by management and cultural factors including annual cash-based budgeting and too little attention to long term asset management.

3.36 A modern and well maintained capital infrastructure in universities is important to the health of scientific research in the UK because:

- the quality and age of the facilities and equipment determine the quality of the science that an institution can do. Failure to invest will progressively put the UK at a competitive disadvantage given the increasingly global nature of the science research market; and
- universities with older laboratories and outdated equipment will find it increasingly difficult to attract and retain the best research talent.

3.37 The poor state of infrastructure in UK universities featured in Lord Dearing's report on higher education in 1997 and, more recently, in Sir Gareth Roberts' report on the supply of scientists and engineers (see chapter 4). There have been estimates of the extent of the investment needed to bring the research capital stock in UK universities up to the required level to compete internationally. One, in the run-up to the 2002 Spending Review, estimated a required spend of £3.5 billion on infrastructure (including equipment)[21]. Such estimates depend on the assumptions made. And, of course, the backlog cannot always be distinguished from forward looking investment needs and priorities. Nevertheless, there is a clear need for significant investment, particularly given how much of the estate comprises buildings erected in the 1960s, which are now reaching the end of their useful lives.

3.38 In the last two Spending Reviews the Government recognised this problem and, in partnership with the Wellcome Trust, launched the Joint Infrastructure Fund (JIF) and the Science Research Investment Fund (SRIF) to provide £1.75 billion for investment in research infrastructure. While JIF and SRIF have been successful in increasing investment in research infrastructure, they only run to 2003-4 and do not therefore provide the certainty to enable universities to deal with their long term capital requirements on an efficient and planned basis. SRIF also included a requirement for universities to raise their own or third party resources amounting to 25 per cent of projected spend. This has the advantage of encouraging partnership and of buttressing financial discipline in choice of projects. The longer planning horizon implied by a permanent capital stream should help to attract third-party partners. On the other hand, a contribution as high as 25 per cent has caused problems for some universities through distorting their higher level priority setting.

3.39 The Government has now concluded that it should:

- **institute a dedicated earmarked capital stream for science research infrastructure. It will build up from £400 million in 2003-04 to some £500 million by 2004-05**[22]; and

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[21] JM Consulting (2002), Study of science research infrastructure (www.ost.gov.uk/research/funding/underinvest/index.htm)

[22] These figures aggregate DfES resources (for England only) and OST resources (for the UK as a whole). It will be for the devolved administrations to determine how far to allocate their share of the England only funding for research capital to these purposes.

- given the scale and likely timescale for righting the problem, **reduce the contribution that universities have themselves to make to new infrastructure projects.** It will therefore reduce the contribution that universities have to make from own or third party resources from 25 per cent to 10 per cent.

3.40 Capital funding will be distributed, as SRIF has been, on the basis of research excellence and volume, with higher education institutions drawing down their allocation in exchange for an infrastructure investment strategy. Separately, increased capital for higher education will also allow arts and humanities investment to increase. Under SRIF, a separate capital stream was earmarked for the modernisation of Research Council Institutes and the development of large national facilities. This line will continue, alongside the capital for university science research infrastructure. **Furthermore, an element of the capital stream will be retained centrally to support strategic rationalisation and restructuring of the university science base.** Funds will only be available where it can be demonstrated that the restructuring would produce a critical mass of international research excellence that could not be achieved by the institutions using their individual funding allocations. This might be as part of institutional mergers. This funding should only support the research element of such restructuring; the teaching and regional benefits should be funded from other relevant sources.

Increasing Funding Council resources

3.41 The measures outlined in this chapter to increase capital resources for research, increase the cost contribution from Research Councils, and the new framework for other partners, should all contribute to larger and better balanced funding streams. It will also be important that reforms to the RAE buttress the measures in this strategy to improve long term sustainability, and make provision for the very best research to be rewarded properly. In the meantime the Government recognises that existing levels of excellent research will be jeopardised without further Funding Council resources, when at the same time the outcome of the 2001 RAE shows there is now more high quality research undertaken than ever before. The scale of the assessed improvements following the 2001 RAE outstripped the available resources. **The Government will therefore significantly increase real terms spending on recurrent spending on research, with extra resources for HEFCE[23] starting in 2003-04 and rising to an additional £244m in 2005-06, compared with 2002-03 levels.** The major part of these increases could be expected to be spent on science, which has historically accounted for around 80 per cent of DfES' recurrent funding of university research. Precise arrangements for distribution of this funding will be announced in due course. This will help to restore balance in the dual support arrangements.

[23] The devolved administrations will receive their share of the additional funding in the normal way, and will, if they so decide, be able to use it to fund recurrent research in their univerisities.

3.42 These increases in research funding will be made in the context of a balanced overall funding settlement for higher education, which recognises the strong linkages between teaching and research. The 2002 Spending Review will ensure a real terms rise in total institutional funding per student in the three years to 2005-06, providing additional resources for teaching, access, pay and capital investment in teaching infrastructure and estates, which will benefit arts and humanities disciplines as well as science. The Government will set out its broader strategy for higher education in a strategy paper this autumn.

The challenge for universities

3.43 The Government believes that the changes outlined above represent a solid contribution to a more sustainable research base. However, decisions about which projects to accept and how to fund them are taken at the university level. Universities themselves must therefore be ultimately responsible for ensuring that science and engineering research output in the UK is sustainable in the long term.

3.44 The increase in the volume of research that universities carry out and the increasingly diverse range of funding they receive means that they now need more and better information than previously to enable them to manage their businesses effectively. They need to ensure they are investing enough for long term needs as well as covering their current costs. Equally, the principles set out here about the use of Funding Council resources will require them to think more strategically about the work they do and how they fund it.

3.45 The implementation in universities of TRAC[24], a management system for tracking the costs of research, was required following the 1998 spending review. For the first time, it provides universities with the financial data they need to meet the demands of managing research in the current climate and has enabled them to understand better the true costs of the research they carry out. This must now be used to create sustainable research businesses, so that the full economic costs devoted to research are covered from the range of public and private funding available to universities. This cannot be achieved immediately. But the Government expects universities progressively to put in place the necessary systems and policies, with a view to their individually achieving a sustainable position. Progress will be reviewed before the next Spending Review. Given the importance of transparency to research customers and Government, and the importance of setting the right financial context for university decision-making, **the Government will ask the Funding Councils to review, via an independent evaluation, how best to improve further universities' financial reporting and activity costing, building on the progress to date and balancing reporting requirements against the benefits to funders and universities.**

[24] Transparent Approach to Costing, a new regime for improving the public accountability of research and other publicly funded activities, and for improving information for management within institutions. This was introduced following the Comprehensive Spending Review in 1998, and has now been implemented across the higher education sector.

Maintaining cutting-edge research

3.46 This chapter has shown how the Government, working in partnership with the universities, research charities and business, is prepared to put university research onto a sustainable basis. This is intended to create the foundations for a continuing growth in research activity.

