The Race to the Top

A Review of Government's Science and Innovation Policies

Lord Sainsbury of Turville

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Foreword

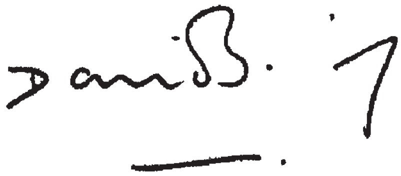
This Review of the Government's science and innovation policies was commissioned by Gordon Brown, then Chancellor of the Exchequer, as part of the 2007 Comprehensive Spending Review (see Terms of Reference in Annex A). He asked us to look in particular at the role that science and innovation can play in enabling the country to compete against low-wage, emerging economies such as China and India. This we have done enthusiastically because we believe that this is one of the major challenges the UK faces, and in Chapter 1 we have set out the strategy we believe the country should adopt if we are to be a winner in "The race to the top".

In producing our Review we have consulted many organisations, including companies, trade associations, universities, the Trade Union Congress and government departments. We have collected their views about the opportunities and barriers to innovation in the UK, and involved them in the development of new policies. This approach has resulted in a review which we believe is both innovative and firmly focused on creating the conditions which industry, scientists and engineers have told us will most effectively stimulate innovation. I would like to thank all those who have been involved for the proactive and positive approach they have taken, and to thank our advisory panel (Professor Brian Cantor, Sir John Chisholm, Hermann Hauser, Sir Robin Saxby and Richard Lambert) for their valuable input. And I would like to acknowledge the excellent support I have received in producing this Review from the Treasury team led by Sophie Dean.

The Review builds on what we believe is an evidence-based appraisal of our innovation performance. This is set out in Chapter 2, and shows that in a number of critical areas we are doing better than is commonly thought. In recent years the share of high-technology manufacturing and knowledge-intensive services in the UK's total value added has grown rapidly (Chapter 1), there has been a dramatic increase in the amount of knowledge transfer from British universities (Chapter 4) and we are beginning to see the growth of exciting high-technology clusters around many of our world-class research universities (Chapter 9). At the same time, we continue to maintain our outstanding record of scientific discovery. In the future it will no longer be necessary to start every report of this kind with the dreary statement that, while the UK has an excellent record of research, we have a poor record of turning discoveries into new products and services.

While we believe that our record of innovation is better than is commonly supposed, we have not yet produced the best possible conditions to stimulate innovation in industry. We see many opportunities to build on the successful policies that have been introduced in recent years and to improve our performance, and we have put forward a number of key recommendations covering the Technology Strategy Board (Chapter 3), knowledge transfer (Chapter 4), science and engineering education (Chapter 7), government departments (Chapter 8) and the Regional Development Agencies (Chapter 9). These recommendations cover many areas of government and, therefore, their implementations will require careful and effective monitoring.

In the years ahead, the size of our economy will inevitably be overtaken by countries with larger populations. But this is not the correct way to measure our performance. We should seek instead to steadily increase our GDP per head. If we maintain our support for flexible labour markets and free trade, and invest in the future in areas such as science and innovation, education and the technological infrastructure of the country, there is no reason why we cannot do so. In today's fast-changing world we can be a winner in the "race to the top", but only if we run fast.



Lord Sainsbury of Turville

Executive summary

The best way for the UK to compete, in an era of globalisation, is to move into high-value goods, services and industries. An effective science and innovation system is vital to achieve this objective. The UK is internationally renowned for its research base and this status requires continued support. The Review recommends more effective ways to exploit our investment in research. Government policy has typically focused on the supply-side factors affecting innovation; some of these areas need continued attention. The provision of innovation support is fragmented and a new leadership role for the Technology Strategy Board (TSB) will co-ordinate across Research Councils, Regional Development Agencies (RDAs) and government departments. A major campaign to improve science, technology, engineering and mathematics (STEM) teaching in schools is needed. The Review recommends building on the success of our knowledge-transfer initiatives in four key areas, and support for early-stage technology companies. Demand-side factors, such as procurement and regulation, which can play a critical role in encouraging innovation, have received too little government focus. The Review shows that value for money and innovation can be complementary objectives in government procurement and urges government departments and the economic regulators to engage in emerging technology development in collaboration with the TSB.

THE RACE TO THE TOP

Globalisation brings opportunities and challenges. It provides UK companies with access to new and larger markets, cheaper intermediate goods and lower prices for consumers, but many of our companies have to compete with companies in emerging economies, such as China, with wage costs that can be 5 per cent of the UK's.

Company strategies based on low costs alone will end up in a downward spiral, each year bringing a new low-cost competitor. The best way for the UK to make the most of globalisation opportunities is to support the restructuring of British companies into high-value goods, services and industries. We should seek to compete with emerging economies in a "race to the top" rather than in a "race to the bottom".

The UK is well placed to take advantage of the new markets. We have a flexible labour market, an extraordinary record of scientific discovery, a large and growing supply of high-quality university graduates, an open economy and an international outlook.

The shares of manufacturing and services in the UK's GDP is seen by some as a measure of our economy's success or failure. But we should measure our performance by how fast we move into knowledge intensive goods and services and out of low value-added ones. On this measure, UK companies have made good progress in recent years and we see plenty of opportunities for further growth.

However, there will be increasing competitive pressures on companies across the developed world, and some adjustment costs. In 1980, less than one-tenth of manufacturing exports came from the developing world. Today it is almost one-third and in 20 years' time it is likely to be one-half.

The speed of this change is likely to lead to calls for protection of domestic markets, resulting in retaliatory protectionism by other countries and greater adjustment costs in the long run. These calls should be resisted.

Instead, the Government must provide the essential public goods required for success in a dynamic and innovative knowledge economy that will enable us to compete against low-wage countries like India and China. This means comparing all parts of our innovation ecosystem against other leading countries.

THE NATIONAL INNOVATION ECOSYSTEM

A country's innovation rate depends on inter-linked activities which include: industrial research; publicly funded basic research; user-driven research; knowledge transfer; institutions governing intellectual property and standards; supply of venture capital; education and training of scientists and engineers; innovation policies of government departments; science and innovation policies of RDAs; and international scientific and technological collaboration.

The two most commonly used measures of innovation performance are the quantity of industrial research and the volume of patenting. The UK's performance is unimpressive on both counts. However, our performance is greatly affected by the structure of industry. UK companies spend similar proportions of their sales on R&D as their competitors within a sector, but have a stronger presence in successful sectors where little, if any, R&D investment as a percentage of sales (e.g. oil and gas, financial services) is reported. This suggests that rather than seeking to raise the amount of research performed by all industries we should focus our efforts on the four major goals developed by the TSB:

- to help our leading sectors and businesses to maintain their position in the face of global competition;
- to stimulate those sectors and businesses with the capacity to be among the best in the world to fulfil their potential;
- to ensure that the emerging technologies of today become the growth sectors of tomorrow;
- to combine all these elements in such a way that the UK becomes a centre for investment by world-leading companies.

Trends in publicly funded R&D show that there has been a steady increase in the amount of money spent by the Research Councils, but a decline in government department funding of R&D as a percentage of GDP, mainly accounted for by a decline in MOD spending. This is of concern for the quality of our public policy-making, and the stimulation of innovation in the companies with which government departments interact.

Research outputs from publicly funded R&D remain, however, of a very high standard. On the latest data (2004), the UK was ranked second in the world to the USA in its share of world publications (9 per cent) and world citations (12 per cent). The UK is a more consistent performer across the range of research disciplines than most other countries, ranking second in the world in seven of the ten disciplines.

The policy response to the UK's innovation performance needs to consider two cross-cutting issues:

1. The different requirements of manufacturing and services: we need to build up skills in the management of fragmented manufacturing chains, and to focus our research efforts and skills development on the complex, high-value production activities likely to be successful in high-cost economies.

   We need to understand better how innovation takes place in the very different industries which make up the services sector, so that the Departments for Innovation, Universities and Skills (DIUS) and for Business, Enterprise and Regulatory Reform (DBERR) can apply their current policy initiatives more effectively.

2. The role of Higher Education Institutions (HEIs) in the knowledge economy: HEIs play an increasing role in the economy and the UK, with its world-class universities, is well placed. A diversity of excellence is required, with research universities focusing on curiosity-driven research, teaching and knowledge transfer, and business-facing universities focusing on the equally important economic mission of professional teaching, user-driven research and problem-solving with local and regional companies. Research, teaching and knowledge transfer are fundamental roles for any HEI. But the way these are done will be very different and some students will be attracted by one type of educational experience and some by the other.

POLICY RECOMMENDATIONS

A new leadership role for the TSB. The TSB has a key role to play in addressing the fragmented technology and innovation landscape in the UK. Chapter 3 describes how its transformation into a business-driven Executive Non-Departmental Public Body in July 2007 has the potential substantially to improve the UK's innovation performance. The Review recommends that the TSB is given a new leadership role, working with the RDAs, the Research Councils, government departments and the economic regulators to co-ordinate public sector technological innovation activity, leverage public sector resources and simplify access to funds for business. With increased resources the TSB should extend into new areas, such as the services sectors (including the creative industries) in which technological innovation is important. It should develop an international strategy, and it should work more closely with UK Trade and Industry (UKTI) to enhance the UK's position as a centre for investment by world-leading companies.

Building on our success in knowledge transfer. The translation of university research into commercial goods and services has significantly increased in the past decade. The number of spin-off companies, the number of patents, the income from licensing agreements and the income from business consultancy have all increased (see Chapter 4). The performance of our universities in this area is now comparable with US universities. We are also seeing significant clusters of high-technology businesses growing up around our world-class research universities (see Chapter 9). Chapter 4 outlines the four main areas in which the UK can strengthen its knowledge transfer performance. The Higher Education Innovation Fund (HEIF), which makes a significant contribution to knowledge transfer activity, should move to a fully formulaic basis and increase support for knowledge transfer between business-facing universities and local small and medium-sized enterprises (SMEs). The Research Councils (RCs) should agree and be measured against firm knowledge transfer targets, including specific targets for knowledge transfer from their own institutes, and for the funds they will be spending on collaborative R&D through the TSB. The successful Knowledge Transfer Partnerships (KTPs) that place newly qualified graduates in companies, and for which there is high industry demand, should be doubled in number, subject to the Business Support Simplification Programme (BSSP). To improve access for SMEs, a shorter, more flexible, mini KTP scheme should be introduced, subject to the BSSP. The Review sees considerable scope for further education (FE) colleges to help raise the innovation performance of SMEs and recommends that KTPs are further extended to FE colleges.

Using intellectual property rights, standards and metrology to improve knowledge transfer. Effective knowledge transfer requires specific institutional arrangements to pass knowledge from research establishments into wealth-creation and public policy-making, and an infrastructure of intellectual property rights, standards and metrology. Historically, the information contained in patent databases has not been fully exploited, with estimates that up to 30 per cent of worldwide R&D projects are merely a duplication of existing technology. Chapter 5 recommends that more effective use be made of the UK Intellectual Property Office (UKIPO) patent registration database, through open access and electronic searching. Education and outreach programmes initiated by UKIPO should be extended to better inform potential innovators. Standards institutions, such as the British Standards Institute (BSI), should be adequately represented within the TSB Knowledge Transfer Networks to enable the speedy dissemination of knowledge derived from standards. Finally, the Review recommends that the proposed AIMtech incubation facility at the National Physical Laboratory is supported. AIMtech will allow the rapid commercialisation of metrology expertise.

Targeted support for early-stage high-technology companies. Venture capital forms an integral part of the innovation system by providing a vital early-stage source of finance and management and market experience. However, Chapter 6 shows that early-stage high-technology start-ups have experienced some difficulties in attracting equity finance, due to the specific risks involved in these investments. The Review recommends that, subject to the BSSP, a nationally-agreed specification for proof-of-concept funding should be developed to provide initial funding to entrepreneurs. Together with other recommendations, such as reforms to the Small Business Research Initiative, the new formula for HEIF and the support of RDAs for incubators, high-technology clusters and business-readiness services, this should provide a significant boost for investment in early-stage high-technology companies.

A major campaign to enhance the teaching of science and technology. Demand for science, technology, engineering and mathematics (STEM) skills will continue to grow. The UK has a reasonable stock of STEM graduates, but potential problems lie ahead. There has been a 20-year decline in the number of pupils taking A-level physics. The Review recommends a major campaign to address the STEM issues in schools. This will raise the numbers of qualified STEM teachers by introducing, for example, new sources of recruitment, financial incentives for conversion courses, and mentoring for newly qualified teachers. The Government should continue its drive to increase the number of young people studying triple sciences, and consider entitlement for all pupils to study the second mathematics GCSE (due to be introduced in 2010). The Review believes that there is a major need to improve the level of career advice given to young people, so that they are aware of the exciting and rewarding opportunities open to those with science and technology qualifications. It welcomes the recent appointment of a national STEM careers co-ordinator and the "Careers from Science" website and suggests that careers advice be built into the curriculum for pupils and into Continuing Professional Development (CPD) for teachers. The rationalisation of extracurricular STEM schemes is supported, with suggestions for those schemes that should be taken forward, including a national science competition. The Higher Education Funding Council England (HEFCE) "Strategic and Vulnerable Subject Advisory Group" should be turned into an "Advisory Group on Graduate Supply and Demand" which produces an annual report detailing the number of students graduating in particular subjects, how easily graduates get jobs in particular areas, and in what areas industry foresees shortages of graduates arising. The Review believes that such a report would be very valuable for students, Vice-Chancellors and government.

A key role for government departments. Government departments can play an important role in stimulating innovation in the companies with which they interact, but in the absence of a clear directive and adequate resources, they are failing to meet the challenge. Innovation should be embedded in Departmental Strategic Objectives and the Director of Innovation at DIUS should produce an annual Innovation Report on the innovation activities of the DIUS, including the TSB, other government departments and the RDAs. Chief Scientific Advisors should work more effectively with their departments and with the Treasury spending teams to agree and manage their R&D budgets, and together to identify and act on cross-cutting areas of research. The Review welcomes the "Transforming Government Procurement" report and recommends that the Government urgently press ahead with plans to improve procurement capability. Good procurement practice can achieve innovation and value for money. The Small Business Research Initiative (SBRI), by which departments spend 2.5 per cent of their R&D budget on research contracts with SMEs, should be reformed to resemble more closely the successful US scheme. SBRI should fulfil departmental objectives and provide valuable support to early-stage high-technology companies. It should be managed in conjunction with the TSB.

Increasing regional focus and resource on science and innovation. National policies create a framework for innovation but the locus of much innovation is at the regional level where employees, companies, universities, research institutions and government interface more directly. There is increasing recognition of the potential of RDA science and innovation polices to drive regional economic growth. The Review recognises the progress made so far by the RDAs to support science and innovation and recommends that further resources are directed to four specific areas, subject to the BSSP: TSB programmes; Knowledge Transfer Partnerships between universities and business; high-technology clusters around world-class research universities; and proof-of-concept schemes consistent with a nationally agreed specification.

Linking up with centres of excellence around the world. International collaboration is important if the UK is to stay at the leading edge of world science and innovation and benefit from the 90 per cent of the world's scientific output that is produced elsewhere. The UK needs to make this collaboration a core part of its strategy, and to improve co-ordination of the UK bodies involved. The Review recommends that a number of the Global Science and Innovation Forum (GSIF) proposals be put into immediate effect: Research Councils should focus resources into single points of contact in key countries; a new fellowship scheme and alumni network should be set up by the Royal Society, with support from the other academies; the TSB should develop an international strategy; the Science Bridges scheme, establishing formal links with universities overseas, should be extended; and the Director-General of Science and Innovation should work with the USA to solve "the double jeopardy" issue for scientists.

A GLOBAL LEADER IN SCIENCE AND INNOVATION

The UK has made good progress in recent years in meeting the challenge of globalisation and upgrading its industry, but we should not underestimate the speed of change in the world economy, and the need to improve the innovation ecosystem.

Companies have to innovate, and so does government. In addition to policies that create the best possible conditions for companies to innovate and grow, the UK needs a vision of our role in the global knowledge economy, and a strategy to ensure we are one of the winners in the "race to the top".

The UK should be a country famed for its innovation as well as its outstanding record of discovery; a country that invests in business R&D, education and skills, and exports knowledge-intensive goods and services to the world. We should seek to be a country that enjoys strong science and technological links with the best research around the world, so that we can stay at the cutting edge. The UK should be the partner of choice for global businesses looking to locate their research, and for foreign universities seeking collaboration with the science base or business.

Finally, we should be a country to which talented entrepreneurs and world-class companies come from around the world to perform research and set up high-technology companies, attracted by the quality of our research, by the strong links between our universities, research institutes and industry, by geographic clusters of high-technology companies, by their ability to raise finance, particularly venture capital, and by our quality of life.

It is not possible to predict where the new jobs will emerge in the future but it is possible to see many opportunities for UK companies to create new products and services, and new industries in areas as diverse as aerospace, pharmaceuticals, biotechnology, regenerative medicine, telemedicine, nanotechnology, the space industry, intelligent transport systems, new sources of energy, creative industries, computer games, the instrumentation sector, business and financial services, computer services and education.

At no time since the Industrial Revolution has the restructuring of global economic activity been so great, and we need to accept that China and India are now seeking to upgrade their industries. We can be one of the winners in "the race to the top", but only if we run fast.