3.47 In the last spending review, the Government made available an additional £350 million for science and engineering research over the three years to 2003-04. £250 million of this total was earmarked for investment in three specific new cross-Research Council programmes: e-science, genomics, and basic technology. This boost to spending enabled UK researchers to move rapidly into expanding new areas of major importance.

3.48 Two years on, the UK is well placed to build on this, especially after the formation of Research Councils UK (RCUK) in May 2002, following the Quinquennial Review of the Research Councils. One of RCUK's early tasks will be to develop a Research Council investment strategy which will, in turn, enhance the quality of research investment prioritisation in the future. A start has already been made down this road. OST and the Research Councils have developed and published a long term road map for investment in large scale science facilities and, in the course of the last year, the Councils developed a range of priorities for new areas of science research which hold great promise for the future.

3.49 **To ensure that the UK can remain in the forefront of scientific research, the Government will increase the resources available to the Research Councils – above and beyond the increases described above to enable the Councils to make a larger increase to universities' indirect research costs – by £136 million in 2004-05 and £300 million in 2005-06.** This will enable the Councils to maintain growth in the volume of science which they fund, building further on the significant new resources made available in 1998 and 2000. Details of how these new funds will be invested through the Research Councils will be announced later this year, but some early indications of areas of interest are described below. This investment provides for growth in funding of research programmes of 5 per cent per year in real terms from 2002-03 to 2005-06.

3.50 To remain internationally competitive in science, it is important to accompany investment in front line research by making investments in a carefully constructed portfolio of large instruments and facilities which are crucial to the performance of world class science. The Government has recently confirmed its intention, through the formation of a joint venture with the Wellcome Trust, to build the Diamond Synchrotron. **This has now been fully costed and the Government is committing a further £122 million from 2002-03 to 2005-06 to ensure the project is built to time and specification. Additional resources rising to £30 million per year by 2005-06 will also be made available to allow new investments to be made in other large facilities and in renewal of infrastructure at the Research Councils' own Institutes.**

Future Research Council investments

3.51 A key issue for the Research Councils in the period ahead will be to consolidate their existing core programmes following a period in which increases in research funding have tended to be directed more towards specific new programmes.

3.52 Beyond this, the Councils have identified a wide range of fertile new areas for research investment. RCUK will advise on the prioritisation of these areas to be funded as resources allow. The new money made available for investment in such programmes will be augmented by contributions from the Councils' existing budgets as lower priority areas are phased out over the next three years. Examples of the opportunities for outstanding new areas of investment which will be considered by RCUK in drawing up its advice include:

- **Brain science:** recent advances in molecular biology and imaging, coupled with an influx of multi-disciplinary scientists into this arena, should enable UK basic science to become better aligned to serve clinical need and lead to the development of preventative strategies.
- **Regenerative medicine:** the UK recently became the first country in the world to approve properly conducted research into the use of embryonic stem cells. There is now an opportunity to develop the potential of stem cell based therapies for repair and replacement of tissues and organs.
- **Proteomics:** research into what proteins do, and how they do it, building on the foundation created by the recent genome sequencing programmes. Proteomics work will enable the UK to benefit fully from the investment to date in genomics, and move towards targeted development of drugs and plant and animal breeding.
- **Sustainable energy:** to support the UK's goal of access to secure, safe and reliable energy at competitive prices, while meeting the challenges of global warming, requires significant scientific underpinning from across the research disciplines. This programme aims to build on the UK's existing research strengths to address the technological and societal challenges of sustainable energy supply.
- **Rural economy and land use:** the UK rural economy faces significant shifts in economic, political and environmental drivers. Against a background of agricultural policy reform, growing land pressures, and climate change, inter-disciplinary research can help generate viable options for land use: delivering safe and efficient food production, in a manner which enhances biodiversity and sustains a healthy rural economy.

Box 3.2: University Veterinary Teaching and Research

The health and welfare of farm animals is vital to the well-being of the countryside, the performance of the economy, and a safe food chain. Veterinarians play a crucial role in clinical practice and research. Their effectiveness can only be sustained by ensuring that veterinary science has sufficient teaching capacity and access to research funds. Historically, however, the costs of clinical veterinary training in universities have not been fully funded. There has been no equivalent to the resource available from the NHS for the clinical training of doctors. This deficiency has impacted on both teaching and research.

The Government is therefore planning to inject £15m of funding over the Spending Review period into a new strategic partnership with The Wellcome Trust to strengthen clinical veterinary teaching and research in universities. The Government will consider the need for additional resources in the light of the review of exotic farm animal infectious disease conducted by the Royal Society. The Trust will be making an associated investment of £25m over five years into animal diseases in developing countries that will complement this initiative. Strategic arrangements for managing and co-ordinating these new resources will be developed in the light of the review. DEFRA will lead the co-ordination with key roles played by HEFCE and the Biotechnology and Biological Sciences Research Council and with the participation of the Royal College of Veterinary Surgeons.

Conclusions

3.53 University research in the UK is a key source of the ideas and inventions that are necessary for the UK to create the innovative new products and services needed to increase productivity and economic growth. It is already a world leader in terms of research outputs. However, the increasing diversity of the funding system, the changing balance within it, along with incentive and management issues, mean that funding has had to be enhanced and restructured. This chapter has set out reforms affecting all stakeholders in the research community, against a shared interest they all have in a healthy, well functioning research base.

3.54 These reforms should ensure that the UK continues to produce the ideas and research that are needed to support innovation. To benefit from them, however, requires highly skilled individuals, who can develop them and turn them into products and services that the private sector can take into new markets. Ensuring that the UK has the skills base to achieve this is the subject of the next chapter.

Box 3.3: Scientific Research and the British Library

The British Library has an important role to play in supporting scientific research in the UK, by providing access to its scientific reading rooms, and through its document supply service. In 2001, the Library provided over one million scientific, technology, medicine and engineering documents to higher education institutions and industry in the UK. In addition, five million scientific journals, monographs and patents are consulted each year in the reading rooms. The Library estimates that the opportunity cost saving to universities of its provision is £50m per year. It has potential to provide particular benefit to smaller firms which are less able than large companies to hold substantial collections of scientific journals and other publications.

The Library is facing pressures from increases in publishing output (running at 10 per cent per year) and from inflation in the cost of publications (around 7 per cent per year). It is also considering how best to meet increasing requests for information to be supplied electronically and has identified priorities for digitisation to focus on the most useful and relevant parts of its collection.

The Library is funded by the Department for Culture, Media and Sport and receives an annual grant of around £86 million. It also receives around £28 million per year from provision of services, largely the document supply service, which charges at cost for its standard service, but offers value added services such as express delivery for a premium charge. The work of the library is also of relevance to the work of both DfES and DTI/OST; HEFCE and the Library launched a strategic alliance in March 2002.

Recognising the value placed on the British Library as a resource to scientific researchers in the UK, both public and private, the Government will be reviewing the Library's resource plans for the coming years. This should allow the Library, among other things, to step up the level of digitisation of its collection, enabling more researchers to have quicker access to its collection, and to search the Library's databases more effectively.