1 The race to the top

INTRODUCTION

1.1 Globalisation means living in a world of opportunities and challenges. China, Russia and other emerging economies, which were once barricaded behind political and trade barriers, are opening up many opportunities for European exports. In 2003 alone, China's share of EU15 exports increased by 40 per cent, as it overtook Japan in importance as a destination for European exports. Consumers are also benefiting from lower prices for goods and services bought abroad.

1.2 At the same time many UK companies are having to meet the challenge of competition from firms in emerging economies, where wages can be a tiny fraction of the UK's. Competition for capital, the rising tradability of goods and services and the unprecedented increases in the world supply of workers prompt concerns that globalisation is leading to downward pressure on low skilled wages and that advanced economies can no longer levy a fair share of taxation from capital, and must lower labour and environmental standards for fear that companies and jobs will go elsewhere. As a result, protectionist sentiment can increase based on the view that these countries are locked in "a race to the bottom".

1.3 But the reality is very different. The gains from globalisation should allow all members of society to become better off and, by investing in skills and a productive science base, more people can be given the opportunity to access these gains and share in the benefits of a more globalised world. Countries have not lost their ability to regulate and tax their economies, as the highly taxed but internationally competitive Nordic countries demonstrate. Quality outputs commanding high prices can only be made with quality inputs: skilled labour, a productive science base and an attractive business environment. Taxes well spent will boost an economy's productivity, and the evidence suggests that efforts by national governments to compete for foreign direct investment (FDI) through low standards or lax enforcement of environmental protection are likely to be unsuccessful and counterproductive.

1.4 So we should not see ourselves as competing with developing countries in "a race to the bottom", but in "a race to the top". The advanced economies cannot and should not seek to compete internationally on the basis of low wages. Company strategies that depend on low costs will end up in a downward spiral, where each year brings a new competitor: today the coastal regions of China, tomorrow the interior of China, or Vietnam and Indonesia.

1.5 Countries such as China and India will not be content for long on the lower rungs of the economic ladder, remaining forever in mass production manufacturing based on low technology, low wages and low skills. They are determined to improve the quality of their goods and services, increase their rates of innovation, and move into high-value-added goods and services.[1]

[1] Broadly, "value added" is the difference between the costs of inputs purchased from other firms and the value of output produced.

1.6 The UK is in a strong position to respond to these challenges. Macroeconomic stability, flexible markets and openness to competition has made the UK home to world-class business. The UK's financial markets, pharmaceuticals, creative industries and high-technology manufacturing are thriving and will continue to improve under a strong business environment. The challenge for the UK, therefore, as for other developed countries, is to continue to upgrade our knowledge and skills and move into new high-value-added goods and services and new high-value-added industries. This means that science and innovation has to be at the top of our agenda.

THE OPPORTUNITIES AND CHALLENGES OF GLOBALISATION

1.7 The word "globalisation" has been used loosely to describe many changes in our economy and society in recent years. It is, therefore, important to focus on the central idea: that changes in the international economy are leading to the emergence of a single world market for labour, capital goods and services. Globalisation today is the product of a number of political, economic and technological changes that have provided huge benefits to the global economy, including lifting millions of people out of poverty.

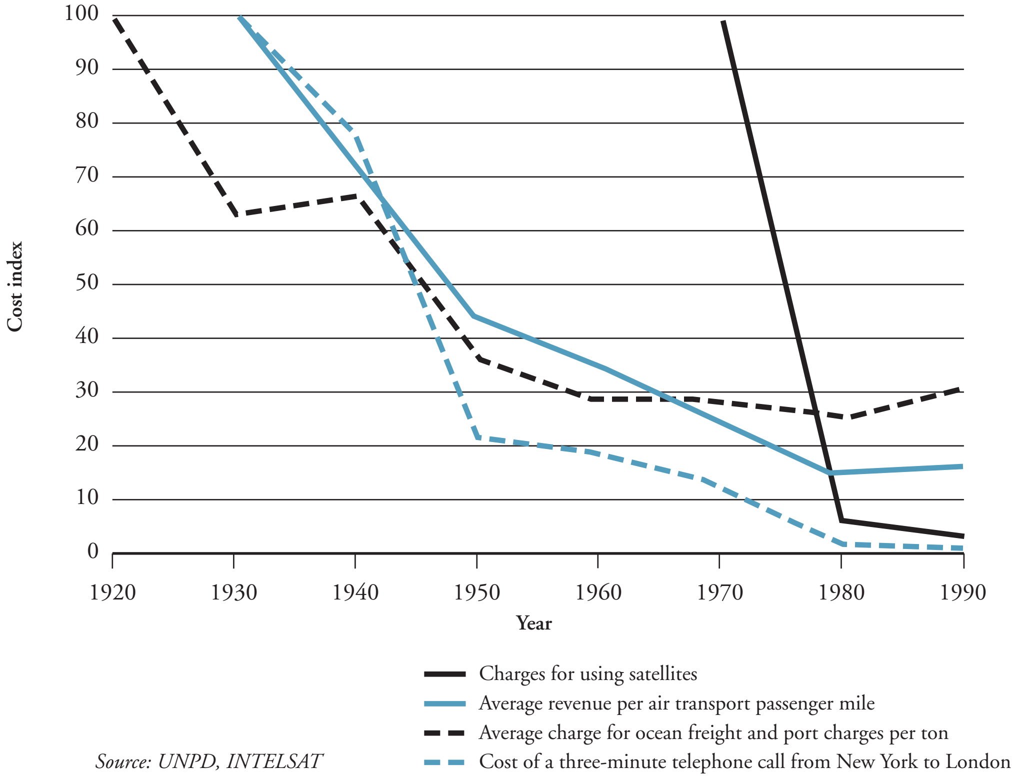
Reducing the cost of information and travel

1.8 First, improvements in communications and transport technologies have significantly lowered the cost of moving information, goods and services across long distances (Chart 1.1), making global operations easier and faster. Technological advances in communications systems and falling costs of communication have facilitated global transactions and improved information flows, enabling the fragmentation of global manufacturing chains. Software programming, call-centre services, back-office operations, medical transcription, legal and accounting services can all be provided remotely from other countries through increasingly efficient information and communications technologies. This is a two-way flow of goods and services: it provides new sources of imports and new markets for exports. The UK benefits from both flows. Business is able to restructure production, taking advantage of the opportunities being offered in emerging economies to reduce costs, while the same technological breakthroughs create the means to access new markets and to export increased numbers of high-value goods and services.

1.9 Major technological advances in transportation have significantly lowered the costs and increased the quality of global transport infrastructure. This has extended the reach of firms, making new markets accessible, and promoted trade based on comparative advantage. The shift away from shipping manufactured goods to air transport, combined with a reduction in the average ocean shipping time from 40 days to 20 days, has reduced the tariff equivalent of time costs from 32 per cent to 9 per cent.[2] Reductions in delivery time increase market responsiveness and allow for improved business practices, such as just-in-time delivery.

[2] *Time as a trade barrier*, Hummels D., working paper, Purdue University, 2001.

Chart 1.1: Costs of transport and communications



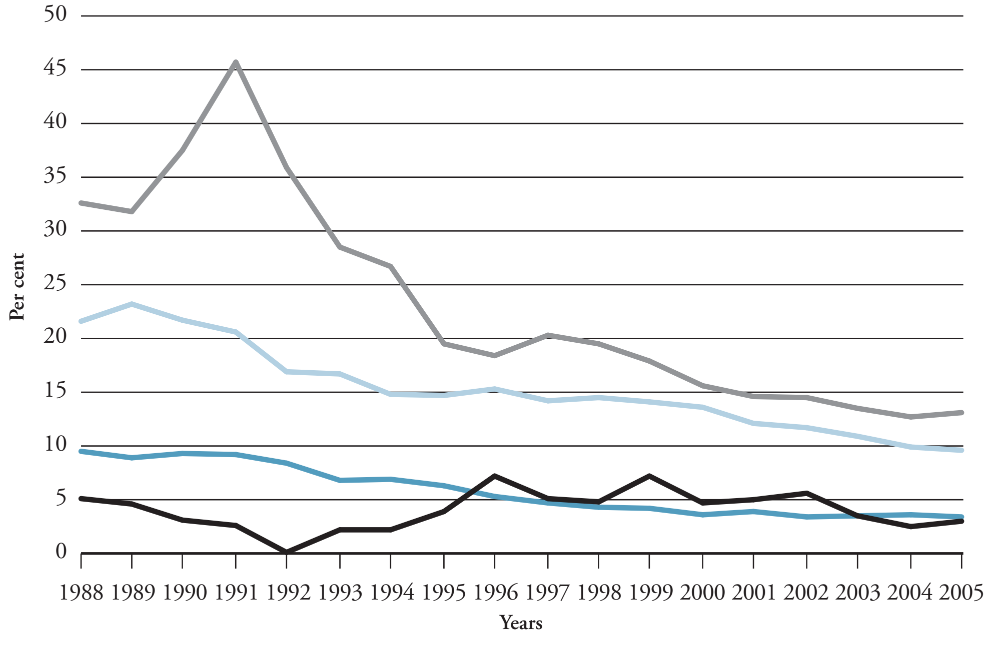
Source: UNPD, INTELSAT

Falling tariff barriers

1.10 Second, tariff barriers that distort world markets have fallen. Trade barriers prevent efficient allocation of productive resources by providing a competitive advantage to domestic producers in markets that would be better served through trade. They limit competition, impose costs on consumers and taxpayers and, worst of all, prevent developing countries from accessing vital international markets. Tariffs are highest in those sectors where the developing world has a comparative advantage: agriculture and labour-intensive goods.

1.11 Between 1981 and 2005, tariff barriers fell in most countries. Since 1988, average applied tariff rates have more than halved in the USA and fallen by over 70 per cent in the EU. As Chart 1.2 shows, this pattern has been played out in all broad country groups. But there is a long way to go and it is vital not to become complacent. The Doha Development Agenda, launched by the World Trade Organization in 2002, is key to this progress.

Chart 1.2: Average applied tariff rates



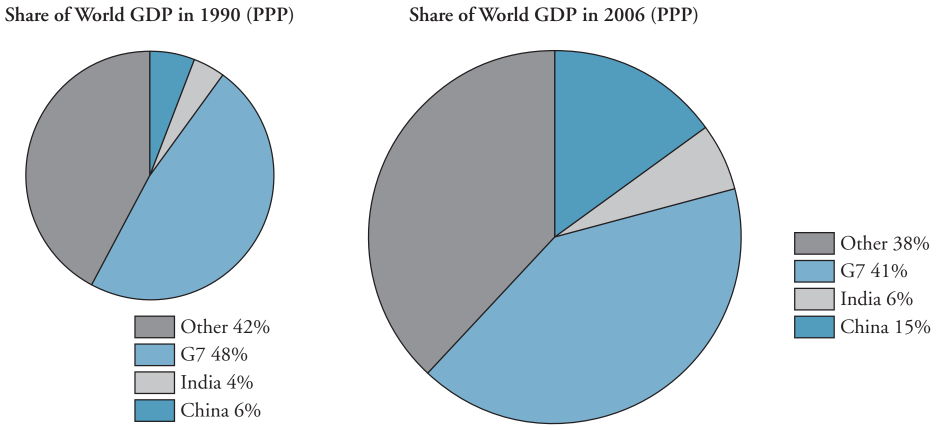
Source: World Bank

Expansion of markets

1.12 Third, new markets have emerged and, with them, vast numbers of hard working, highly motivated and relatively cheap workers have entered the world economy. Within the past 20 years, the size of the global economy has increased following the adoption of freer market policies and the integration of several economies into the global trading system – most notably China and India, but also Central and South America, the former Soviet Union and other parts of Asia.

1.13 The balance of global activity is shifting from Europe and the USA to Asia. As Chart 1.3 illustrates, China and India's share of world GDP has increased significantly since 1990 while the G7 countries' share has decreased in the same period. Asia may account for over half of global growth over the next 15 years, by which time China and India are individually forecast to be bigger than the UK, French and German economies combined (in purchasing power parity terms). The emergence of new economies offers potential benefits to all countries. The new markets will add approximately 1 billion consumers to the world market, and China and India's combined share of global expenditure is expected to double over the next 15 years.

Chart 1.3: Share of world GDP (purchasing power parity)



Source: IMF

THE FRAGMENTATION OF THE MANUFACTURING CHAIN

1.14 To understand what is happening in the world economy, it is also necessary to be aware of one other change taking place in parallel with globalisation that has had a major impact on the location of industry. Manufacturing that used to be contained within the four walls of a single factory can now – through the use of digital technologies and improvements in communications and transport – be broken down into modules distributed (potentially) around the world. This has produced a fragmentation of the manufacturing chain.

1.15 Manufacturing is a sequence of functions, covering R&D, design, supply management, production, distribution, logistics and sometimes the provision of after-sale services. New technology has made the co-ordination of these activities across distances much easier, even when the different stages are located in different countries.

1.16 This fragmentation of manufacturing can speed up the rate of innovation because it is possible to flexibly pull together combinations of sophisticated components that were invented for quite different purposes. The Apple iPod could move from concept to market in less than a year because it combines components that were already being made by others.

1.17 Modularity such as this opens up opportunities for innovation, but it also creates more competition at each point along the value chain. Fragmentation of the manufacturing chain increases the competition faced by any production being performed in-house, because each module faces rivals that are concentrating their resources on producing that module better than anyone else. As a result, each activity that a company keeps in-house has to be tested against the best-in-class competitors from around the world.

1.18 Fragmentation is a mode of specialising and making the most of comparative advantage. UK firms can increase their productivity and reduce prices by outsourcing the parts of their production chain more efficiently located in other parts of the world. The increased productivity in domestic firms derived from outsourcing is great enough that it has been found to have positive employment effects that outweigh the initial loss of jobs from outsourcing.[3]

1.19 Outsourcing is also a two-way channel. Whilst UK firms outsource the low cost, repetitive tasks from their production chain, they are benefiting from increased demands for goods and services from firms in other countries looking to outsource parts of their production chain. This increase in trade underlies the rise in UK exports of services such as those shown in chart 1.7.

1.20 Fragmentation, therefore, has two important policy implications: first, we should accept that companies may have to outsource some part of their manufacturing chain to compete. At the same time, Britain has the opportunity to attract parts of the manufacturing chains of foreign countries.

1.21 Second, in every industry we should focus our innovation, our inward investment policies, and our export promotion activities on the knowlege-intensive parts of the manufacturing chain. In some cases this will be R&D and design; in other cases it will be the production process itself.

A STRATEGY TO COMPETE IN THE GLOBAL ECONOMY

1.22 Globalisation opens up many new opportunities for companies in developed countries, and the UK is in many ways well placed to take advantage of them. We have a flexible labour market, an extraordinary record of scientific discovery, a large and growing supply of high-quality university graduates and an open economy with an international outlook.

1.23 But there will be some adjustment costs and we should not underestimate the competitive pressures that globalisation will put on companies in the developed world. Globalisation has led to a major restructuring of global economic activity. In 1980 less than a tenth of manufacturing exports came from the developing world; today it is almost 30 per cent. China alone is producing 70 per cent of the world's photocopiers, 50 per cent of cameras, 40 per cent of microwaves and 25 per cent of textiles. India is making huge strides forward in the services sector.

1.24 These challenges have led to calls for increased protection of domestic markets, support for restrictions on foreign ownership, resistance to foreign goods, an unwillingness to allow currencies to adjust to export strength and a slowdown in world trade talks. Globalisation may be beneficial for the whole economy, but without effective transitional support it is likely to impose high costs on some individuals, particularly unskilled workers.

1.25 However, calls for protectionism need to be resisted as it will always provoke protectionism in others. Such protectionism is short-sighted and in the long run leads to greater adjustment costs than if global change is welcomed and policies which allow the economy to restructure are implemented. Most economists would argue, and experience demonstrates, that open trade between nations leads to higher employment and a higher standard of living than that achieved in closed economies. The Government has had a strategy in place for a number of years to help companies succeed in the global economy, by focusing on policies to raise productivity through the five drivers: innovation, skills, competition, investment and enterprise.

[3] Amiti, Mary and Shang-Jin Wei, *Fear of Service Outsourcing: Is It Justified?* NBER Working Paper number 10808, September 2004.

1.26 A nation's standard of living over a period of years depends on the rate of productivity growth and levels of employment. Productivity depends on the quality of products, the prices that they can command in the marketplace and on the efficiency with which they are produced. For a nation to achieve sustained productivity growth it needs to continually upgrade its economy. Its companies must increase their productivity in existing industries by improving product quality, adding new and attractive features, using new product technology and raising production efficiency. And an upgrading economy must develop the capability to compete in new and more sophisticated industries, where productivity is generally higher.

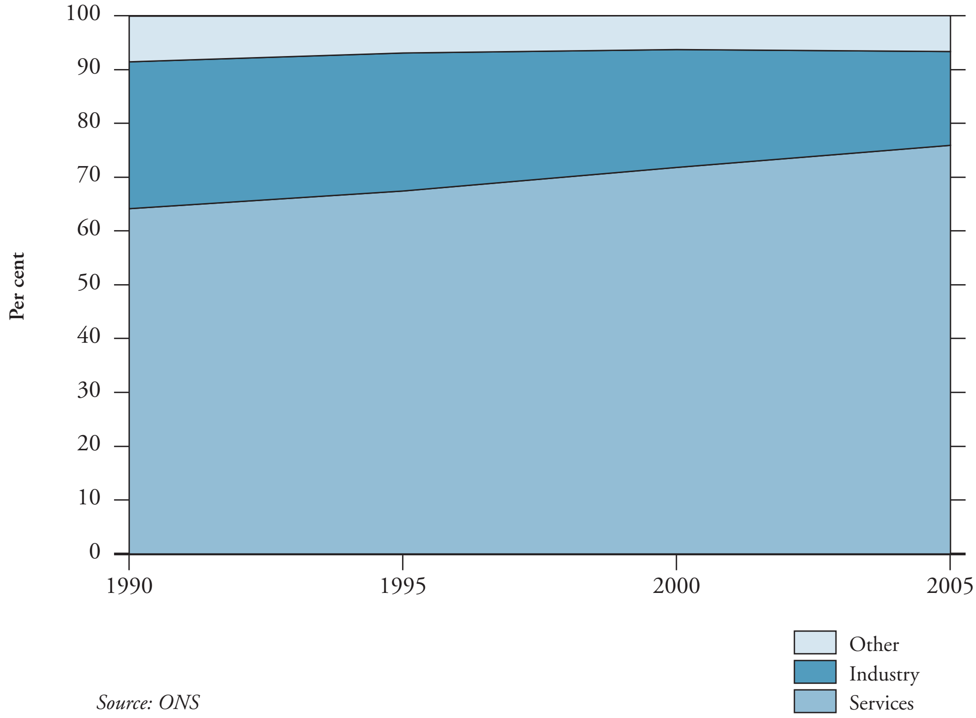
1.27 In a race to the bottom, cheap labour and a "favourable" exchange rate may be the best ways to achieve competitiveness, but in a race to the top, the goal for companies must be to develop the products and services that command premium prices in international markets and which can support high wages.

1.28 The best strategy for the UK and other developed countries is to recognise that we have a comparative advantage in knowledge-intensive industries, and to continue to build a strategy based on openness, flexibility and investment in knowledge and skills that enhances our comparative advantage. This strategy will lead to a better response to globalisation than would protectionism and fear of change and will enable companies to produce more knowledge-intensive goods and services and move more quickly into the new knowledge-intensive industries. Companies translate new ideas into new products and services, or new processes and production methods and it is support for this innovation that will help boost productivity and standards of living.

THE RESTRUCTURING OF THE UK ECONOMY

1.29 The challenges of globalisation have created substantial pressures for economies to move away from historic areas of strength and to focus on those where they can maintain the biggest possible comparative advantage in the future. This is already happening in some areas of the economy. In the UK, and most OECD countries, there has been a decline in manufacturing as a percentage of GDP and a commensurate increase in services. In 1970, manufacturing accounted for 32 per cent of UK output. In 2003 it accounted for 16 per cent, due in part to increased productivity and increased incomes which lower the proportion of income spent on manufactured goods.

Chart 1.4: UK GDP shares



Source: ONS

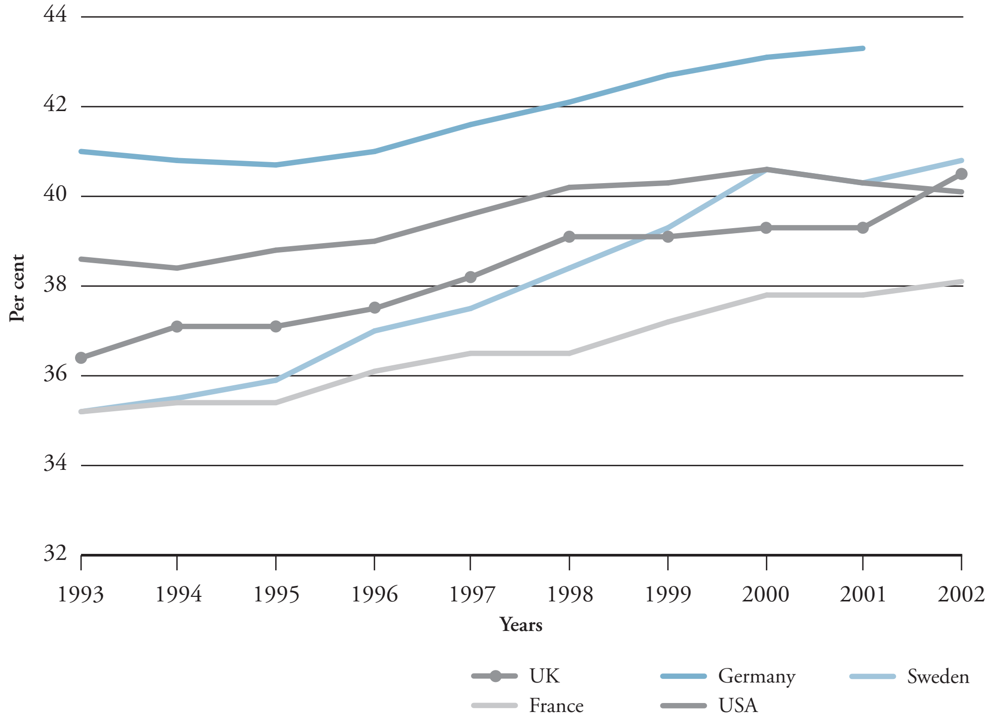
1.28 However, the rise of services and relative decline of manufacturing conceals a more interesting story of economic restructuring towards higher value-added, knowledge-intensive sectors. The following chart shows how manufacturing growth in high-technology subsectors, such as aerospace, pharmaceuticals and computer manufacturing, and knowledge-intensive services (e.g. financial intermediation) has outstripped growth in low-technology sectors. The shift has been especially pronounced in the UK. Chart 1.5 shows how the contribution of high-technology manufacturing and knowledge-intensive services to value added has changed over time in the UK, France, Germany, USA and Sweden.[4]

[3] The definition of high-technology manufacturing is based on the OECD definitions of high, medium-high, medium-low and low-technology manufacturing, which are based on R&D intensity. The definition of high-technology used here is the combination of both high and medium-high. Knowledge-intensive services are defined as communication services, finance services, insurance services, other business services and community, social and personal services.

Table 1.1: Shares in value added, by sector (per cent of gross value-added)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
UK										
High-tech manufacturing	8.0	8.4	8.7	8.5	8.4	8.0	7.7	7.2	6.8	6.2
Low-tech manufacturing	12.3	12.3	12.4	12.2	12.0	11.4	10.9	10.2	9.7	9.0
Knowledge services	28.4	28.7	28.4	29.0	29.8	31.1	31.4	32.1	32.5	34.3
Other services	39.6	39.0	38.9	38.6	38.8	39.3	39.9	39.7	40.2	39.9
High-tech manufacturing and knowledge services	36.4	37.1	37.1	37.5	38.2	39.1	39.1	39.3	39.3	40.5
France										
High-tech manufacturing	6.9	7.0	7.3	7.2	7.6	7.7	7.7	7.5	7.6	7.4
Low-tech manufacturing	11.5	11.3	11.3	11.1	11.0	10.9	10.5	10.6	10.5	10.5
Knowledge services	28.4	28.3	28.1	28.9	28.9	28.8	29.5	30.3	30.3	30.8
Other services	42.2	42.4	42.4	42.3	42.7	42.9	42.8	42.2	42.2	42.1
High-tech manufacturing and knowledge services	35.2	35.4	35.4	36.1	36.5	36.5	37.2	37.8	37.8	38.1
Germany										
High-tech manufacturing	11.9	11.7	11.6	11.4	11.6	11.8	11.6	11.9	12.1	–
Low-tech manufacturing	11.7	11.4	11.1	10.8	10.7	10.8	10.6	10.6	10.4	–
Knowledge services	29.1	29.0	29.2	29.6	30.1	30.3	31.1	31.2	31.2	–
Other services	36.5	36.9	37.5	37.8	37.8	37.7	37.7	37.9	38.3	–
High-tech manufacturing and knowledge services	41.0	40.8	40.7	41.0	41.6	42.1	42.7	43.1	43.3	–
USA										
High-tech manufacturing	7.2	7.4	7.3	7.2	7.2	7.3	7.0	6.9	6.0	5.9
Low-tech manufacturing	9.4	9.4	9.5	9.3	9.2	9.1	9.1	8.8	8.4	8.1
Knowledge services	31.4	31.0	31.5	31.9	32.4	32.9	33.3	33.7	34.2	34.3
Other services	43.4	43.3	43.1	42.7	42.5	42.3	42.2	41.9	42.6	43.3
High-tech manufacturing and knowledge services	38.6	38.4	38.8	39.0	39.6	40.2	40.3	40.6	40.3	40.1
Sweden										
High-tech manufacturing	8.5	9.6	10.1	10.2	10.5	10.9	11.1	10.7	9.5	9.5
Low-tech manufacturing	10.3	10.9	12.2	11.4	11.4	11.3	10.9	11.4	11.2	10.7
Knowledge services	26.7	25.9	25.9	26.8	27.1	27.5	28.3	29.9	30.9	31.2
Other services	43.1	42.6	41.4	41.5	41.3	40.9	40.8	39.5	39.2	39.4
High-tech manufacturing and knowledge services	35.2	35.5	35.9	37.0	37.5	38.4	39.3	40.6	40.3	40.8

Chart 1.5: Contribution to value added of high-technology manufacturing and knowledge-intensive services



Source: OECD, DSTI (STAN industrial database), 2004

1.29 In the UK between 1992 and 2002, the share of high-technology manufacturing and knowledge-intensive services in total value added increased by over 12.5 per cent (Table 1.1). This compares with less than 10 per cent in France and less than 5 per cent in the USA. Knowledge-intensive services (primarily financial intermediation) have led this shift, increasing by 23 per cent. High-technology manufacturing has fallen as a share of total value added, but less than the low-technology end of the sector. At a more disaggregated level, some high-technology manufacturing sectors, such as pharmaceuticals and the manufacture of aircraft, have shown robust growth rates.

[4] DTI analysis of HMRC data.

1.30 In manufacturing, growth has averaged approximately 0.5 per cent over the past decade, but there is a wide dispersion of rates among different sectors (Table 1.2). The chemicals and man-made fibres, electrical and optical equipment, and transport equipment sectors have experienced average growth rates in excess of 2 per cent per annum over the period 1995–2006, while more-traditional sectors have declined. In 1981, 8.4 per cent of UK goods exports were classified as high-technology. In 2006, this had risen to 25.7 per cent.[4]

Table 1.2: Average annual growth rates by sector, UK, 1995–2006

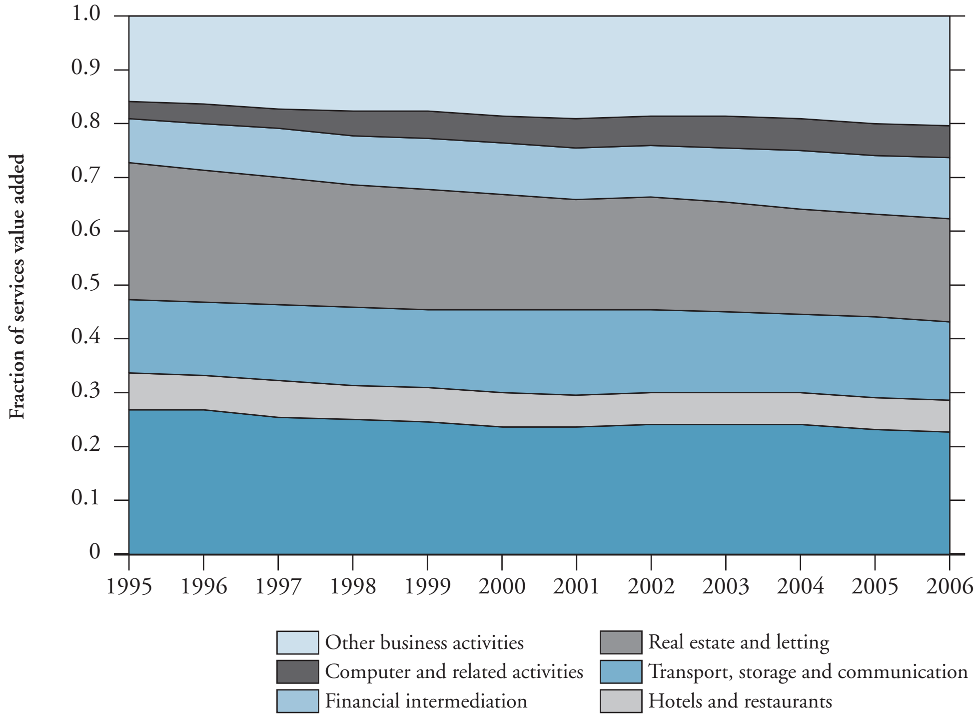
Sector	Average annual growth rate 1995–2006 (per cent)
Chemicals, chemical products and man-made fibres	2.6
Transport equipment	2.3
Electrical and optical equipment	1.2
Other manufacturing	0.9
Other non-metallic mineral products	0.8
Food, beverages and tobacco	0.4
Basic metals and fabricated metal products	0.3
Machinery and equipments not elsewhere classified	0.3
Wood and wood products	–0.3
Rubber and plastic products	–0.5
Pulp, paper and paper products; publishing and printing	–1.2
Coke, petroleum products and nuclear fuel	–1.7
Textiles and textile products	-4.9
Leather and leather products	–8.6
Total manufacturing	0.5

1.31 The OECD classifies manufacturing industries as high-technology, medium-high tech, medium-low technology and low-technology based on their R&D intensity in 12 OECD countries. In the UK, the three sectors with the highest growth rates are classified as a mixture of high and medium-high technology and those with the lowest growth rates are classified as low and medium-low technology.

1.32 In the past ten years in the manufacturing sector, the UK has begun to move away from low-value production processes and towards the higher value processes. More low-value intermediate and final goods have been imported, reducing costs for both firms and consumers, while productive resources in the UK are shifted to higher value manufacturing processes. But minimising these adjustment costs involves investment in skills to augment the move to higher value activities, incentives for science and innovation and an attractive business environment. Many dimensions of locating in the UK involve higher costs than in emerging competitor countries; the UK must create an environment in which the value added from locating in the UK offsets these higher costs.

1.33 Restructuring has the potential to expand service sectors; new opportunities created by information and communications technologies have not yet been fully exploited. As in the manufacturing sector, the average growth rate of services masks a wide distribution of sector growth rates. At a more disaggregated level, high growth rates can be observed in a number of knowledge-intensive service sectors (Chart 1.6): financial services, business services and computer and related activities have all increased substantially as a share of total economy value added.

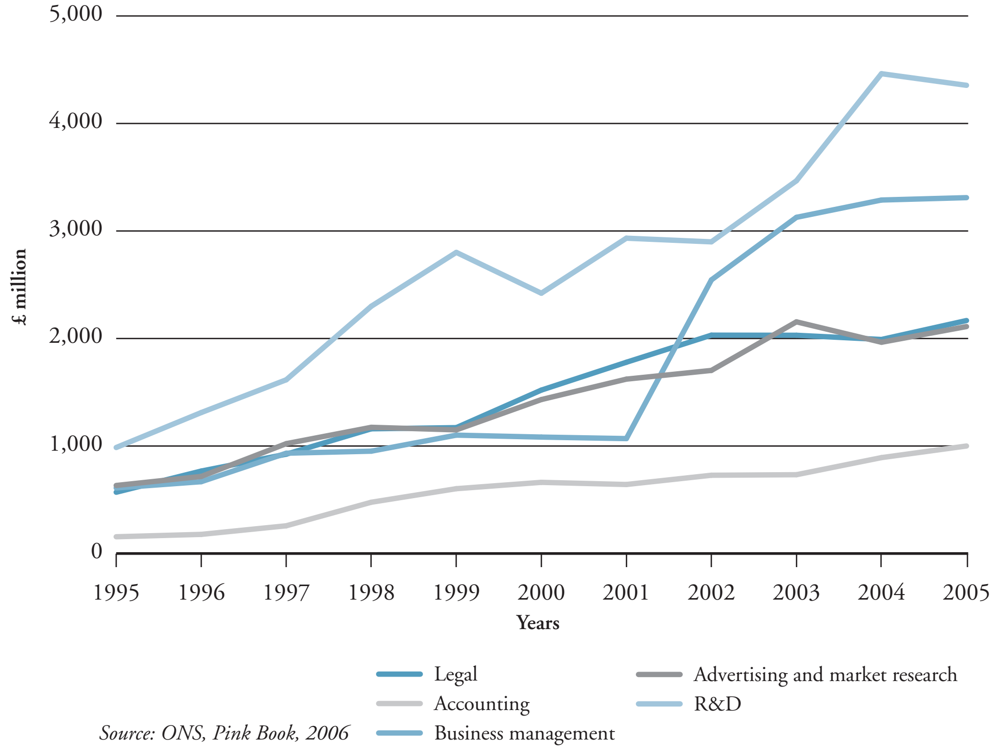
Chart 1.6: Services value added



Source: ONS

1.34 A similar trend is apparent in UK service exports; the share of financial services, computer and information services, other business services and personal, cultural and recreational services have increased significantly over the period 1995–2005. The trebling in the total value of other business service exports over this time period can be broken down further (Chart 1.7), revealing the knowledge-intensive activities that underpin this increase.