4 SKILLS

Introduction

4.1 The previous chapter set out the Government's strategy for sustaining and enhancing scientific research in UK universities. Putting their funding on a more sustainable basis ensures that they can operate at the cutting edge of science and create the new ideas that, alongside business investment, generate innovation. The need for human ingenuity both in making new discoveries and – in industry – in developing new products and services, means that innovation is also critically dependent upon the availability of skilled scientists and engineers, as well as technicians and other R&D support staff.

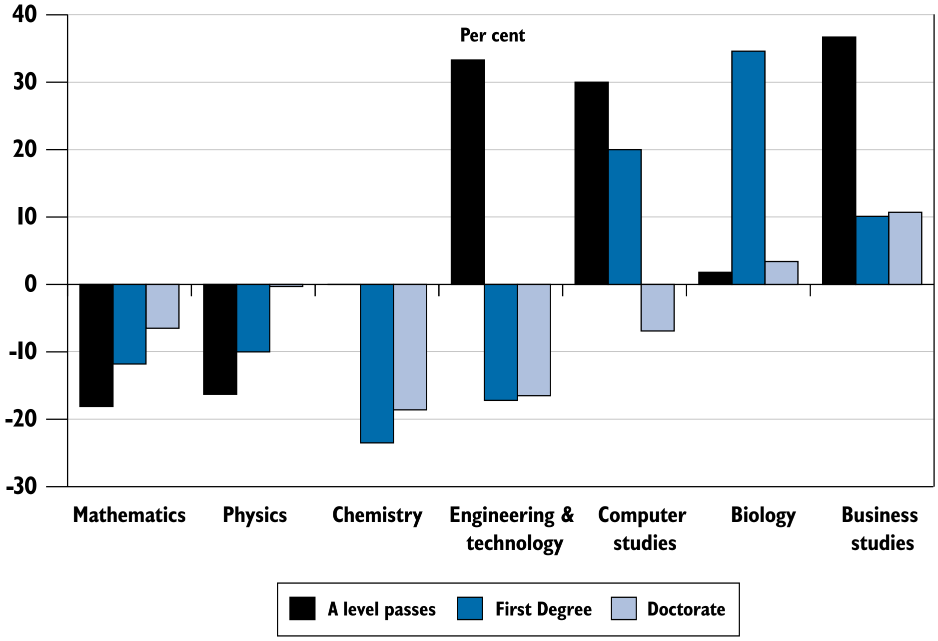
4.2 At the time of the 2001 Budget the Government asked Sir Gareth Roberts, President of Wolfson College, Oxford, to lead a review to determine whether the UK has an adequate supply of people with science, technology, engineering and mathematics skills. The Review's final report was published in April 2002[25]. It found that fewer students in the UK are choosing to study many science and engineering disciplines – particularly physical sciences, mathematics and engineering (see chart 4.1). As a result of these trends, and increasingly attractive opportunities for skilled scientists and engineers to work outside R&D, the Review found evidence of emerging shortages in their supply to R&D employers. The Review concluded that these emerging shortages will act to constrain R&D and innovation in the UK, not just in these disciplines but also more widely, since much cutting edge research is multi-disciplinary.

4.3 The Review also concluded that securing a strong future supply of scientists and engineers will require co-ordinated action from the Government, employers and universities to ensure that:

- those individuals gaining graduate and postgraduate qualifications and training in science and engineering are given attractive options to work in university and private sector research and development; and
- there is a strong supply of students at every stage of the education system both able, and wanting to study and work in science and engineering.

[25] ***SET for success:*** The supply of people with science, technology, engineering and mathematics skills.

Chart 4.1: Change in numbers taking science and engineering courses, 1994-95 to 1999-2000



Source: Data from DFES, HESA and Govt Actuary's Dept, as presented in the Roberts Review.

4.4 To ensure this, the Review identified responsibilities and challenges for the Government, R&D employers and others with an interest in science, engineering and innovation in the UK. Together with schools, colleges and universities, the Government has a role in ensuring that sufficiently attractive opportunities exist for individuals to study science and engineering subjects. (This includes the need for schools, colleges, universities and related organisations to be responsive to the requirements of employers). The Government has a role, again in partnership with universities, in offering attractive employment opportunities in scientific research in universities and the public sector. Furthermore, the Government has a role in creating a favourable environment for scientific research and development, through improving the public's understanding and perception of science, engineering and technology.

4.5 However, the Review was clear that ultimate responsibility for an appropriate flow of scientists and engineers into private sector R&D rests primarily with employers, and with their ability and willingness to offer opportunities that are competitive with the other sources of employment open to highly-skilled scientists and engineers.

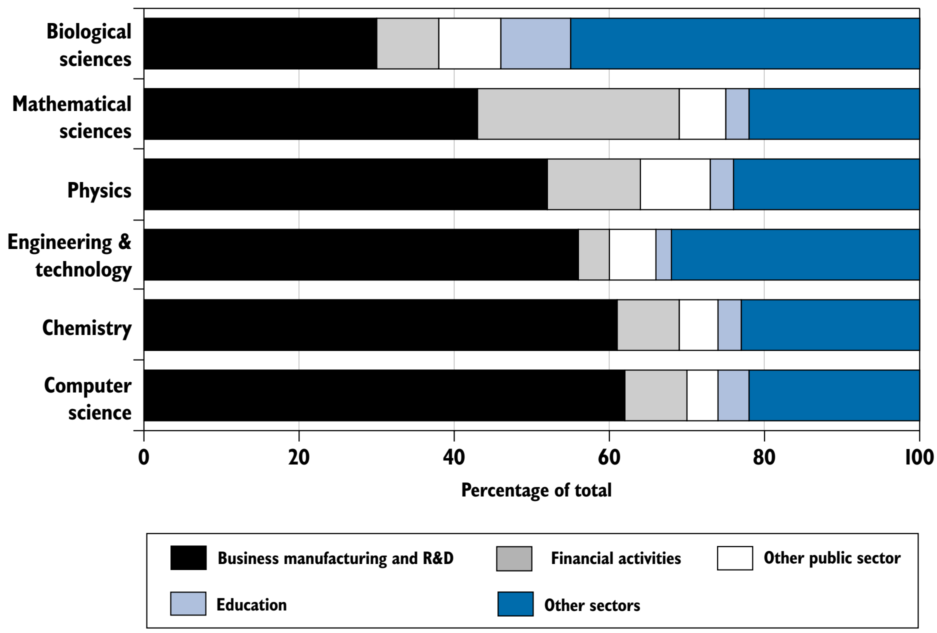
4.6 The Government's detailed response to each of the Review's recommendations is at Annex A. This chapter sets out in broader terms how the Government intends to address the issues that Sir Gareth Roberts raised in his report.

Creating attractive careers in science and engineering

4.7 The most highly skilled scientists and engineers have many career options on completing their studies. Crucially, they have a choice of whether to stay in scientific research and development in either the public or private sectors, to work in other areas related to science and engineering (for example, teaching), or to leave science and engineering altogether. It is important that enough choose to remain in science and engineering not only to produce research and innovative output itself but also, in schools, colleges and universities, to train future generations.