Chart 1.7: Other business service exports



Source: ONS, Pink Book, 2006

1.35 The share of high-tech manufacturing and knowledge service sectors in the economy is a crude way of looking at industrial restructuring. There will obviously be some high-technology manufacturing companies and knowledge-intensive service companies in industrial sectors that are not, as a whole, high-technology or knowledge-intensive. But it nevertheless seems to us to provide a better picture of the restructuring in the economy than simply looking at the percentage of GDP that manufacturing and services represent. It is more useful because it focuses attention on the key policy issue: the extent to which companies are moving into high-technology or knowledge-intensive areas where they are likely to be better able to compete against low-wage emerging economies.

THE CHALLENGE FOR GOVERNMENT

1.36 As has been shown, it would be an error to ignore globalisation and to retreat into protectionism. It would be expensive for developed countries and destructive of the opportunities for billions of people in the developing nations. If economic co-operation breaks down it will also be more difficult to bring about the international co-operation necessary to deal with global challenges such as climate change, the spread of infectious diseases and terrorism.

1.37 But while globalisation is a necessary condition for prosperity, it is not a sufficient one. If the UK is going to maintain its competitive advantage in knowledge-intensive industries, the Government must produce the best possible conditions for companies to innovate and grow, as well as a set of social institutions that will deliver equality of opportunity and broad-based gains in living standards. The Government must ensure that national prosperity does not come at the expense of social mobility, social justice and a sense of economic security. If the gains for all of society are not clear to people, we can be certain that the pressures for protectionism will grow.

1.38 The challenge, therefore, is not to hide behind trade barriers and engage in a race to the bottom, but to refocus government so that it supports knowledge generation, innovation, education, training, infrastructure development and labour market policies that can give those who lose their jobs the opportunity to retrain and switch employment, maintaining their standard of living. In today's global economy, investment in science and innovation is not an intellectual luxury for a developed country, but an economic and social necessity, and a key part of any strategy for economic succcess.

2 The innovation ecosystem

FACTORS AFFECTING A COUNTRY'S INNOVATION PERFORMANCE

2.1 An economy's rate of innovation depends on a range of activities and the links between them. To provide the best conditions for companies in the UK it is necessary to consider an innovation ecosystem and not a number of disconnected policies.

2.2 Companies may take the lead, but do not innovate in isolation. They collaborate with and compete against other firms, who can be suppliers, customers or competitors. They also interact with other organisations such as banks, venture capitalists, universities and research institutes, and those public agencies responsible for areas such as competition policy, drug regulation and intellectual property rights (IPR).

2.3 The knowledge produced in industry, universities and government research institutes is clearly a key input for any innovation ecosystem. Research performed by industry itself correlates most closely with the innovation performance of countries, making it the most important single input.

2.4 The second key input is government-supported research, both basic research and applied or user-driven collaborative research (Chapter 3). There are those that argue that government should only support basic research, and that companies should be left to perform user-driven research. Against that, some argue that we can get basic knowledge from anywhere in the world, and that government should concentrate on funding the collaborative user-driven research that will be of most value for UK companies.

2.5 This Review believes that it is essential that government supports both. The majority of radical innovations spring from basic research, and such work is necessary to supply the trained researchers for industry. Both new and established high-technology companies want to work with world-class research universities. This report will show that it is around our world-class research universities that high-technology clusters are forming.

2.6 A strong economic case can be made for government to support user-driven collaborative research. New knowledge – produced by research – is a classic "public good", in the economic sense: the value of its benefits cannot be completely captured by whoever produces it but spills over into the rest of society. Private firms alone, in seeking to maximise their returns, will undertake less research than is socially optimal. There is a strong argument for government to support companies' research activities. This is one reason why this Review thinks the role of the Technology Strategy Board (TSB) should be expanded.

2.7 Although research is of great importance to any innovation ecosystem, little is to be gained from research in universities, research institutes and further education (FE) colleges if there are not strong links between the researchers and industry, and that is why knowledge transfer, and incentives for it, are so important (Chapter 4).

2.8 The innovation performance of companies is also shaped by institutions – that is, the established practices, rules or laws that regulate the relations and interactions between individuals, groups and organisations: IPR being one example, metrology another. Standards, such as the GSM telecommunications protocol that was so important to the growth of mobile communications in Europe, are another example (Chapter 5).

2.9 Innovation always involves risks, particularly when it is radical innovation carried out by new, high-technology, fast-growth businesses. The scale and skill of a country's venture capital industry, as a repository of risk capital, is therefore crucial to the success of a country's innovation ecosystem (Chapter 6).

2.10 A highly skilled workforce is essential. Skilled labour is probably the least mobile factor of production, making the domestic system of education and training a key part of any innovation ecosystem and of crucial importance for policy-makers (Chapter 7).

2.11 Innovation is not a simple linear process in which research comes first, followed by development and then production and marketing. While the quality of basic research performed by a country is extremely important, there is no innovation pipeline into which public money can be pumped to make new technology and commercial applications pop out the other end.

2.12 Successful innovation is produced by creative interaction between demand and supply factors. Users now play a significant role. In the old industrial model the world was divided into producers and consumers, but we are now seeing cases of co-creation, innovation increasingly occurs on both sides of the cash register.[1]

2.13 It is easier to influence the supply side of the process, and so policy-makers have tended to concentrate on these factors. However, the importance of demand-side factors should be recognised. The procurement policies of government departments can be a crucial factor in a country's innovation performance. Regulations produced by government departments can have an important impact, in some cases stifling innovation, but stimulating it when the regulations are drafted in the right way (Chapter 8).

2.14 Although national policies create a framework for innovation, the locus of innovation is at the regional level where workers, companies, universities, research institutions and government meet more directly. Regions are the building blocks of national innovation capacity because they offer the proximity vital for collaborative relationships and can provide the specialised assets such as research institutes that enable companies to develop their innovative potential (Chapter 9).

2.15 Finally, the national rate of innovation in the global economy cannot be seen in isolation from the commercial and technological developments in other parts of the world. To stay at the cutting edge of world innovation one needs to engage actively and collaboratively with other centres of excellence. Rising global prosperity has a positive effect on our own economic success (Chapter 10).

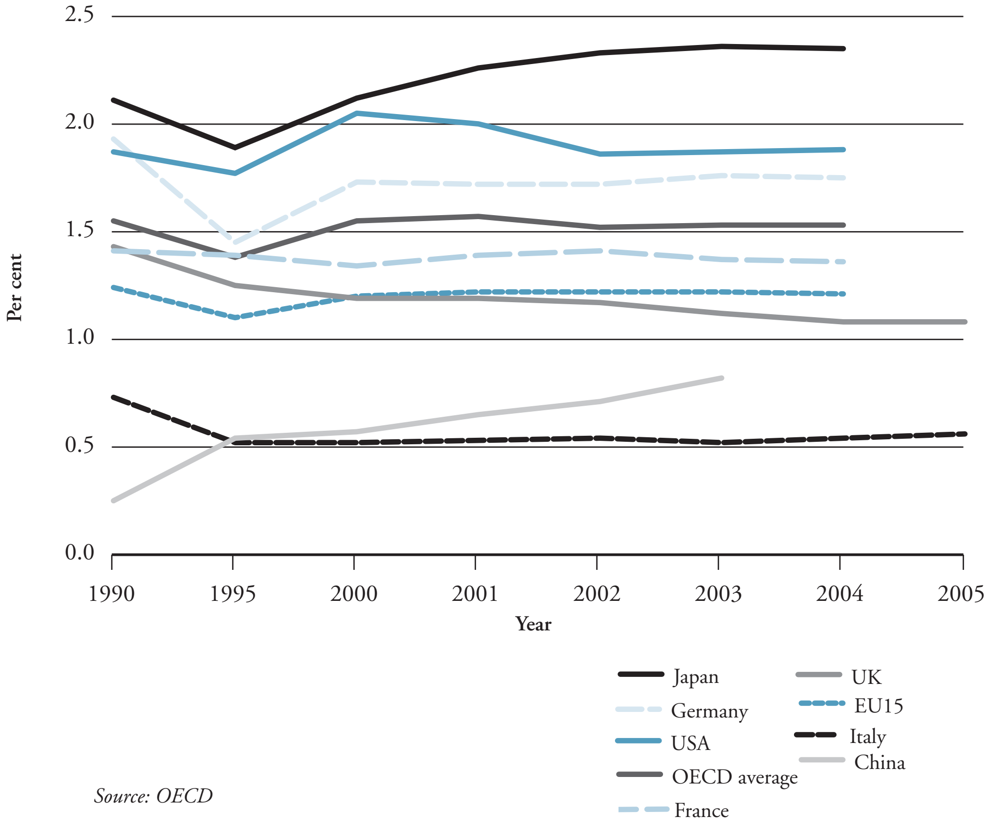
2.16 It can be seen then that a large number of factors affect a country's innovation rate, many of which can be influenced by government. If we want to develop our innovation ecosystem, we need to assess our innovation performance as a country. Then, we can look at the different factors that affect it and benchmark them against other countries.

[1] See, for example, *Democratising Innovation,* Hippel E. Von, 2006.

TRENDS IN PRIVATE SECTOR R&D

2.17 While it is an input rather than an output, one of the most important measures of a country's innovation performance is the amount of research done by industry. Business enterprise R&D (BERD) performed in the UK has shown a slight downward trend as a share of GDP since 1990. Most advanced economies, with the exception of Japan, have experienced fairly steady levels of R&D to GDP since the turn of the century, while China has shown rapid growth in the ratio. These economies have in common a long-term rebalancing towards services and away from manufacturing sectors.

Chart 2.1: International comparison: BERD as per cent of GDP

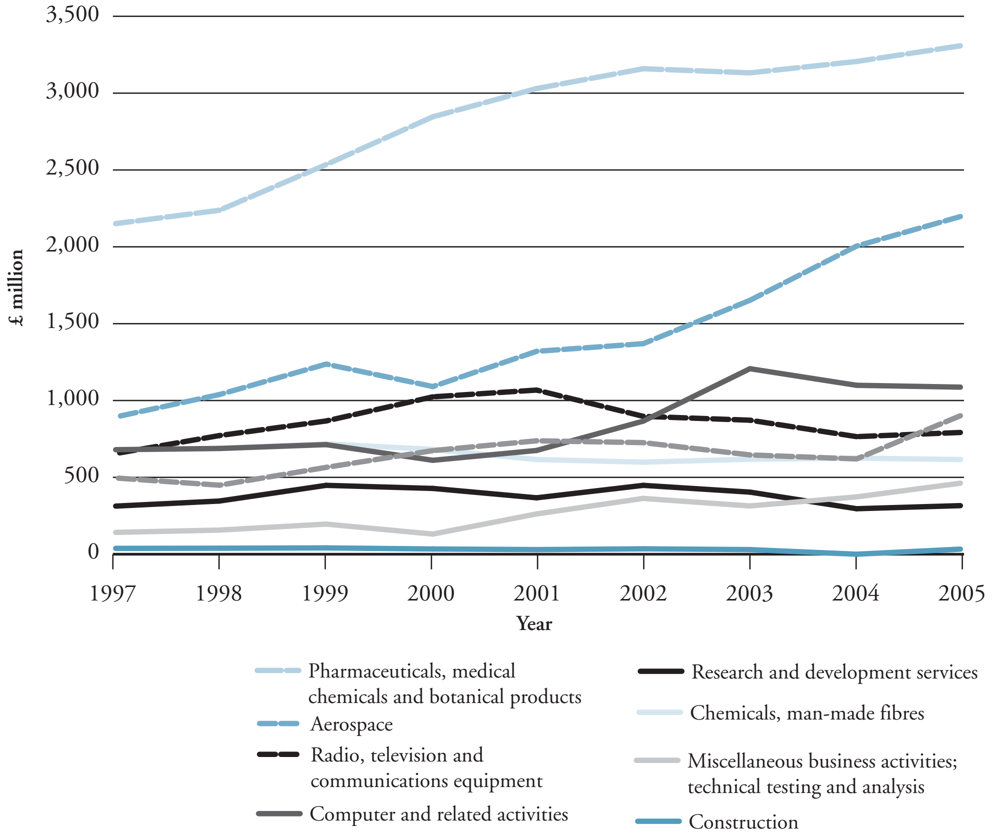


Source: OECD

2.18 In the UK, the growth in BERD in real terms has been dominated by two broad industrial sectors: pharmaceuticals and aerospace. Services, which now account for over 70 per cent of gross value added in the UK, are innovative, but do not undertake R&D in the traditional sense. Some service sectors, such as computing and telecommunications, spend a great deal on R&D – information technology (IT) services were ranked sixth out of all sectors in 2003. However, research commissioned by the then-Department of Trade and Industry (DTI) suggests that while "invention" is well captured in R&D spending, innovation is a more complex process, especially in services. As a result, innovative activity there is often inadequately captured by R&D figures and conventional metrics.[2]

[2] *DTI Occasional Paper #9: Innovation in Services,* DTI, June 2007.

Chart 2.2: BERD detailed product groups



Source: ONS

2.19 The differences in R&D intensity between the UK and other countries are at least in part the result of different industrial structures. R&D-intensive industries account for a smaller share of GDP in the UK than they do in some other economies, such as Germany, and hence overall R&D intensity will be lower even if R&D intensity within industries is comparable.

2.20 The relative significance of this effect depends on the data source used. Data obtained from company accounts and published in the R&D Scoreboard suggest that the intensity gap is entirely due to the UK's industrial structure. UK-based companies spend similar proportions of their revenue on R&D as their competitors overseas in the same sectors (see Tables 2.1 and 2.2). But the UK has a much stronger corporate presence in sectors that are very successful but which historically have reported little if any spend on R&D, such as oil and gas, and financial services. In these industries, competitiveness is not derived from rapid technological development through R&D but from a wider range of modes of innovation and efficiency.[3]

[3] *Economics Paper 11: R&D Intensive Businesses in the UK*, DTI 2005.

Table 2.1: R&D intensity by sector

Group	USA (per cent)	Japan (per cent)	Germany (per cent)	France (per cent)	UK (per cent)	World (per cent)
Pharmaceuticals and health	13.7	10.7	10.9	14.0	14.1	13.4
Electronics and IT	9.4	5.2	8.1	6.9	8.8	7.4
Engineering and chemicals	3.0	4.2	4.4	3.8	4.5	3.7
Low intensity	1.1	1.8	0.8	1.0	1.0	1.2
Very low intensity	0.4	0.7	0.4	0.6	0.2	0.4

Source: DTI R&D Scoreboard 2006 (International 1250)

Table 2.2: Accounting for differences in R&D intensity across countries

Comparison	Difference in intensity (per cent)	Explained by intensity levels within industries (per cent)	Explained by differences in industrial structure (per cent)
UK vs France	–0.83	0.20	1.03
UK vs Germany	2.31	0.34	–2.65
UK vs Japan	–2.00	0.88	–2.88
UK vs USA	2.60	0.49	–3.09

Source: DTI R&D Scoreboard 2006 (International 1250)

2.21 If, however, the analysis uses official BERD statistics, the effect of sector mix is less pronounced, at least in relation to France and the USA.[4] These studies suggest that, at least in parts of manufacturing, there is some evidence of an intensity effect, i.e. the proportion of gross value added spent on R&D in specific industries might be lower than in other countries.

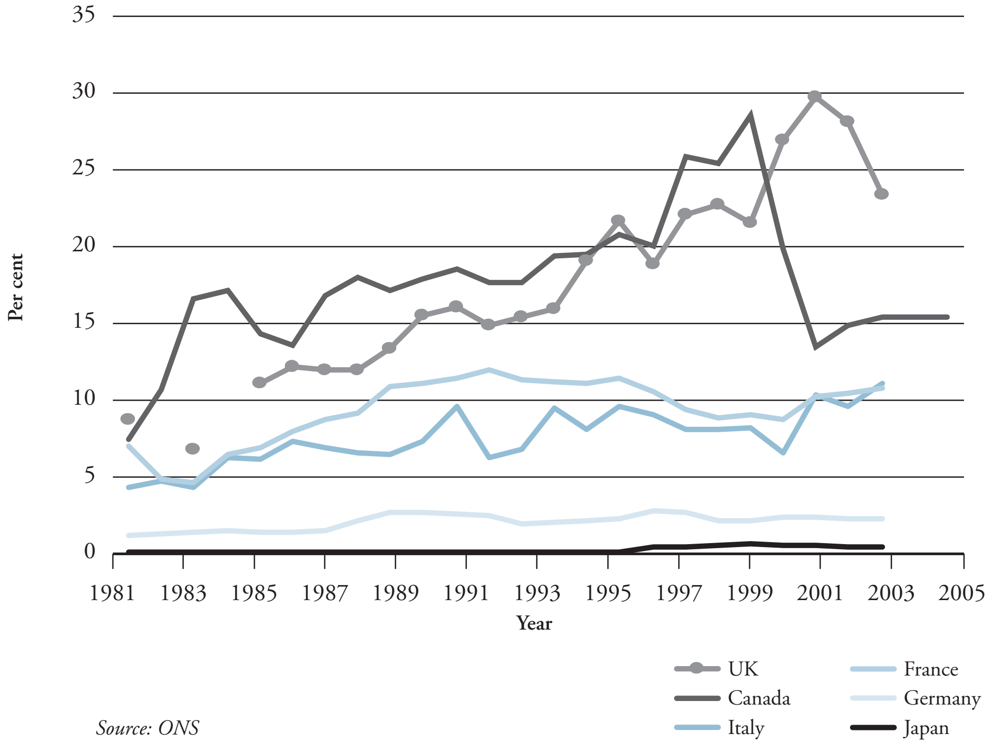
2.22 These two analyses are based on different data sources with different definitions. In particular, the DTI R&D Scoreboards measure the global R&D spend of UK-based companies whereas the data collected by the Office of National Statistics (ONS) measure R&D performed in the UK. It is possible that the differences between the two sets of analyses reflect the location decisions of multinationals in a few R&D-intensive industries, such as automotives, where the UK has a strong manufacturing presence but relatively little R&D is performed in the UK.

International R&D

2.23 UK R&D has historically been highly internationalised, increasingly so in recent years. Chart 2.3 shows the percentage of business R&D performed in the UK financed from abroad. This has increased over time, although the share moves around from year to year, which may reflect the timing of small numbers of large investments by multinationals.

[4] See studies by the Institute of Fiscal Studies and DTI, *Economics Paper 11*.

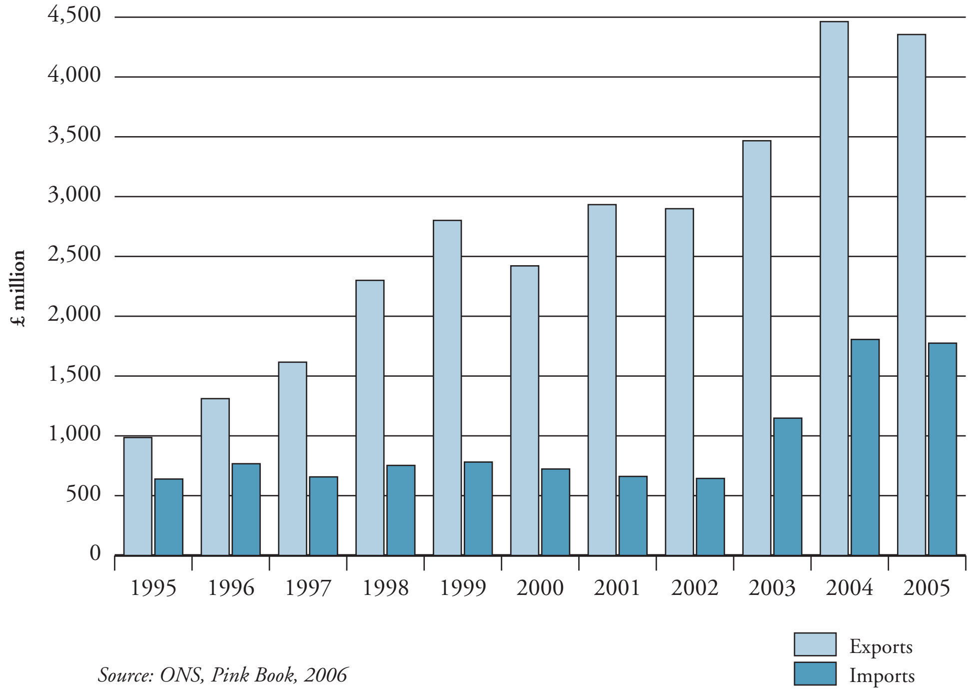
Chart 2.3: Percentage of BERD financed from abroad, 1981–2005



Source: ONS

2.24 The significant inward flow of R&D investment – foreign companies carrying out R&D in the UK that will in many cases then be transmitted throughout the world – is one reason why the UK shows a strong and increasing balance of trade in R&D services (see Chart 2.4). These figures show that overseas customers are increasingly purchasing R&D services from UK suppliers. In some cases these will be private R&D service companies, in others it will be operating divisions of multinationals receiving R&D from their UK laboratories.

Chart 2.4: Exports and imports R&D, by year



Source: ONS, Pink Book, 2006

2.25 While these figures do not suggest that overseas R&D investment has been sufficient to bridge the gap in R&D intensity between the UK and the OECD average, they suggest that the UK has been a highly attractive location for mobile R&D. It will be important to maintain that advantage in the future.

R&D tax credits

2.26 International evidence from OECD countries suggests that direct subsidies, in the form of tax credits to private firms, can help boost R&D.[5] UK R&D tax credits were introduced in April 2000 for companies that are small and medium-sized enterprises (SMEs).[6] The scheme was extended to other companies in April 2002, and a vaccines research relief was introduced in April 2003.

2.27 The R&D tax credit allows companies to deduct 150 per cent (SME scheme) or 125 per cent (large company scheme) of qualifying expenditure on R&D activities[7] when calculating profit for tax purposes. Standard tax treatment normally allows companies to deduct 100 per cent of R&D expenditure when calculating their taxable profits, effectively acting as a subsidy for research and development. Some complications emerge when a large company subcontracts R&D to an SME: in this case, the SME may claim the credit under the large company scheme.

[5] See, for example, Nick Bloom, Rachel Griffith, John van Reenan, "Do R&D tax credits work? Evidence from an international panel of countries, 1979–1994", *Journal of Public Economics* (August 2002).

[6] R&D is defined for tax purposes in Section 837A of the Income and Corporation Taxes Act 1988. Broadly, R&D takes place when an overall project seeks to achieve an advance in science or technology.

[7] Principally, these are expenditure on staffing costs, materials used in the R&D, externally provided workers and in certain cases some of the costs of sub-contracted R&D.

2.28 Take-up has risen substantially since the scheme's introduction, from under 2,000 companies in 2000–01, to over 6,000 in 2004–05, the last year for which figures are available. A total of 1,300 claims were made by large companies, the rest by SMEs; however, the bulk of supported spending (£4.9 billion) is made by large companies, with SMEs accounting for £1.6 billion of supported spending in the last financial year.

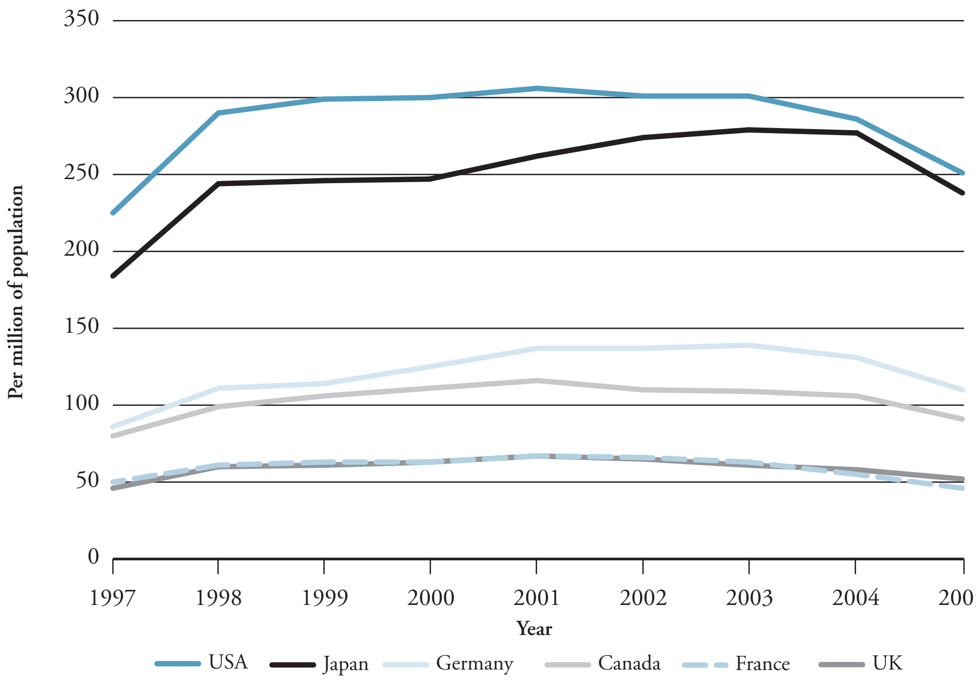
2.29 The scheme is broadly considered to be a success, with 57 per cent of surveyed companies saying that it was an incentive for them to boost R&D spending.[8] HMRC evaluation into the scheme is ongoing, and a more comprehensive study will be completed when sufficient data are available.

2.30 This Review believes that R&D tax credits have played an important part in supporting and sustaining business R&D in the UK, and supports their continued operation.

UK PATENT TRENDS AND INTERNATIONAL COMPARISONS

2.31 A second figure which is widely used to measure a country's innovation performance is the number of patents per head. Chart 2.5 shows that, adjusted for population size, the UK is granted significantly fewer US patents per head than either the USA or Germany, and has a world share of around 2.3 per cent of total US patents granted. This share has been stable since 1997.[9]

Chart 2.5: US patents granted



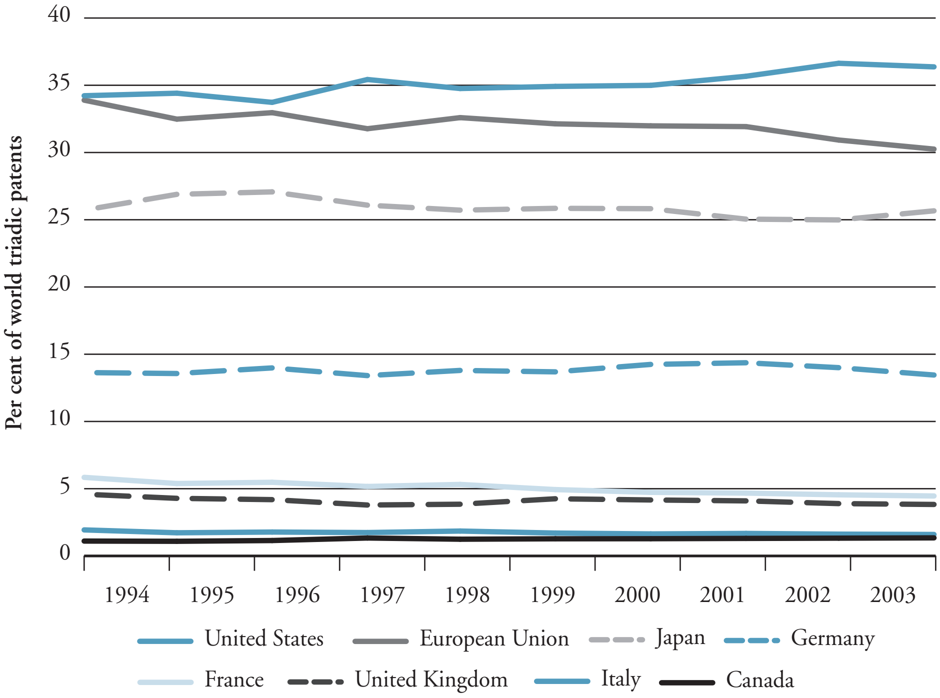
Source: OECD Compendium of Patent Statistics, 2006

[8] BMRB Social Research for HMRC, Tax Credits Final Report (December 2005) at http://www.hmrc.gov.uk/randd/rand-taxcredits-final.pdf

[9] US patent data are used as the main patent indicator, with triadic patents as supporting evidence. In the Government's consultation on productivity indicators, there was strong support among respondents for the more timely data collected at the US Patent and Trademark Office over the more comprehensive triadic patent data. The Government accepted this recommendation and uses US data in the core set of published productivity indicators, whereas triadic patent data are used to provide supporting retrospective evidence. See *Benchmarking UK Productivity Performance: The Government's Response to the Consultation on Productivity Indicators,* HM Treasury and DTI, October 2004, p. 13.

2.32 Under an alternative measure of patenting, "triadic" patents are counted, which are registered in the European Patent Office, the US Patent and Trademark Office, *and* the Japanese Patent Office (JPO). The UK has maintained its world share of around 4 per cent since 1997. In a further breakdown of the EU countries, the UK and France have similar world shares. Germany leads with 13 per cent.[10]

Chart 2.6: Triadic patents granted, by country



2.33 Relatively low levels of business R&D in the UK may partly explain our level of patenting. The OECD has examined the link between R&D and patenting for 19 OECD countries over the period 1986–2000.[11] It found that for both domestic patents and for triadic patents there is a clear positive link between R&D and subsequent patenting, and that the principal effect comes from R&D in the business sector.

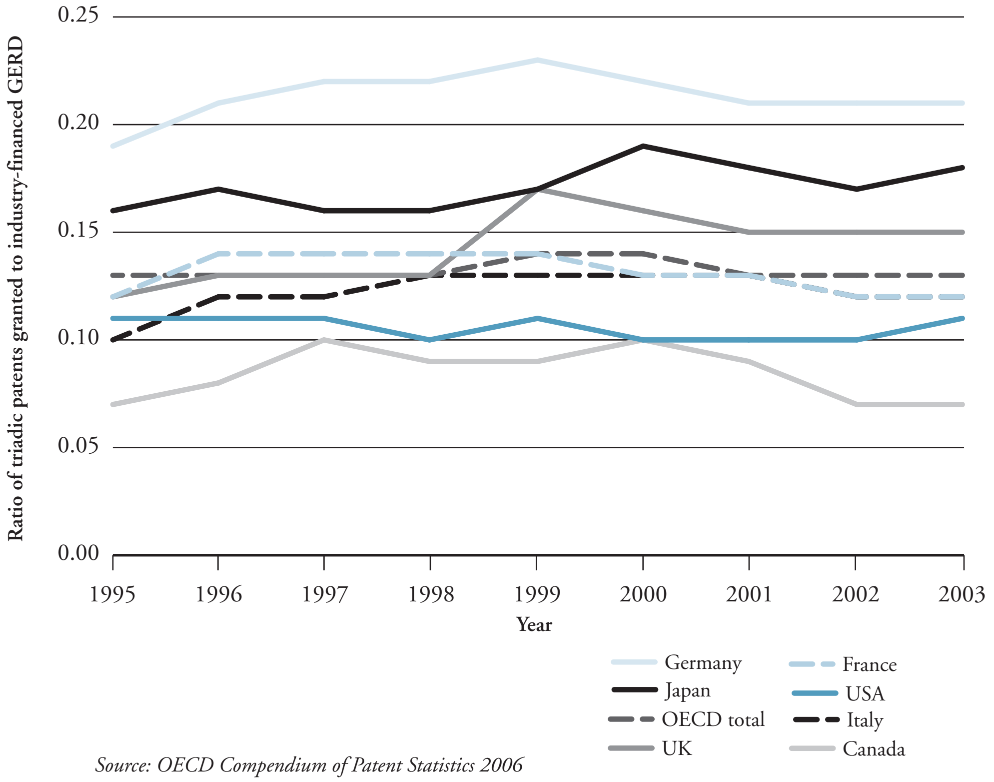
2.34 To account for the effects of R&D, it is useful to calculate measures of patent intensity, which normalise the number of patents by the amount of business R&D spend. Chart 2.7 shows that once the effects of business R&D have been taken into account, the UK performs much more strongly on triadic patenting.[12] The UK is third, behind Germany and Japan, well above the OECD average and the USA.

[10] *Compendium of Patent Statistics*, OECD 2006.

[11] *From Ideas to Development: The Determinants of R&D and Patenting*, Jaumotte, F. and Pain, N., OECD Economics Department Working Papers, No. 457, (2005).

[12] Triadic patent families refer to patents applied for at the EPO, USPTO and JPO based on the earliest priority date, and the inventor's country of residence.

Chart 2.7: Patent intensity[13]



Source: OECD Compendium of Patent Statistics 2006

2.35 A comparison of industrial composition can help to explain differences in aggregate patenting activity between countries. The UK is not far behind Japan and the USA, and ahead of the other G7 countries in high-technology manufacturing share in gross value added[14] but performs less strongly in medium- to high-technology manufacturing (including electrical machinery, motor vehicles and other transport equipment). Due to sectoral differences and the strong relationship between patenting and the amount of R&D carried out by business, the UK's relative strengths and weaknesses across sectors are also reflected in total patenting performance.

2.36 Sectoral differences in patenting are highlighted in the then-DTI's 2006 R&D Scoreboard,[15] which contains data on the largest 1,250 R&D-active companies worldwide. It shows that UK patent intensity (US patents granted in 2005 per £10 million R&D investment) varies strongly between sectors, with the highest ratios in the electronics, technology hardware and personal goods sectors, and the lowest in pharmaceuticals and telecoms (see Chart 2.8). This ranking was stable over the previous three years. The low ratio for pharmaceuticals reflects the substantial R&D investment needed to ensure a patented compound is effective and acceptable to regulatory authorities.

[13] Industry-financed GERD refers to the gross domestic expenditure on R&D financed by industry, given here in million USD using purchasing power parities as at year 2000. The ratio is calculated with R&D expenditure lagged by one year. Industry-financed GERD is broadly comparable to business expenditure on R&D used elsewhere in this report.