4.8 Chart 4.2 shows the first destinations of graduates with science and engineering degrees. This shows that the majority currently go on to careers in private sector R&D, although the financial services sector is an important employer for mathematics (and, to a lesser extent, physics) graduates.

Chart 4.2: First destination of science and engineering graduates, 1999–2000



Source: Data from Higher Education Statistics Agency, as presented in the Roberts Review.

Improving the attractiveness of careers in business R&D

4.9 The number of scientists and engineers employed in R&D[26] in business has declined by around 20 per cent since the mid 1980s[27], although there has been an upturn more recently. These trends reflect overall levels of R&D expenditure in the UK. If the UK is to continue to improve its innovation performance the numbers of scientists and engineers available, and wanting, to work in R&D must keep pace with increasing levels of R&D. To ensure

[26] Business manufacturing and R&D includes a few other small areas of employment. See the Roberts Review for further details.

[27] Data is from OECD and OST, presented in the Roberts Review report

this it is crucial that businesses undertaking R&D offer competitive career packages attractive to the best scientists. (Similar challenges face universities and public sector research institutions recruiting scientific research staff, as discussed later).

4.10 However, the Roberts Review found that many highly skilled scientists and engineers are not attracted to careers in scientific research and development. The Review concluded that this lack of attractiveness was contributing significantly to the recruitment difficulties experienced by R&D employers, evidenced by employers surveys. Overall shortages of skills commonly possessed by skilled scientists and engineers were also seen to lead to some businesses, principally in the financial services sector, using differential salary premia to attract science and engineering graduates in certain disciplines.

4.11 In his final report Sir Gareth Roberts identified insufficiently competitive remuneration packages as a significant factor in R&D employers' difficulties in trying to recruit the most talented scientists and engineers. Evidence presented in the report showed that despite limited salary differentiation by some R&D employers, technical graduates working in the electronics, pharmaceuticals and R&D services sectors still typically earn significantly less than their counterparts in the financial services and computer services sectors[28]. Furthermore, this difference is more pronounced at the top end of the salary range. For example, those in the top decile of earnings in R&D employment receive around 20 per cent less than their counterparts in financial services. This suggests financial services and computer services companies are targeting financial rewards to recruit and retain the very best people. Data from the Labour Force Survey and the Institute of Physics supports this analysis.

4.12 The Roberts Review also found that non-salary factors may deter people from careers in R&D in the private sector. These include relatively weak career structures and insufficient opportunities to keep in touch with subject developments. The Government agrees with the Review that employers need to recognise these weaknesses and to address them to improve the attractiveness of jobs in scientific R&D for the most able scientists.

4.13 The Government is also committed to improving opportunities in science, engineering and technology for groups that are currently under-represented in this area (for example, women and certain ethnic minority groups). The Government notes the concern expressed in the Roberts Review on this issue, and agrees that a number of the Review's recommendations, coupled with existing measures, should help to improve participation from these groups. Furthermore, the Government has asked Baroness Greenfield to advise on a stronger and more strategic approach to increasing the participation of women in particular.

[28] Mason (1999), The labour market for engineering, science and IT graduates: are there mismatches between supply and demand, NIESR.

Improving the attractiveness of careers in higher education

4.14 Universities are also facing stiff competition for the most talented scientific staff – from overseas as well as from other UK employers. They are reacting to this changing environment, as are their counterparts abroad. There is increasing differentiation of salaries at senior levels to reflect market forces. However, universities report significantly less variation in pay amongst junior and middle-ranking academic staff. Instead, many appear to be promoting more staff to professorships and other senior posts, or offering staff other benefits such as fewer teaching hours. Such approaches can be effective in attracting and retaining individuals. However, they are less visible to those considering careers in scientific research and are therefore less effective (compared to more visible and explicit salary increases) in promoting careers in these areas where competitive pressures are greatest.

4.15 The Government recognises that universities need to respond to the challenges of an increasingly competitive labour market and that this implies more differentiation in pay than previously at all levels. In the 2000 Spending Review, £50 million was allocated in 2001-02, followed by £110 million and £170 million in the two subsequent years, to support higher education institutions' human resource strategies, which include measures to recruit and retain the best staff.

4.16 **The Government agrees with Sir Gareth's conclusion that more, permanent, funding is needed and will therefore allocate further resources in the 2002 Spending Review for pay increases targeted on the recruitment and retention of permanent staff in all disciplines (including, but not only, those in science and technology) where there is the greatest competition.** These increases will be based on priorities identified in universities' human resource strategies.

4.17 Improving pay and conditions for the most talented researchers will enable R&D businesses, universities and public sector research establishments (PSREs) to compete in a global marketplace. It can be a powerful signal to potential researchers. But it is only part of the answer. It is also essential to address shortcomings and difficulties at every stage of the education process, to improve the flow of highly skilled scientists and engineers from which universities and R&D businesses have to recruit.

Fostering scientific talent

Improving the attractiveness of scientific PhDs

4.18 Postgraduate study is fundamental to the development of the highest level of science and engineering skills. It develops specialist knowledge and, particularly at the PhD level, trains students in the techniques and methods of scientific research. With the increasing sophistication of much R&D activity, the majority of the UK's future scientific researchers need to have postgraduate qualifications. Yet as with students at A-level and degree level, there is concern at the falling numbers of postgraduate students in some subjects. For example, there was a 9 per cent reduction in the number of PhDs in the physical sciences awarded to UK-domiciled students between 1995 and 2000. Of concern, too, is the attractiveness of PhDs to the best students – for example, in chemistry the proportion of PhD students with a degree class of 2:1 or higher fell in the late 1990s.

4.19 If UK universities and businesses are to undertake the cutting-edge research necessary to lift the UK's innovation performance, they need to work with Government to ensure that the most able undergraduate scientists are attracted to postgraduate study. To achieve this, two sets of issues need to be addressed:

- the immediate attractiveness of a PhD compared to other options; and
- the options opened up as a result of gaining a PhD.

4.20 The Roberts Review found features of science PhDs deterring too many of the most able students, and concluded that two in particular should be addressed:

- the level of the PhD stipend and that many PhDs continue beyond the time for which funding is available; and
- the nature of a science PhD in the UK and how far it confers the balance of skills required to conduct high quality R&D in business.

Ensuring the PhD stipend is attractive to the best graduates

4.21 Until 1998 the basic stipend for most Research Council PhDs had been unchanged in real terms since 1966. Since 1998, the Government has raised the level of Research Council PhD stipends significantly, from under £5,500 to a planned £9,000 in 2003-04[29]. Despite these rises, PhD stipends remain far below what able graduates can earn elsewhere: the mean post-tax graduate salary expected for a first job in 2000 was over £12,000. They are also below typical PhD stipends in the US.

4.22 It would be unreasonable to expect PhD stipends to compete with top graduate salaries as there are other benefits from carrying out research and gaining a PhD. However, in an increasingly competitive labour market, where there is a premium on the most talented, the Government accepts that PhD stipends should rise further.