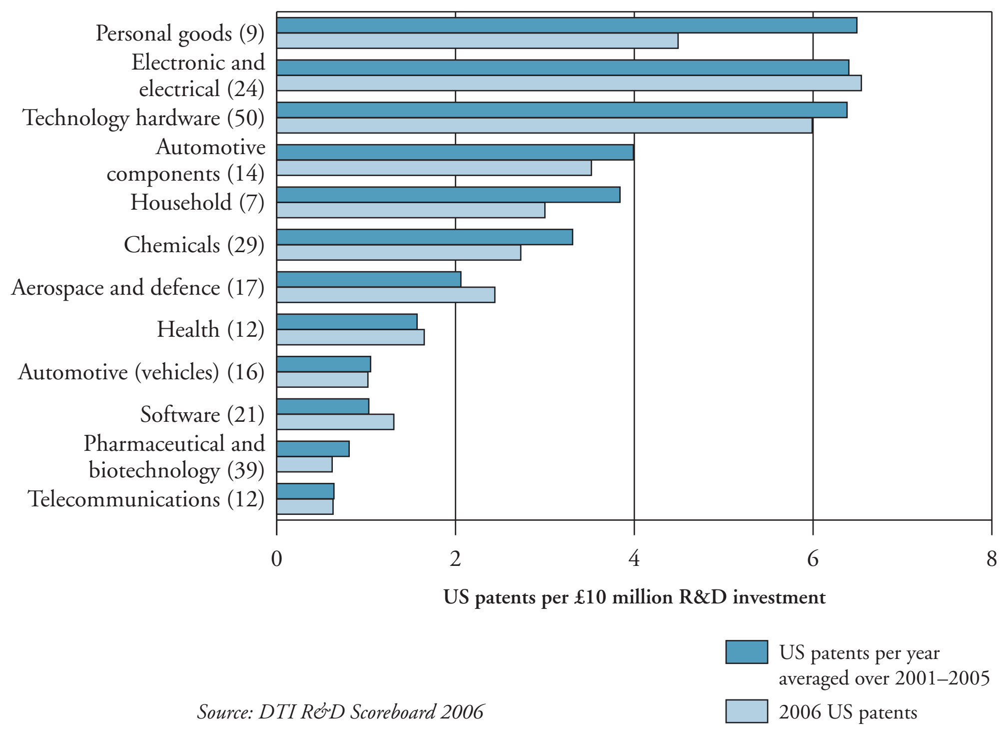
[14] High-technology manufacturing includes pharmaceuticals and office, computer and communications equipment.

[15] Sixteenth edition of the DTI annual *R&D Scoreboard* (available at www.innovation.gov.uk/rd_scoreboard). The *R&D Scoreboard* uses for its patents-to-R&D ratio same-year data for both number of patents granted and R&D investment.

2.37 In other sectors of the economy, such as financial services, publishing and electronic media, patenting may not be an appropriate means of protection, and alternative protection methods may be more suitable. The UK Innovation Survey shows that UK firms use a variety of methods to protect their innovations. Less formal methods (such as lead time advantage and secrecy) seem to be preferred to more formal methods (such as patenting), perhaps due to their lower cost and to the high proportion of service companies in the UK. While close to 30 per cent of engineering-based manufacturers use patents to protect their intellectual property (IP), fewer than 20 per cent of companies in knowledge-intensive services use the same tool.[16] A continuing sectoral shift towards high-value-added services would imply a shift away from formal IP protection devices; nonetheless, informal and strategic protection is important across all sectors.

2.38 These findings suggest that differences in patenting activity can be attributed to each country's relative economic specialisation: for example, countries specialising in areas including electronics and technology hardware (such as Japan) will tend to record much higher levels of patenting activity than countries strong in pharmaceuticals (such as the UK). Differences in legal systems also produce differences in patenting activity.

Chart 2.8: US patents per £10 million R&D investment



Source: DTI R&D Scoreboard 2006

[16] Data supplied by OSI.

TRENDS IN PUBLICLY FUNDED R&D

2.39 Table 2.3, based on departmental accounts, shows that – as a percentage of GDP – while the science base (Research Councils and HE research expenditure) has increased significantly in the past ten years, civil government spending fell in the last years for which there are figures, and is now lower than at the start of the decade. Defence R&D spending, as a percentage of GDP, has declined almost continuously.[17] Chapter 8 examines the causes and consequences of this in more detail.

Table 2.3: Public R&D spend as percentage of GDP, 1997–2005

	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06[18]
Science base	0.281	0.271	0.271	0.283	0.31	0.29	0.338	0.343	0.368
Civil departments	0.156	0.143	0.127	0.153	0.158	0.174	0.171	0.14	0.121
Defence	0.281	0.245	0.247	0.323	0.204	0.257	0.238	0.216	0.182
Total public R&D spend	**0.717**	**0.660**	**0.665**	**0.668**	**0.672**	**0.761**	**0.747**	**0.699**	**0.671**

2.40 Around three-quarters of the R&D performed in the public sector is self-funded by the public sector, and this proportion has remained steady since 1997,[19] as in France and Germany. However, there have been significant increases for the USA, Canada, Scandinavian nations, China and other Asian nations.[20] Table 2.4 shows that the amount of R&D in the UK performed in the public sector as a percentage of GDP is lower than the OECD average and other G7 countries.

Recommendation 2.1

The Review strongly recommends that the Government continues to fund increases in basic science in line with the Ten Year Science and Innovation Framework 2004–2014; that it increases the funding of the TSB; and that civil departments and the MOD are encouraged to seize the opportunities to improve their performance by raising the level of their R&D.

[17] DIUS figures, taken from *SET Statistics 2007*. Note that these are figures for expenditure by public sector, which will differ from performance. SET statistics for defence are net of monies received for research work MOD contracts in; this removes the impact of the Defence Evaluation and Research Agency (DERA) privatisation in 2001, which appears in the ONS expenditure figures.

[18] Estimated outturn.

[19] ONS GERD data.

[20] *PSA Target Metrics for the UK Research Base*, DTI, December 2005 (indicator 1.02).

Table 2.4: International comparisons for R&D performed in the public and private sectors, 2004, percentage of GDP

2004	Public sector	Private sector	Total
Canada	0.89	1.12	2.01
France	0.78	1.34	2.14
Germany	0.75	1.75	2.5
Italy	0.56	0.53	1.1
Japan	0.73	2.39	3.18
UK	**0.58**	**1.09**	**1.78**
USA	0.69	1.88	2.68
EU15	0.84	1.07	1.91[21]
Total OECD	0.66	1.53	2.25

Source: ONS data for UK, OECD data for all other countries

Research outputs arising from R&D performed in the public sector

2.41 The main research outputs from public sector R&D are additions to the stock of knowledge and the stock of skilled graduates and researchers. Chapter 7, on the supply of scientists and researchers, deals with skills; here, we briefly survey the measurable addition to the stock of knowledge made by public sector research.

2.42 The number of research papers published in journals and the number of subsequent citations of those papers are the two main indicators used to denote the scale and quality of research activity.

2.43 In 2005, the UK was ranked second in the world to the USA in its share of world publications (9 per cent) and world citations (13 per cent). The UK also produces a high proportion of the world's most influential papers relative to its share of all publications, producing over 13 per cent of the most cited 1 per cent of papers.[22]

2.44 A major strength of the UK's research base is that it produces a more consistent performance across the range of research disciplines than most other countries, ranking second in the world in seven of the ten disciplines. A summary of the UK's performance in each broad discipline category is given in Table 2.5.

[21] Calculated from figures in http://europa.eu/rapid/pressReleasesAction.do?reference=IP/02/939&format=HTML&aged=0&language=EN&guiLanguage=en

[22] *PSA Target Metrics for the UK Research Base,* DTI, March 2007, p. 27. Available at http://www.berr.gov.uk/files/file38817.pdf (accessed 11 July 2007).

Table 2.5: UK's world rank in citation share by discipline

Research field	World ranking in 2004	Trend in share of citations 2000–2004
Biological sciences	2	no change
Business	2	increase
Clinical sciences	2	no change
Environmental sciences	2	decrease
Humanities	2	increase
Pre-clinical and health-related sciences	2	no change
Social sciences	2	no change
Mathematics	3	decrease, but recovery in 2004
Physical sciences	4	no change
Engineering	4	decrease, but recovery in 2004

Source: PSA Target Metrics for the UK Research Base, DTI, December 2005 (indicator 3.02)

2.45 While the UK research base has performed extremely well in recent years, the trends in citation share for each discipline show the challenge of the growing shares of new research nations, including China, India, South Korea and Singapore. China has accelerated to a more than fourfold change in its share of world citations between 1995 and 2004, and although ranked eighteenth by volume in 1995, it now ranks eighth. China shows particular growth in mathematics, engineering and the physical sciences.[23]

2.46 The UK leads the G8 in research productivity, with far more citations from each pound spent on public sector R&D.[24] But can the UK continue to sustain its strong performance in the face of the growing strength of the new research nations?

2.47 Publications and citations may not be an equally good measure of research activity across all disciplines. In particular, the research activities of the humanities and social sciences extend to other modes of output. The Research Councils (RCs) produced their first year's set of baseline data in 2006 on their output frameworks, which includes data on each RC's contribution to the global knowledge pool. The data provide more detail on the breadth and scope of outputs of the research base other than publications, including conferences, performance and visual media outputs. Trends and patterns will emerge as additional years of data are collected.

[23] *PSA Target Metrics for the UK Research Base,* DTI, March 2007, p. 27. Available at http://www.berr.gov.uk/files/file38817.pdf (accessed 11 July 2007).

[24] *Science and Innovation Investment Framework 2004–2014: Progress Against Indicators,* DTI, July 2006.

2.48 These figures indicate clearly that our basic research base is an outstanding asset for this country. We must make certain that we continue to fund it properly and build on recent successes in transferring knowledge into industry.

Appraisal of the innovation ecosystem

2.49 The above figures show that UK industrial R&D is not seriously out of line with other economies, given our industrial structure. However, the trend in R&D spending by government departments is of concern, both in terms of public policy-making and the stimulation of innovation in the companies with which they interact. The figures suggest that, rather than seeking to raise the amount of research undertaken by all businesses, we should focus our efforts on the four major goals developed by the TSB:

- to help our leading sectors and businesses to maintain their position in the face of global competition;
- to stimulate those sectors and businesses with the capacity to be among the best in the world to fulfil their potential;
- to ensure that the emerging technologies of today become the growth sectors of tomorrow; and
- to combine all these elements in such a way that the UK becomes a centre for investment by world-leading companies.

2.50 But improving our innovation performance requires an assessment of all elements within the innovation ecosystem. If we want to raise the level of innovation in our industries to the highest level, each element of our innovation system must be functioning effectively.

INNOVATION IN MANUFACTURING AND SERVICES

2.51 The following chapters of this report look at the different elements of the innovation ecosystem. But first, two cross-cutting issues need to be considered: first, the extent to which innovation differs in the manufacturing and services sectors; and, second, what implications this has for public policy.

2.52 Since the 1950s, output and employment in the services sector have grown very quickly across the industrial world. As early as the 1970s, services constituted more than half of the value added in EU countries, and by the beginning of the new century this had grown to two-thirds. There are those who argue innovation in services is very different from that in manufacturing; in contrast to manufacturing, science and technology play a negligible role. Therefore, a radical new set of policies are needed to incentivise innovation in the services sector. These arguments need to be examined very carefully.

2.53 First, while we measure manufacturing and services separately in our national statistics, the line between them is blurred.[25] Software for an aeroplane produced by an aeroplane manufacturer is classified as manufacturing, but if it is outsourced to a computer services company it is classified as a service. Jet engine manufacturers such as Rolls-Royce no longer sell engines and spare parts, but propulsion services, because the value of services on a product through its lifespan can exceed original sales by as much as five times.[26] Evidence from the EU Community Innovation Survey suggests that around one-quarter of innovative manufacturers undertake service innovation, while about 40 per cent of retail and distribution innovators describe themselves primarily as goods innovators.[27]

2.54 Second, the most striking feature of the services sector is its wide range of different activities, each with different characteristics. The internationally agreed classification used in national accounts means that the services sector encompasses the whole economy except for manufacturing, construction, energy and utilities, and agriculture. The contrasts within the services sector are as significant as those between the sector and manufacturing. 'Services' includes everything from computer services and R&D contract services, through finance, insurance and real estate services to personal care and cleaning.

2.55 Some of these industries invest heavily in R&D. Of the UK's industrial R&D in 2005, 21 per cent was spent by the services sector.[28] The 2003 DTI analysis of company annual reports and accounts ranks IT services fifth among all industries in worldwide R&D spending in 2003, and sixth among UK industries in the same year. It is not correct to say that science and technology play no part in innovation in the services sector.

2.56 There is also no reason to think that "framework conditions" such as taxation, competition, regulation, public procurement and skills are any less important in manufacturing than in services. And while there may be more "hidden innovation" in the services sector – in the sense of innovation not caught by R&D statistics and patent data – there is no doubt a lot of "hidden innovation" in manufacturing.

2.57 Finally, the challenge for manufacturing and services is the same. In both cases, the challenge is to move out of low-value-added areas and into high-value-added areas. As a result of steadily increasing productivity in manufacturing, and the fact that as incomes rise, people spend a smaller proportion of their incomes on manufactured goods, the percentage of manufacturing in our GDP is likely to decline. Rather than accepting this downward trend, we should be asking ourselves how we can increase the amount of high-value-added manufacturing and take advantage of all the opportunities which exist to do more.

2.58 While innovation in manufacturing and services is more similar than is sometimes thought, the challenges for policy-makers are not the same. Much knowledge has been built up in the Department of Business, Enterprise and Regulatory Reform (DBERR) on how science and technology can contribute to innovation in manufacturing industries, and what framework conditions impact on the rate of innovation. The challenge is to use the knowledge to devise policies that enable industry to move more rapidly into higher value-added areas. In the service

[25] Crespi, G., Criscuolo, C., Haskel, J. and Hawkes, D., 'Measuring and Understanding Productivity in UK Market Services', *Oxford Review of Economic Policy*, 22:4, 2006.
[26] *Innovate America: National Innovation Initiative Summit and Report,* Council on Competitiveness, 2002.
[27] *Occasional Paper #9: Innovation in Services*, cited in DTI, June 2007, p. 3.
[28] ONS.

sector, that knowledge does not exist; the focus of the then-DTI's activities has been almost exclusively on the manufacturing sector. It is crucial that the DBERR makes the resources available to work effectively with the services sector. This will enable Government to devise policies which increase the sector's rate of innovation.

Identifying high value opportunities in manufacturing

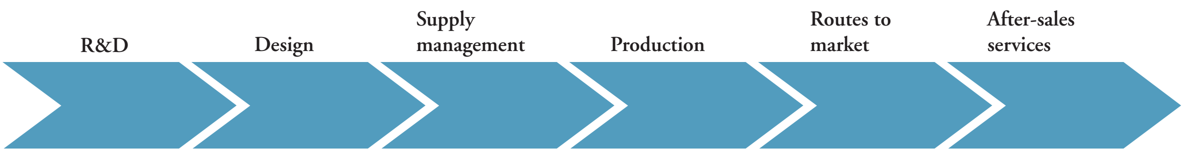
2.59 Manufacturing has been undergoing a major period of change in recent years, and if we are to seize the opportunities open to us as a country, we need to adopt a new approach.

2.60 Early manufacturing companies were typically vertically integrated, undertaking as many operations as possible on their own premises. As skills, capabilities and demand increased, subcontractors emerged who could supply parts, sub systems or services competitively. Typically, such subcontractors would develop long-standing relationships with their customers.

2.61 Over the past 20 years, these relatively stable arrangements have changed as competition and customer demand for greater variety have grown. These trends have been encouraged by the removal of trade barriers and falling costs of transportation, increasing the exposure of all manufacturers to global competition. Meanwhile, the reduction of cycle times for innovation has forced companies to adopt new models for product and service development. Manufacturing in the modern world is networked, global and fast.

2.62 In this environment, companies can focus on a single activity in the value chain. The electronics company Flextronics, for example, concentrates on production as a contract manufacturer. The pharmaceutical company GSK has strength in multiple activities, including R&D, production and distribution. BAE Systems, a defence company, has a co-ordinating role across the value chain as a systems integrator. Companies are adapting and engaging in one, some or all of the links in the value chain – from R&D through production to service provision – as shown in Figure 2.1.

Figure 2.1: Value chain of manufacturers



2.63 Company decisions about which activities to engage in (either in-house or outsourced) are complex. They are influenced by many factors, including the maturity and complexity of the product and its production processes, maturity of the sector and the history and ownership of the company. In each case, a deep understanding of the value chain and the links between activities provides significant advantage, as companies can tailor their activities to their capabilities and context.

2.64 Managing complex distributed value chains is demanding, especially in areas where technology is changing rapidly and relationships with suppliers and partners are shifting. The ability to manage these can be a significant competitive advantage.

2.65 Companies that can co-ordinate across the full value chain often have the opportunity to capture disproportionate value from their integration activities. Apple Computer undertakes product design and co-ordinates across the chain, including offering music downloads as a service. Their latest iPod video player has over 450 parts, with production outsourced to Japan, China and other Asian countries.[29] The chip that controls the player is sourced from the company PortalPlayer, which in turn licenses microcircuit designs from another company, ARM.