4.23 **The Government will therefore provide resources in the Spending Review to increase the minimum PhD stipend to £12,000 a year by 2005-06. Additional funding will be provided for the Research Councils to increase the stipend still further in areas where recruitment is difficult. As a result, the Government expects that the average PhD stipend will increase to**

[29] DTI (2000), Excellence and opportunity: a science and innovation policy for the 21st century.

over £13,000 by 2005–06. The Government also accepts that it is necessary to provide the flexibility to permit a longer time for PhDs. Funding will therefore be provided to extend the average length of funding to 3½ years. Research Councils UK will consult later this year on detailed implementation issues, including the issue of any additional costs incurred by universities.

Improving the training given to PhD students

4.24 Students need to know that a science PhD will equip them with the skills relevant to their future careers. In many areas over half of PhD graduates go into jobs in business. So such skills must be relevant to that environment as well as to university and public sector employment. The Roberts Review concluded that PhD programmes do not deliver the quality of training required by industry. The most significant weakness is in the level of training provided in transferable skills, such as management and project planning.[30]

4.25 The Government agrees that there needs to be a new impetus to improve standards of PhD training. **To encourage universities to address the skills acquired by PhD students, and to ensure they are relevant to business, the Government expects all universities to meet high quality minimum training standards on their PhD programmes, and agrees that all funding from HEFCE and the Research Councils in respect of PhD students should be made conditional on meeting these standards. The Government has also provided additional funding to the Research Councils in the Spending Review to enable enhanced training for their PhD students, as recommended in the Roberts Report.**

4.26 The Government believes that a combination of increased stipends and better training content will improve the attractiveness of PhD study to the most talented undergraduate scientists. However, PhD study is not an end in itself. Its importance is that it is the route into many careers in scientific R&D. As set out above, the Government will provide funding to enable universities to improve the pay of key academic researchers. Just as importantly, industry must rise to the challenge of providing attractive career packages for R&D work in industry.

4.27 It is also necessary to ensure that there are clear routes into careers in business and academia following postgraduate study.

Ensuring postdoctoral research is attractive to the best PhD graduates

4.28 A third of PhD graduates in the UK go on to spend time as postdoctoral researchers where they learn how to run research projects – skills that are vital as academic staff or researchers in the private sector. There are currently some 10,000 postdoctoral researchers in the UK funded by the Research Councils, with many more funded from other sources. However, the position

[30] The New Route PhD, which is being developed in 23 English universities, begins to address this issue. It aims to allow students to develop a fuller and individually-tailored range of skills, including in general areas such as management and enterprise, alongside a major piece of research in their chosen discipline.

of postdoctoral researcher is unattractive to many PhD graduates. The Roberts Review identified poor pay and conditions, including short-term contracts that rarely provide security beyond the current project, as particular problems. Furthermore, there is little career advice and only around 20 per cent of postdoctoral researchers become full time academics. The rest leave for jobs outside, in R&D in business, in teaching, or often outside science and engineering altogether, despite as much as ten years training in their discipline.

4.29 The Research Careers Initiative has made progress in addressing these problems. However, the Government believes there needs to be further and faster progress to ensure that:

- salaries for postdoctoral researchers are more attractive to the best scientists and engineers;
- there are clear career paths into business R&D and academia for postdoctoral researchers; and
- conditions of employment are significantly improved, including job security and training opportunities relevant to both business and academia.

4.30 To address these issues, the Government will provide funding in the Spending Review to:

- **increase the average Research Council postdoctoral salary by around £4,000 by 2005-06.** As with the PhD stipend, the Government also believes that salaries should be varied better to reflect labour market pressures;
- **improve the training opportunities available to postdoctoral researchers.** The Government will provide additional funding to the Research Councils to deliver additional training for contract researchers and will work with RCUK and HEFCE to ensure that this is put into practice. The Government will ask HEFCE to make clear that support for postdoctoral researchers will be expected to feature in institutions' human resources strategies. This will help ensure that researchers are prepared for future careers in higher education or industry; and
- **create 1,000 new academic fellowships over five years to provide more stable and attractive routes into academia, working with organisers of similar existing fellowships, such as the Wellcome Trust and The Royal Society.** Further details will be announced later this year.

4.31 Taken together, the changes above should encourage more of the best emerging scientists at undergraduate level to continue their studies and pursue careers in research and development in both the private and public sectors. The changes are necessary because without them these people will pursue careers in other areas or will go abroad to continue working in science. Both outcomes would have negative effects on the capacity of the UK to produce world-class science and innovation.

Accessing scientific talent from abroad

4.32 The UK can also seek scientific expertise from abroad. As the market for top scientists has become increasingly global, countries have sought to attract skills from other countries. Most developed nations, including Germany, the US and Canada have introduced schemes to attract skilled individuals. In Canada one scheme has been targeted specifically at research positions in universities.

4.33 UK employers need to be able to access scientific talent from abroad. Recognising this, the Government has reformed the work permit and immigration systems to make it easier for employers to recruit staff from abroad. Work permits now last for five years, rather than four, and processing times have fallen significantly. Applications are typically now processed within 24 hours of receipt. It is also easier for overseas students to obtain permission to work in the UK after graduating. This is crucial as increasing numbers of students from abroad come to study in UK universities – for example, nearly half of all engineering and technology doctorates are awarded to non-UK students.

4.34 To increase further the numbers of highly skilled people who come to work in the UK, a new Highly Skilled Migrant Scheme was launched on 28 January 2002. The scheme enables highly skilled individuals to come to the UK and look for work without the need for a specific job offer. Applicants can demonstrate their eligibility for the scheme through educational qualifications, work experience, achievements in their field or past income.

4.35 The Roberts Review found that awareness of these changes amongst employers and universities was poor, particularly amongst small and medium sized businesses. **To address this the Government will step up the provision of information about these changes. In particular, Work Permits UK will develop concise and tailored information for smaller employers, and will work with the Small Business Service and employers groups to target the advice towards those who might benefit. Work Permits UK will also consult employers and others on the merits of adding more fields of science and engineering to the list of areas of national skills shortage.** This would further ease recruitment of scientists and engineers from abroad. Furthermore, the Government will take steps to improve awareness of the options and routes into employment available to foreign students in UK universities.