2.66 ARM is a successful UK microcircuit design company that licenses its designs to a network of partners. It does not have production facilities, but a very sophisticated knowledge of production processes and excellent links between design and the final user of the product. ARM's R&D processes are discussed in the box below.

Private sector R&D decisions – two case studies

ARM

ARM, based in Cambridge is the world's largest supplier of semiconductor IP. ARM-designed processors are installed in a range of electronic products, including mobile telephones, PDAs and MP3 players. Last year, 2.5 billion microprocesses were shipped. However, none are manufactured by ARM itself: the company uses a business model based on the open licensing of chip designs, leaving the processing and manufacturing of semiconductors entirely to other organisations.

This high level of outsourcing allows ARM and its partner companies to concentrate their resources and expertise on their core business. The company has 13 R&D centres worldwide, all of which were acquired by ARM as existing, successful research centres. The choice of research locations, given ARM's identified needs, was principally driven by the need to find scarce skills in chip design, and the ease with which existing operations could be integrated into ARM's corporate structure. For example, the Belgian company Adilante specialises in the hardware acceleration of algorithms. This was identified as a strategic area for ARM. A Scottish research centre specialising in the same field but of lower cost was also surveyed, but the choice of Adilante was made because it had a better previous record, with its technology already integrated into one existing product. Companies want the best people *and* the best deal. Cost alone does not determine research location.

Pfizer

Pfizer is the world's largest pharmaceutical company, and the biggest single inward investor in pharmaceutical R&D in the UK. The growing complexity of medical research has resulted in closer and more complex links between R&D and markets. The particular pressure in medical research is to deliver safe and reliable new drugs to market as speedily as possible, and so close integration of R&D with ancillary services, such as takes place in Pfizer's European R&D headquarters at Sandwich, Kent, is vital.

Like other pharmaceutical companies, Pfizer has started locating R&D facilities in emerging economies. Such economies offer both a growing scientific research base and expanding product markets. Pfizer opened R&D facilities in Shanghai in 2005, and has just announced a $300 million facility to be sited in South Korea. Location decisions are steered by a number of factors, but proximity to markets is especially important.

[29] *Who Captures the Value in a Global Innovation System? The Case of Apple's iPod*, Linden, G., Kraemer, L. and Dedrick, J., Personal Computing Industry Center working paper, June 2007.

2.67 In emerging industries, companies can capture significant value from production activities. As new industries emerge from the science base, production is typically more closely linked to R&D and involves higher skills and more sophisticated processes. Production in regenerative medicine, for example, involves a very advanced knowledge of biology coupled with sophisticated process and automation knowledge. The company Intercytex recently demonstrated significant developments in producing skin substitutes.

2.68 In industry sectors with intrinsically complex production processes, significant value can be captured from this stage of the value chain. In biopharmaceuticals, for example, there are very close linkages between development and production. In this industry, product performance is determined by the production process. The skills and sophisticated process technologies required make biopharmaceuticals a high-value production activity. It is also worth noting that regulators may require continuity from prototype development to production.[30]

2.69 The fact that production may allow the capture of value from new ideas can sometimes be overlooked – particularly where production is seen as a "standardised" or commodity activity. But early development of production capability may provide a more rapid and protectable route to market than outsourcing, and it avoids the risks of losing vital production knowledge and IP. These high-value production activities need to be clearly understood so that, where appropriate, support can be targeted to assist their development.

2.70 For high-cost economies such as the UK, the activities that are likely to thrive are those that by their nature are complex and high-value-adding, and those that act as a key part of a global value chain. Depending on the circumstances, these activities may include R&D, design, production or service: none should be ruled out when developing strategies and policies.

2.71 The need for a better understanding of the skills required to manage the design and operation of globally distributed, flexible value and supply chains is increasingly recognised. The Centre for Telecommunications Value Chain Research[31] in Dublin, for example, engages in research on new radio, optical and control technologies for telecommunications networks, but it also explores the ability to manufacture and construct such networks at affordable cost via modelling and analysing decision-support techniques across the entire value chain. This encompasses architectural design, through component realisation and production, to reliable network operation. The US National Science Foundation has also made several investments in this area – the Industry/University Cooperative Research Centre, for instance, and the Center for Engineering Logistics and Distribution.[32]

2.72 In the UK, the development of the EPSRC Innovative Manufacturing Research Centres (IMRCs) has provided an important national research resource, encouraging an integrated approach to manufacturing. Their "Grand Challenges" address key issues across the manufacturing value chain, from new production methods (regenerative medicine and 3D miniature products), through design (immortal information[33]), to innovation and productivity. The two pilot EPSRC Integrated Knowledge Communities (IKCs) offer the potential to map the evolution of specific technologies to better understand the links between fundamental science, applied science, process development and business-model development. There is still a need, however, for a better understanding of global value chain design and management.

[30] For a case study discussion of R&D-manufacturing interdependencies in the pharmaceutical industry, see *When Does Co-location of Manufacturing and R&D Matter?*, Ketokivi, M., 2006.

[31] For more details see www.ctvr.ie

[32] Further detail can be accessed at www.nsf.gov/eng/iip/iucrc/directory/celdi.jsp

[33] This refers to information that remains accessible and usable over at least the duration of a long-term project.

Recommendation 2.2

Research into the structure and dynamics of value chains should be supported across the Research Councils. The capability to integrate stages globally may be a major opportunity for the UK to draw on its traditional strengths in innovation and its international outlook.

Recommendation 2.3

Flexible integrated mechanisms such as the IKCs and IMRCs should be deepened and strengthened, as they help to match developments in products and services with developments in science and technology.

Recommendation 2.4

The Technology Strategy Board should work with the Research Councils to identify the complex, high-value-added production technologies that current and emerging industries require and which are likely to flourish in high-cost economies. Research and the development of skills in these technologies can then position the UK to be a leader in these fields.

Identifying high-value opportunities in services

2.73 A number of recently published reports have demonstrated the volume of "hidden innovation" that takes place in the service sector. Hidden innovation is defined as forms of innovation not captured in traditional measures, such as patenting. Innovation in tangible products is probably easier to recognise because of its physical and 'codifiable' nature, but there are many examples of services innovation. Two are described below.

Oil and gas

2.74 Innovation in oil production frequently depends on collaboration between production and service companies to develop new technologies and techniques for exploration. This is especially true for the more difficult conditions found in mature (already developed) and in frontier (difficult to develop) fields.[34]

2.75 Two examples of important innovations are nuclear magnetic resonance (NMR) measurement and four-dimensional seismic surveys, both of which reduce exploration costs and optimise production from wells.

2.76 Following some initial research in the oil sector, the full potential of NMR was recognised by a team of US medical researchers. It was then developed in collaboration with teams from both oil-service and production companies.

2.77 Due to the requirement for expertise from many fields, including geology, engineering and data processing and analysis, four-dimensional seismic surveys (three dimensions plus time) were developed through partnership between production companies and highly specialised supplier companies.

[34] See *Hidden Innovation*, NESTA, 2007.

Financial services 2.78 Many banks now offer a whole range of services online, facilitated by information and communications technology (ICT). A recent development has been Open Plan, a process/business model innovation introduced by the Woolwich that enables customers to access and link all their financial holdings (savings and current accounts, mortgage, etc.). through one portal. Open Plan customers can use both traditional methods of communication, such as branches and automated teller machines, and new channels, such as telephone call centres, internet and digital television.[35]

2.79 Instead of seeking to develop a new set of policies to incentivise innovation in the services sector, the DIUS is focusing its efforts on applying its current policy initiatives more effectively to the sector. This Review welcomes this approach. The following actions are being taken by the Government:

- The former DTI's Business Relationship Section is being reorganised so that there is a unit specifically covering the services sector within the Department for Business, Enterprise and Regulatory Reform (DBERR);
- The terms of reference of the new TSB have been amended to make it clear that it covers technology issues in the services sector as well as in manufacturing;
- The TSB is running a series of workshops in particular service sectors considering service innovations. These events will cover financial services, retail and logistics, design services, the service "wraparound", and manufacturing and environmental services;
- The TSB will set up a business-led Knowledge Transfer Network (KTN) for the creative industries. It will be established along the lines of existing KTNs, but how it engages, the services it offers and the models of attending, accessing and networking will be geared to the specific needs of creative businesses; and
- Five industry-led action groups will be set up by DBERR in the services sector to identify innovation in them and share the lessons of the UK's best. The groups are being developed in partnership with NESTA, with the first looking at the retail sector in partnership with the British Retail Consortium. Other areas being considered with industry include transport logistics, business services, environmental services and the construction industries.

2.80 It is difficult to measure innovation in the services sector, and due to differences between the industries that make up the sector it is difficult to develop policies to stimulate it. No country has yet found a way of doing so. The approaches taken by DIUS and DBERR, in this Review's opinion, offer a practical and effective way of tackling this difficult policy area.

Universities in the knowledge economy

2.81 The second of the two cross-cutting issues is the role of universities in the new knowledge economy. Today, we are seeing a transformation in the purpose and self-image of universities. Politicians, industrialists and economists are beginning to see universities as major agents of economic growth as well as creators of knowledge, developers of young minds and transmitters of culture.[36] The change in the purpose and self-image of the university has been driven by the concept of the knowledge economy, an economy in which ideas and the ability to manipulate them are of more importance that the traditional factors of production. In this economy, a world-class university looks an increasingly useful asset.

[35] Occasional Paper #9: Innovation in Service, DTI, 2007.

[36] See, for example, *Academic Capitalism: Politics, Policies and the Entrepreneurial University*, Slaughter, S. and Leslie, L., 1999.

2.82 The UK is well-supplied with world-class universities. The USA leads the way, but the UK is in a good position, particularly in comparison with other major European countries. Shanghai's Jia Tong University, in its 2005 rankings of world universities, has 36 USA universities in the top 50 and just 9 from Europe, of which 5 are in the UK. According to its rating system, the only two universities in the top ten that are not American are Cambridge and Oxford: a recent Times Higher Education Supplement league table included 20 American universities in the top 50, with 13 from Europe, of which 8 were from the UK.

Table 2.6: The world's top ten universities

	Country	Global rank
Harvard	USA	1
Cambridge	UK	2
Stanford	USA	3
Berkeley California	USA	4
Massachusetts Institute Technology	USA	5
California Institute Technology	USA	6
Columbia	USA	7
Princeton	USA	8
Chicago	USA	9
Oxford	UK	10

Source: Jia Tong University

2.83 We should, however, guard against a situation where all our universities aim for the same goals. What is required is a diversity of excellence, with research universities focusing on curiosity-driven research, teaching and knowledge transfer, and business-facing universities focusing on the equally important economic mission of professional teaching, user-driven research, and problem-solving with local and regional companies (see case study below).

2.84 Both types of university should carry out all three activities – research, teaching and knowledge transfer – but the way they perform them will be very different. We should not waste time debating whether one type of economic mission is superior to the other, but should accept that both types of economic mission are equally important – and that some students will be attracted by one type of educational experience, and some students by the other.

2.85 This Review makes two important recommendations to improve the incentives for business-facing universities to undertake more knowledge transfer, as we see a major economic opportunity for them to do so. These incentives cover the use of extra Higher Education Innovation Funds and an increased number of Knowledge Transfer Partnerships.

A business-facing university – University of Hertfordshire

The University of Hertfordshire aims: "to be recognised as a new model of a university through far-reaching engagement with business, community and international partners, shaping the future success of their graduates operating in the global environment, and advancing the prosperity of their region".

The university encourages a constant interchange between business, academics and students. Many university staff members spend a proportion of their time working in industry, running their own businesses, keeping their knowledge up to date and helping to develop students' business skills. The university's business-facing activities include:

Business Link Merger

In 2005, the University merged with Exemplas, Hertfordshire's Business Link, creating new links with a network of 50,000 local businesses, mostly SMEs. Survey results since the merger show an increase in satisfaction from business clients and many examples of clients gaining from the increased access to university expertise. Other positive impacts include: an increase in applied research (more than 20 KTPs); growth in professional development programmes; more students working in business as part of their studies; and an increase in graduate employment skills.

Entrepreneurship

The University directly supports entrepreneurial activity through their Innovation Centre, which provides office space and access to university expertise to start-up and established SMEs, including graduate and academic entrepreneurs.

Business experience for undergraduates

Students with business experience have better employment prospects than those who don't.[37] The University provides short placements, long placements, internships, and overseas work experience.

World-class research facilities: BioPark Hertfordshire

In 2006, with support from the East of England Development Agency, the University acquired the former Roche Products pharmaceutical research facilities in Welwyn Garden City – 80,000 ft^2 of state-of-the-art laboratories, offices and meeting facilities. BioPark is dedicated to assisting businesses in the bioscience and health-technology sector to grow, including spin-outs from the university and spin-in companies taking advantage of the technical and business support expertise. There are currently two spin-out companies based on research undertaken in the university, in the fields of infectious disease diagnostics and biosensors, that intend to take up residence at BioPark. All tenants have access to the university's significant information resources and knowledge base. Some of the business researchers will become visiting Professors and Fellows of the University; research students will support these enterprises, and other students will gain from work experience in the laboratories and offices, improving their employment prospects and providing invaluable expertise to business.

[37] 'Employing graduates', YouGov survey commissioned by University of Hertfordshire, July 2006.

3 Technology Strategy Board

3.1 The Technology Strategy Board (TSB) was established in October 2004 to manage the main technology programmes of the then-Department of Trade and Industry (DTI), following a commitment in the DTI's Innovation Report of 2003. The TSB is made up largely of business people and venture capitalists. Its vision is:

> *For the UK to be seen as a global leader in innovation and a magnet for technology-intensive companies, where new technology is applied rapidly and effectively to wealth creation.*

3.2 Over its first two years the TSB has made good progress, and in the March 2006 Budget Report it was announced that the TSB would be given a greater role in stimulating business innovation, and that plans for it to operate at arm's length from government should be developed.

3.3 The progress to date and the creation of the TSB as an executive non-departmental public body (NDPB) in July 2007 represents an important opportunity to put in place a business-driven organisation with the potential to make a significant difference to the UK's innovation performance. The establishment of the new TSB will improve strategic focus, the ability to recruit people with industrial skills, and consistency and coherence in the delivery of the Government's agenda in the area of technology and innovation.

THE CURRENT ACTIVITIES OF THE TSB

3.4 The strategy of the TSB has four major goals:

- to help our leading sectors and businesses to maintain their position in the face of global competition;
- to stimulate those sectors and businesses with the capacity to be among the best in the world to fulfil their potential;
- to ensure that the emerging technologies of today become the growth sectors of tomorrow; and
- to combine all these elements in such a way that the UK becomes a centre for investment by world-leading companies.

This strategy is delivered through four main programmes: user-driven collaborative R&D, Knowledge Transfer Networks (KTN), Innovation Platforms and Emerging Technologies.

3.5 The programme of user-driven collaborative R&D is achieved through open competitions for funding held every six months. The projects supported are part funded by government and bring together businesses and universities and other research partners to carry out research with a future commercial goal. The competitions to date have been highly successful, with more projects capable of being funded than the available budget. An average of one in six applications are approved for funding.

3.6 Over 600 user-driven collaborative R&D projects have already been approved for funding, ranging from £3,000 to £95 million. There is an average of five partner organisations per funded project, with small companies making up over a third of the organisations involved. The 600 projects already approved for funding represent over £900 million of R&D investment by government and business, with £465 million being committed by business and £435 million being committed by government.

3.7 The funding committed by government is not only an investment by the Department for Innovation, Universities and Skills (DIUS), but by a range of government organisations which includes the Research Councils (RCs), Department for Environment, Food and Rural Affairs (DEFRA), Department for Transport (DfT) and the Ministry of Defence (MOD), and the Regional Development Agencies (RDAs) and Devolved Administrations (DAs). The money from the RDAs and DAs has gone on three large projects related to aerospace: the Environmentally Friendly Engine; Autonomous Systems Technology Related Airborne Evaluation and Assessment (ASTRAEA), and the Integrated Wing.

3.8 Funded projects cover a diverse range of areas. These include: a project researching biodegradable plastics for future cars and boats; a project to develop an on-plastic organic light-emitting diode solid state lighting system geared toward the flat panel display market; a project to produce software for a visualisation and simulation of complex manufacturing systems featuring technology transferred from the serious computer games industry; and a project to develop an in-body microgenerator that will convert energy from human body movement into power for implanted medical devices, such as pacemakers, electrical stimulators, instrumented joints and body area network applications.

3.9 The second major programme through which the TSB delivers its strategy is KTNs. Each network is established in a specific field of technology or business application and brings together a variety of organisations such as businesses (suppliers and customers), universities, research and technology organisations and the finance community to enable the exchange of knowledge and the stimulation of innovation in the network.

3.10 The purpose of the KTNs is to improve the UK's innovation performance by increasing the breadth and depth of the knowledge transfer into UK-based businesses and by accelerating the rate at which this process occurs. Businesses and academics that join a KTN thereby gain access to the very latest developments and marketing opportunities in the area of technology covered by the KTN. They will be signposted to the very best UK scientific and manufacturing facilities available to research and apply new developments and to the best places to find funding.