Inspiring young people to study science and engineering

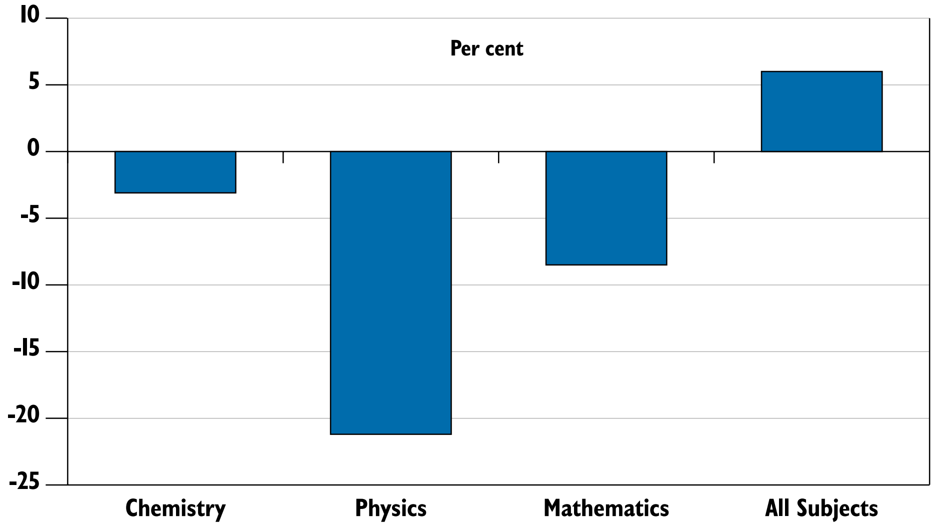
4.36 Assisting universities and other employers to access scientific and technical talent from across the world will help to improve the supply of scientific and technical expertise in the UK. However, the domestic supply of people wanting, and able to, study science and engineering will always be critical to ensuring that there are adequate numbers of skilled scientists and engineers in the UK. It is therefore vital that young people at school find science and engineering subjects stimulating and are keen to study them beyond GCSE and A-level.

Enthusing pupils at school to study science, mathematics and technology

4.37 The experiences that students gain in school are crucial to their subsequent education and training and to their careers. Since 1997, standards in primary and secondary schools have risen considerably, as a result of the Government's emphasis on, and investment in, school education. Nevertheless, the Government is concerned that fewer pupils are choosing to study areas of science, technology, engineering and mathematics at A-level and beyond.

4.38 The Government's concern is based on analysis from the Roberts Review, which found that numbers taking A-levels and degrees in many scientific subjects are decreasing. For example, between 1991-92 and 1999-00 the numbers of people taking A-level physics fell by 21 per cent. In the same period there was a 9 per cent reduction in students taking A-level mathematics, and a 3 per cent reduction in chemistry, despite rises in life sciences, computer sciences and an overall rise of 6 per cent in all subjects (see chart 4.3).[31]

Chart 4.3: Percentage change in pupils taking selected A levels, 1991–92 to 1999-00



Source: Data from DfES, as presented in the Roberts Review

[31] Furthermore, proportionately fewer female and ethnic minority pupils study science beyond 16.

4.39 The Roberts Review identified several reasons for these trends, including:

- shortages in the supply of appropriately trained science and mathematics teachers in schools;
- that many school laboratories are out of date; and
- the need for curricula to keep up with the fast pace at which modern science is developing and to appeal positively to pupils.

4.40 Addressing these issues should help increase the number of students choosing to take further courses in these subjects and improve their numeracy and scientific ability. Critically, given the increasing dependence of many sectors of the economy on science and technology, it will also improve the scientific and technical literacy of the general population.

Increasing teacher numbers in science and mathematics

4.41 Vacancy rates for teachers of the physical sciences, mathematics and IT are higher than for teachers of most other subjects, and it has been consistently difficult to recruit adequate numbers of graduates to teacher training programmes in these subjects. Furthermore, the Roberts Review showed that significant numbers of science teachers are required to teach areas of science outside their expertise.

4.42 The Government presented a new vision and direction for the teaching workforce in the Secretary of State for Education's speech to the Social Market Foundation last autumn. The vision involves remodelling the school workforce to drive up standards and free teachers to teach. This will lead to new models of organising teaching and learning, including in science and mathematics. And it should also have a positive impact on recruitment and retention of teachers in these and other subjects.

4.43 In the meantime, there are still recruitment and retention problems that the Government is determined to address. Part of the current problem is that graduate numbers in mathematics and the physical sciences are declining and there is therefore a smaller pool from which teachers can be drawn. The Government has also recognised the financial disadvantage that new graduates can suffer as a result of choosing to undertake the further year's training needed to become a teacher, rather than going straight into salaried employment. It is addressing this through the introduction of teacher training bursaries. For those training as, and becoming, teachers in shortage subjects, including mathematics, the physical sciences and IT, Golden Hellos and the writing-off of student loans provide even more financial support during the early years of teaching.

4.44 Although these measures have begun to have a positive effect, difficulties remain. **Over the Spending Review period, the Government is determined to enhance pupils' science, mathematics and technology education by improving prospects for the recruitment and retention of science and mathematics teachers, including through paying more to good science**

and mathematics teachers. Therefore, the Government will consider further targeted incentives, building on student loan write-offs and the flexibilities already available to schools, and will be asking the School Teachers' Review Body to consider how the teachers' pay and conditions system might be adapted over the Spending Review period to enable schools to offer more targeted incentive packages to tackle problems with the recruitment and retention of science and mathematics teachers. Further details will be announced later this year.

4.45 To further improve schools' ability to provide high-quality teaching in science, the Government is providing resources in the Spending Review to:

- **introduce a major programme that will pay science, mathematics, IT and engineering undergraduates and postgraduates to return to schools during their studies and support teachers in the classroom and laboratory, with appropriate support and training to equip them to be effective.** This will operate as part of an initiative covering other subjects as well and will act to improve the support to teachers and pupils – particularly in practical classes – and provide pupils with excellent role models. The Government will build on the teacher associate scheme – which pays participants up to £40 a day – to deliver this programme. The Government's aim is to ensure that, as quickly as possible, all secondary schools within easy reach of a university are covered by the programme; and

- **improve the science-related training and development available to science teachers, both in their initial teacher training and throughout their careers to ensure that their skills and knowledge are relevant and up to date. The Government and the Wellcome Trust will launch a joint initiative to establish a national centre for excellence in science teaching.** Together with supporting networks, including a number of regional centres, this will enable teachers to enhance their professional skills through engaging with contemporary scientific ideas and training in effective teaching approaches and modern scientific techniques. The aim is to bring about changed teaching practice, to inspire pupils by providing them with a more exciting and intellectually stimulating and relevant science education, and to raise morale in the profession. It will be funded jointly by the Wellcome Trust and the Government, with the Trust contributing up to £25 million and the Government providing additional funds to support the initiative. Teachers and schools will be encouraged to take advantage of this initiative through, amongst other measures, having participants' travel costs and the related costs of supply teaching cover subsidised.

Improving teaching facilities

4.46 The environments in which science and related subjects are taught is crucial to pupils' quality of education. However, reports from Ofsted show that science laboratories in secondary schools are generally in a worse state than the school estate overall. Only a third are estimated to be of a 'good' standard or better. The Government is clear that, as in universities, this situation must be improved. Capital spending in schools has increased by over £2 billion since 1996-97, following many decades of under-investment. Some has been spent on science facilities, and an additional £60 million has been targeted specifically at schools science laboratories. However, the Government agrees with the Roberts Review that there is a need for such investment to be given higher priority.

4.47 **In this Spending Review, therefore, the Government will provide funds within the overall increase of over £1 billion for capital investment in education to improve significantly the quality of school science and technology laboratories and equipment. The Government will also prioritise investment in school laboratories from all sources of capital funding, and will include progress on improving the quality of science laboratories in its appraisal of local education authorities' Asset Management Plans. The Government's aim is to meet the initial modernisation target set in the Roberts report by the end of the Spending Review period, and to be on track to meet the 2010 modernisation target set in the report.**

Box 4.1: Specialist science and technology schools

The White Paper, *Schools achieving success*, published in September 2001, extended the range of specialisms under the Specialist Schools Programme to include science. The first 24 secondary schools to be designated as Science Colleges will become operational from September 2002. These will join the growing network of 992 specialist schools, including 443 Technology Colleges. Secondary schools that place a special emphasis on teaching science and technology promote an ethos which is scientific, technological, enterprising and vocational. Science and Technology Colleges extend learning opportunities in their chosen specialisms, for example, by providing a wider range of courses in their specialist subjects. They raise standards of achievement for pupils across the ability range by broadening their understanding of technology, science and mathematics and the relationships between these subjects. Science Colleges and Technology Colleges also play an important role in encouraging increased take-up and interest in science, mathematics and technology more generally, particularly post-16, through the links they are required to have with other schools and the wider community.

Creating exciting and relevant science curricula

4.48 Finally, the science curricula studied at GCSE and post-16 need to be relevant to pupils, and encourage a wider range of pupils to continue study in this area. The Government agrees with the Roberts Review that this will be crucial in increasing interest in the physical sciences, especially among girls and ethnic minorities, who are often under-represented in such subjects. The Government is piloting a new GCSE science programme and will review it in this context as soon as possible.

4.49 **As part of the summer 2003 review of the Curriculum 2000 reforms, the Government will ask the QCA to advise on how effective the recent changes to A-level science have been, and on whether further changes are needed to ease the transition. The Government is also launching an inquiry into post-14 mathematics, with the aim of ensuring that the UK has enough young people with good mathematical skills and knowledge that meets the needs of employers and of further and higher education.**

4.50 **The Government will also seek a step change in the relevance of science curricula to employers through making SETNET and the Education Business Link Partnerships work together to improve the interaction between schools and businesses and others.**

Encouraging the study of science and engineering in further and higher education

4.51 The measures described above should help improve the knowledge and skills of pupils studying science in schools and encourage more students to continue their study of science beyond school into further and higher study. Further and higher education play a vital role in training the next generation of scientists and engineers, as well as technicians and other support staff.

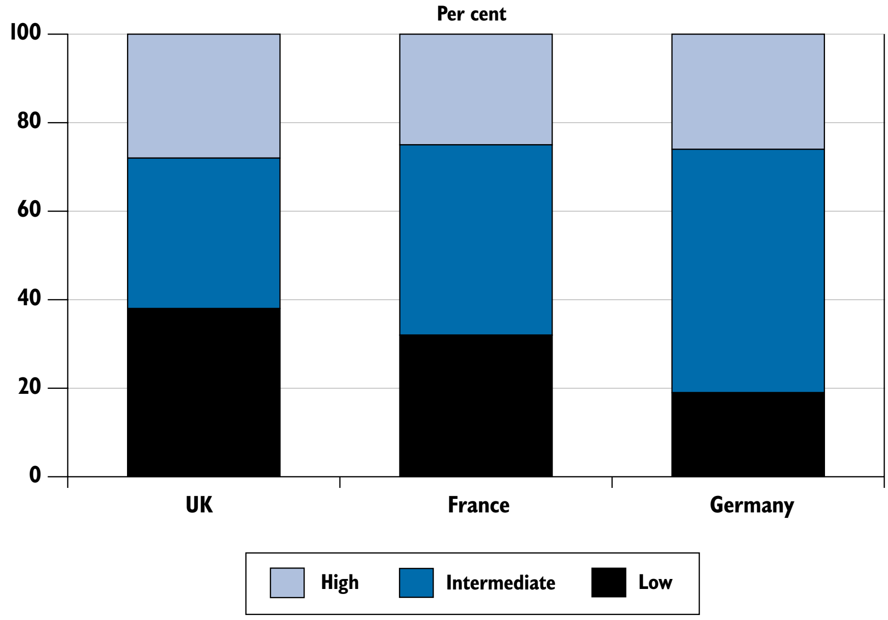
Improving the supply of scientific technicians and other support workers

4.52 Workers with intermediate skills are vital to the overall success of the UK economy. They are particularly important in the fields of science, engineering and technology, through their role as technicians and other support staff. It is important that both young people and adults are encouraged to develop their skills, and that vocational opportunities in science, engineering and technology help to create a pool of skilled workers for the sector.

4.53 Overall, the UK faces a significant skills gap at the intermediate level (see chart 4.4 below). Over a third of the UK workforce (over 8 million people) lack level 2 qualifications, equivalent to 5 good GCSEs. This problem both reduces productivity and leads to social exclusion. The Government is supporting the skills development of young people and helping the adult population improve their skills. Increased spending on education, alongside reforms to ensure that standards in schools and colleges are raised, and the development of new vocational routes for young people, is seen to be having an impact on the skills of young people in the UK.

4.54 The Government is also implementing policies to support adults to improve their skills. Over 1 in 4 UK adults do not have the levels of numeracy expected of an 11 year old. The Skills for Life policy has already helped improve adults' basic skills, and the Government will continue to support this through allocations in this Spending Review. New pilot schemes to test a possible new policy approach to raising the demand for training among low-skilled adults in the workforce, as outlined in the 2002 Budget, will help the Government to develop further policy measures in this area.

Chart 4.4: Employees by skill level, 1999



Source: OECD.

4.55 The Government is developing an education and training system that includes high quality vocational routes to allow young people to develop the kinds of skills required in the science and engineering sectors. Young people are demonstrating a great interest in vocational training in this area – for example, around 16 per cent of young people on Advanced Modern Apprenticeships (AMAs) are on courses related to science and engineering. The Government will continue to promote Modern Apprenticeships with the aim of increasing participation so that by 2004 at least 28 per cent of young people enter a Modern Apprenticeship before the age of 22.

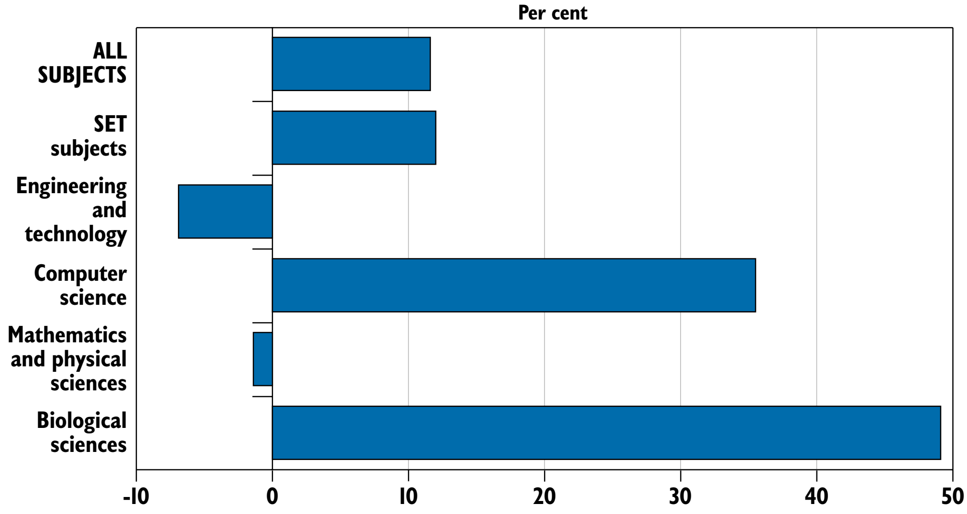
Increasing the attraction of science and engineering degrees

4.56 The Roberts Review found that the rise in the overall supply of graduate scientists and engineers in the UK in recent years masks significant falls in the numbers of graduates in the physical sciences, mathematics and engineering (see chart 4.5). This will have increasingly serious consequences for the UK as it reduces the capability of universities and the private sector to carry out the R&D necessary to increase innovation. Aside from the direct impact from R&D capability in these areas, there will be a read-across to other disciplines, since R&D is increasingly multi-disciplinary in nature.

4.57 In order to reverse these trends and ensure a strong supply of science and engineering graduates across the disciplines, the Government agrees with the Roberts Review that it is necessary to:

- improve science and engineering teaching facilities in universities;

Chart 4.5: Percentage change in first degree graduate numbers, 1995 to 2000



Source: Data from HESA, as presented in the Roberts Review.

- encourage more students to study science at undergraduate level by improving the links between schools and universities and addressing the current perception among prospective students that degrees in these subjects are relatively hard and expensive to succeed in; and
- ensure that science degrees provide graduates with the skills that employers need and value and that rewarding career paths are open into further study and academia.

4.58 Chapter 3 showed that the university research estate is in need of maintenance and refurbishment. There are also significant problems with the teaching estate, and the equipment used in science laboratories is often outdated. This not only impairs the teaching of science and engineering in universities, but also means that graduates are often not familiar with equipment used in R&D in business. As well as the dedicated capital funding stream for research (see Chapter 3) the Government is therefore introducing in the Spending Review significant additional resources for universities to use to maintain and upgrade their science teaching infrastructure. **The Government agrees with the aim of the Roberts report that by 2010 all university science and engineering teaching laboratories should be of a good standard or better (as measured by HEFCE). Resources to start to improve laboratories and move towards this target are included within the overall increase of capital funding for higher education.**

4.59 Improved facilities should have a positive impact on the performance of students learning science at university and will attract more people to undertake such degrees, as well as giving graduates valuable experience working with equipment more similar to equipment used in business R&D.

4.60 Furthermore, as recommended by the Roberts Review, HEFCE is examining the detailed funding formulae for teaching different subjects. Through this review the Government and HEFCE can ensure that in the longer-term teaching funding for different subjects accurately reflects the costs involved in modernising their teaching environments (for example, science and engineering teaching laboratories) in line with technological progress. The Human Resources strategies and associated funding provide a mechanism for institutions to recruit and retain teaching staff in competitive markets, but HEFCE will also consider whether and, if so, how, the teaching funding for different subjects should reflect differing recruitment and retention costs.

4.61 The Roberts Review also concluded that other factors, are important. Some were seen to related to perception: for example, degrees in these subjects are often seen as harder than degrees in arts subjects.

4.62 The perception that science degrees are harder than other subjects is to some extent linked with weak outcomes at school level in the physical sciences and mathematics. The Government is determined to address these perception issues through, amongst other measures, improving staffing and the teaching environment in these subjects at school.

4.63 However, the Roberts Review also identified more tangible issues that could act as deterrents to studying science and engineering. For example, there have been concerns that the greater likelihood of four-year degrees and more structured study in science degrees could act as a disincentive for students, particularly those from disadvantaged backgrounds. The main reason for this is the extra expense of a four-year course and the reduction in free time (or time available for part-time work) available to science students.

4.64 **The Government will ensure that the guidance for allocations of hardship funds by universities recommends that universities take account of contact hours as one of the factors to consider in making these funds available. The Government will also monitor the issue of four-year courses to ensure that their length, when combined with other factors such as student funding arrangements, does not act as a deterrent to students considering pursuing science and engineering courses at degree level.**

4.65 Responsibility for designing and delivering courses lies with institutions and it is ultimately for them to make sure that they teach students what they need to know in order to progress in science, engineering and mathematics courses. The Roberts Review identified though that the variation in the prior knowledge and skills of students can be a challenge to institutions in delivering science and engineering degrees in particular, and institutions already put a good deal of effort into supporting new students. **Mathematics skills can be a particular issue and, as mentioned earlier in this chapter, the Government is launching an inquiry into post-14 mathematics. Furthermore, in order to improve the transition into science and engineering at higher education the Government will work with the higher education sector to pilot and evaluate different approaches to bridging the gap between students' prior knowledge and the requirements of higher education study.**

4.66 Finally, universities must work with business to ensure that their courses are teaching skills relevant to employers. This requires higher levels of interaction between business and universities, which the Government will continue to encourage through its teaching and 'third-stream' funding. Students need to see that they will be rewarded for studying science. So businesses and other employers need to ensure that salaries post graduation are sufficiently competitive and businesses and universities also need to work together to ensure that more information is made available to students, for example through school and university career services, about the rewards of science and engineering degrees. The Government agrees with Sir Gareth Roberts' suggestion that RDAs may well have a role in brokering these relationships in their regions, particularly on behalf of SMEs. The Government also believes that the employers group, referred to in Annex A, should play an important role in encouraging this sort of interaction.

Conclusion

4.67 The need for human ingenuity in making discoveries and creating new products, processes and services means that the UK's innovation performance is critically dependent on a strong supply of scientists and engineers. The Roberts Review set out the challenges that face Government, businesses and others in improving this supply. The policy announcements in this chapter, and also in Annex A, demonstrate the Government's determination to respond to these challenges by improving the teaching available to young people; the prospects for undergraduate and post-graduate study; and the career opportunities for our best researchers.

4.68 Sir Gareth Roberts made clear in his report that action by businesses and other employers is vital role in encouraging more science and engineering graduates to work in research and development. The Government agrees with Sir Gareth Roberts that its resources and efforts in delivering the changes will be less effective if they are not accompanied with action by employers. Therefore, the Government will re-examine, before the next spending review, the response of employers to the challenge set out above – in order to ensure that taxpayers' money continues to be used to best effect.

4.69 Together with the initiatives described in chapter 3, this action will ensure that the UK has a strong research and development capability in the long-term. With a constant flow of leading-edge ideas and highly skilled scientists to develop them, the UK will be in a good position to increase its innovation record and to benefit from technological progress.

4.70 It is crucial, however, that the research that occurs in universities and the public sector can lead to R&D opportunities in the private sector. It is therefore necessary to foster further links between the two and for business to rise to the challenge to improve its performance. The next chapter explores the issue of knowledge transfer, while chapter 6 sets out the challenge to business in detail.