3.11 Each KTN also provides a platform from which a coherent business voice can inform government policy. KTNs provide comprehensive inputs to the technology strategy of the TSB, including an assessment of UK science strengths and business needs. They also provide input on the UK's priorities in the EU Framework Programme and its benefit to businesses.

3.12 There are currently 22 KTNs (with a further two in the pipeline):

- Aerospace and Defence
- bioProcess UK
- Bioscience for Business
- Chemistry Innovation
- Cyber Security
- Electronics
- Electronics-enabled Products
- Food Processing
- Grid Computing Now!
- Healthcare Technologies
- Industrial Mathematics
- innovITS (intelligent transport systems)
- Integrated Pollution Management
- Location and Timing
- Low Carbon and Fuel Cell Technologies
- Materials
- MNT (micro and nanotechnology)
- Modern Built Environment
- Photonics
- Resource Efficiency
- Sensors
- UK Display and Lighting.

Being developed:

- Creative Industries
- Digital communications.

3.13 The third major programme of the TSB is the Innovation Platforms. By bringing together organisations focused on a particular social challenge, an Innovation Platform enables the integration of a range of technologies along with better co-ordination of policy, regulations, standards and procurement. Making future public procurement opportunities more visible to business provides a greater incentive to business to invest in R&D with the knowledge and confidence of future market opportunities. The aim is to deliver a step-change in UK innovation performance, in the quality of public services and in the ability of UK businesses to provide solutions for the global market-place. The TSB has piloted the Innovation Platform concept in two areas, Intelligent Transport Systems and Services, (ITS) and Network Security, investing an initial £10 million in each one. A further three Innovation Platforms have been approved in principle by the TSB: Assisted Living, Low Impact Buildings and Low Carbon Vehicles.

3.14 ITS represent a major opportunity for UK business, both in terms of new market opportunities and also in reducing congestion, estimated by the Confederation of British Industry (CBI) to cost the UK up to £20 billion per year. Most of the building-block technologies are already available, but there is a large scope for longer-term technological innovation to produce higher performance, greater reliability, lower costs and smaller devices. ITS will also generate revenue from a whole new range of services, such as location-based consumer lifestyle services and the needs of vehicle fleet managers, particularly the retail logistics chain. The market for ITS is global, and demonstrating success in one of the most congested parts of the world should provide the ideal stepping stone for UK companies to this wider market.

3.15 The ITS has articulated the "Innovation Challenges" that need to be met by holding of a number of workshops with businesses in co-operation with a number of KTNs, including innovITS, Location and Timing and Industrial Mathematics. A joint DIUS, Engineering and Physical Sciences Research Council (EPSRC) and DfT Future Integrated Transport Systems competition was launched in October 2006, with each organisation committing £3 million, and a further competition in the area of road pricing was announced in May between DfT and DIUS. Further calls, co-ordinated via the Innovation Platform, are expected.

3.16 The Network Security Innovation Platform (NSIP) is another important project. Government departments are major prospective users/purchasers of secure networks, including identity cards, e-borders and MOD's networking of assets. Additionally, there are significant secure identity requirements in global supply chains where sensitive data are being exchanged, such as banking and financial services and the retail sector. As electronic networks increasingly become critical to society, so network security is seen as being a major growth area and one which the UK is well-placed to exploit.

3.17 The NSIP is taking forward two initial challenges, and is working on defining further challenges and identifying the necessary actions needed to bring government procurement and innovative business solutions closer together. The NSIP launched the Human Vulnerabilities in Network Security competition in November 2006 aimed at encouraging technological and socio-technical innovation in establishing effective security cultures and employee risk assessments, as the weakest link in any secure network is often the person using it.

3.18 The fourth major programme of the TSB is Emerging Technologies. The TSB has been working closely with the RCs on emerging technologies to foster business engagement with new technologies emerging from the UK science base at the earliest "business readiness" stage. The first three areas have been identified, and work is moving ahead in quantum technologies, nanomedicine and smart optics.

3.19 In each case, businesses and leading academics are being asked, primarily via workshops, what support might be appropriate. An action plan will then be drawn up, and support will be given in a variety of ways, such as collaborative R&D competitions, user forums, technology showcasing (which provides academics with opportunities to "pitch" their research and its potential to business), development of standards strategies, assessments of global market potential and consolidation of existing activities.

A NEW LEADERSHIP ROLE

3.20 The technology and innovation landscape in the UK is fragmented, with a wide range of organisations aiming to improve the technology and innovation capability of UK business. This is inefficient and means that industry is faced with a bewildering array of organisations and schemes, many of which cover the same ground. In many cases these organisations do not have the resources or the skills to develop or assess technological projects.

3.21 DIUS will set innovation policy and direction, but the TSB has a critical role in helping to achieve these policy objectives. To do so, the TSB needs to improve the fragmentation of innovation support.

3.22 The TSB has already made some good progress in working with government departments, RDAs, DAs and RCs, as well as with business. There has been good engagement with government departments on Innovation Platforms, the collaborative R&D competitions and KTNs, and DEFRA, through its BREW (Business Resource Efficiency and Waste) programme has committed £35 million to date to support collaborative R&D projects and two KTNs.

3.23 The seven RCs, operating through Research Councils UK, have worked closely with the TSB, providing vital information on the strengths of the UK science base and using that knowledge to develop the collaborative R&D competitions.

3.24 The RCs also play a key role in supporting academic participation in collaborative R&D projects that demonstrate significant scientific merit. Over the past year, both the Natural Environment Research Council and the Medical Research Council have joined the EPSRC and the Biotechnology and Biological Sciences Research Council in funding projects as part of the collaborative R&D competitions. To date, approximately £26 million has been committed to projects across a wide range of the competitions held. The development of joint application and assessment procedures between the DIUS and the RCs has been a step in the right direction.

3.25 Good progress has also been made over the past year in developing strong links between the TSB and the nine English regions and three DAs. Representation on the TSB by one member from each English Region and one from each DA ensures that the regional perspective is factored in to all strategic decisions made by the TSB. Work is also continuing to simplify the process of bringing regional funding into the programme of collaborative R&D. To date, the RDAs and DAs have committed over £30 million in support of three large aerospace-related projects. But this Review believes there is more to be done.

Recommendation 3.1

The TSB should be given a new leadership role, with more formal relationships with the RDAs, government departments and Research Councils.

3.26 The precise way that these relationships should operate is set out in Chapter 9 for the RDAs and DAs, in Chapter 4 for the Research Councils, and in Chapter 8 for government departments.

3.27 There are two other areas where it is recommended that action be taken by the TSB to better co-ordinate the activities of the different organisations that have an impact on the UK's innovation performance.

Recommendation 3.2

One of the Chief Scientific Advisors (CSA) should be actively involved with the TSB, attending regular meetings. This should typically be the CSA of the Ministry of Defence, given the size of the department's R&D budget, but he/she would also represent views from other CSAs.

Recommendation 3.3

Regulators should be involved from an early stage in Innovation Platforms, so that they better understand the impact of their regulations on innovation, and can bring valuable knowledge to the members of the Innovation Platforms. Early indications suggest that regulators would be keen to do so.

3.28 Ofcom, for example, is carrying out research into remote monitoring which is of relevance to the Assisted Living Platform, and into wireless applications which is of relevance to the ITS and Services Platform.

3.29 KTNs have already produced a considerable number of technology road maps for emerging technologies. These road maps give a consensus picture of future technology developments and market needs. They enable companies to focus their research efforts where they will have most value, and they also predict the need for highly trained people, standards and metrology.

Technology road maps

Technology road mapping is now widely used at company, sector and national levels to align research investments and other actions with goals and policies. It was originally developed by Motorola in the 1970s, and Bob Galvin, who was CEO of Motorola during the period when road mapping was established, defined it as "an extended look at the future of a chosen field of enquiry composed from the collective knowledge and imagination of the brightest drivers of change in the field".

Typically, a technology road map comprises a chart on which information is captured about the functions and perspectives of an organisation against an agreed time-line. In a company, for example, these might be markets, products, technologies and resources. It is, among other things, a good way of balancing "market pull' and "technology push".

The Foresight Vehicle programme, administered by the UK Society of Motor Manufacturers and Traders (SMMT) with support from the then-DTI, undertook a major technology roadmapping initiative in 2002, with the aim of both identifying the technology areas that would benefit from support and building up the network of organisations involved. The widespread support for and commitment to roadmapping across the industry demonstrates the success of the initiative. The SMMT commissioned an update in 2004 and is currently planning a third round.

Recommendation 3.4

TSB should encourage the production of technology road maps by all fast-growth, high-tech industries as a way to raise their level of innovation and to align technology capability with consumer demand.

NEW RESPONSIBILITIES FOR THE TSB

3.30 This Review understands the challenge for the TSB of turning itself into an Executive NDPB, recruiting new personnel and relocating much of its work. We recognise the importance of not overloading it with new responsibilities and diluting its core mission. However, this Review recommends that there are a few additional tasks that the TSB should take on. We support the decision to give the management of the KTP programme to the TSB, which fits in well with its suite of business-support products, and think a mini KTP scheme should be developed, subject to the Business Support Simplification Programme (BSSP).

Recommendation 3.5

A flexible, short-term Knowledge Transfer Partnership (KTP) scheme should be developed and KTPs extended more widely into the further education sector, as described in Chapter 4.

3.31 To date, the TSB has focused on driving forward technological innovation in traditional manufacturing sectors. As we have seen, however, service sectors where technological innovation is important are now significant and fast-growing parts of our economy.

Recommendation 3.6

The TSB's activities should be extended into those service sectors where technological innovation is important. The TSB has already started work with the creative industries and there is considerable scope for it to extend its work to other areas.

3.32 The RDAs, government departments, UK Trade and Investment (UKTI) and the RCs all need to know about the part played by technology in the competitive strategies of different industries so that they can target their support more effectively. There is a danger that the collection of this information through the use of consultants or discussions with industry is duplicated by the different organisations. This is wasteful of resources and of company time. The TSB has to collect this information in order to support its collaborative R&D programmes and to prevent the duplication of this work.

Recommendation 3.7

The TSB should be made the repository for information about technology's role in the competitive strategies of different industries and should be responsible for providing this when it is needed by other organisations.

3.33 Those responsible for approving government support programmes for collaborative research and development need to have a deep understanding of commercial issues, business planning, the value chain and the linkages between activities in order to ensure business models and routes to market have been fully considered as part of the project approval process. The DIUS has generally reviewed proposals with the assistance of an expert panel of science and engineering reviewers supported by DIUS staff acting as a secretariat. This model, while selecting projects with merit, does not allow for the secondary benefits to be derived from the application and selection process.

3.34 For example, companies who apply to the Advanced Technology Program (ATP) in the USA are judged both on the scientific/technical strength of their application and also on their business plan for taking their technology forward. An essential element of the ATP is the highly qualified staff running the programme, many of whom have business backgrounds and qualifications. This means that they are well-placed to manage the review of both the commercialisation potential and associated business plan of each technology proposal.

Approximately 88 per cent of ATP applications are not funded, and yet each applicant receives one hour of feedback from the programme staff regarding the strengths and weaknesses of their application in both technical and business terms. This feedback is valuable to the companies as it assists them in developing their strategies for raising funds, developing the technology and strengthening any future proposals.

3.35 The restructuring of the TSB provides an opportunity to develop a new cadre of very high-quality professionals to manage the application evaluation process and to substantially improve the performance of funded proposals.

Recommendation 3.8

The process of evaluation for support from the TSB should cover both the technical and business merit. The backgrounds of evaluators within the TSB should be expanded to include technical specialists with strong commercial backgrounds. As in the Defence Advanced Research Projects Agency (DARPA), a proportion of staff in the TSB should be secondees from industry or academia, with an emphasis on selecting high-calibre candidates whose careers will be enhanced by spending two to four years in the TSB.

3.36 The preliminary focus of the TSB has been on domestic support for technological innovation. There is, however, a need for the TSB to start to consider the international agenda and to give greater support to technological collaboration between UK small and medium-sized enterprises (SMEs) and their counterparts in Europe.

Recommendation 3.9

The TSB should take over support for the Eureka programme from DIUS, and offer advice and guidance on Framework Programme 7 to encourage more UK businesses to take advantage of the significant European research funds available. (See Chapter 10 on Global Collaboration.)

4 Knowledge transfer

FROM THE LABORATORY TO THE MARKET

4.1 In the past decade UK performance in knowledge transfer has changed dramatically. As the *Financial Times* reported: "Policymakers and commentators love to draw unflattering comparisons between enterprising US universities churning out commercially exploitable inventions and UK ivory towers that are content to leave research mouldering on library shelves. But the days when critics could bemoan the country's failure to cash in on its world-class research base may be drawing to a close".[1]

4.2 A number of government schemes have been introduced over the past ten years, and these appear to have produced a major culture change within our universities, building capacity, increasing professionalism and making higher education institutions (HEIs) more valuable partners for business. The schemes include: The University Challenge Fund, which provided seed funds to universities; Science Enterprise Centres, to teach entrepreneurial skills to science and engineering undergraduates and graduates; and the Higher Education Innovation Fund (HEIF), to incentivise universities to transfer knowledge into industry and society.

4.3 By almost all measures, we have seen a dramatic increase in recent years in the amount of knowledge transfer from British universities (see Table 4.1 and boxes below).

Table 4.1: Selected indicators 2000–01 to 2005–06

Knowledge transfer indicator	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	Percentage change 2001–02 to 2005–06
Number of new patent applications filed by HEIs	896	960	1,222	1,308	1,649	1,537	72
Number of patents granted	250	198	377	463	711	576	130
Number of licensing agreements	728	615	758	2,256*	2,099	2,699	271
Income from licensing intellectual property (£ million)	18	47	37	38	57	58	215
Number of spin-outs	248	213	197	161	148	187	–25
Income from business (value of consultancy contracts) (£ million)	104	122	168	211	219	236	128

** From 2003–04 onwards more HEIs included software licences.*
Source: Higher Education–Business and Community Interaction

[1] *Financial Times*, 27 June 2006.

4.4 Limited data are available before 2000–01 as many HEIs did not monitor or record knowledge transfer performance until then. But between 1994 and 1999 a total of 338 spin-outs were recorded (an average of 70 per annum). By 2005–06, 187 companies spun out of universities in just one year. As shown in Table 4.1, the number of spin-outs fell in 2003–04. This was due to changes in tax law,[2] which inadvertently acted as a disincentive to HEI spin-outs by creating a tax liability for investors setting up spin-outs at the point when shares were issued to them. The tax law has now been altered and the number of spin-outs is starting to rise again.

4.5 University spin-outs enjoy faster growth and lower failure rates than more conventional start-ups.[3] The total turnover of all active university spin-outs has increased by 240 per cent since 2000–01, and in the past three years 25 spin-outs from UK universities have floated on stock exchanges. These companies raised over £250 million from the capital markets at the initial public offering stage and today have a market capitalisation of more than £1.5 billion. In the past 18 months, six spin-outs have been acquired for £1.8 billion.[4]

Recent examples of knowledge transfer activities

- Formed by the global insurance broker Willis Group Holdings, the Willis Research Network (WRN) is the largest single collaboration between the insurance industry and academia. It offers governments and large organisations access to weather and environmental modelling expertise. This will provide practical research and expert analysis of global catastrophic risks, such as volcanoes, landslides, floods, hurricanes and earthquakes.
- Wolfson Microelectronics plc was spun out of Edinburgh University in 1984 and went public in 2002. It is a global leader in the supply of high-performance microchips. Wolfson's chips are found in PDAs and digital music players, most notably the Apple iPod.
- The Medical Research Council (MRC) will receive over $200 million in licence fees from pharmaceutical company Abbott for rights to market HUMIRA, a treatment for rheumatoid arthritis developed at the MRC Laboratory of Molecular Biology in Cambridge.
- Originally formed in 2002 with venture capital funding, Offshore Hydrocarbon Mapping Ltd grew out of research at the UK's National Oceanography Centre, Southampton, and is world leader in controlled source electromagnetic (CSEM) surveying, data processing and data interpretation for the offshore oil industry. CSEM is increasingly being recognised as a valuable method of de-risking the oil and gas exploration process and creating multimillion pound value for clients.
- The internationally acclaimed Advanced Manufacturing Research Centre (AMRC) at the University of Sheffield, a partnership with Boeing, is a £45 million collaboration between world leaders in the aerospace supply chain, government and international academic institutions. As manufacturers switch from metals to composite materials, it will be critical to accelerate the introduction of materials and processes while reducing costs. The AMRC is meeting this challenge by creating a £15 million Composite and Advanced Materials Technology Centre (CAMTeC).

[2] Part 7, Income Tax Earnings and Pensions Act 2003 (Schedule 22).
[3] "University Companies Pass Investment Test", *Financial Times*, 29 June 2006.
[4] Cambridge, Antibody Technology; NeuTech; Kudos Pharma; Solexa; Domantis; MTEM. Source: Unico.

Progress since the Lambert Review

The Lambert Review, commissioned by HM Treasury, the then-Department for Education and Skills (DfES) and the then-Department of Trade and Industry in November 2002, made a series of recommendations aimed at encouraging effective business–university collaboration in the UK.

Since Richard Lambert reported in 2003, this agenda has become increasingly important as our future international competitiveness rests more than ever on the development, dissemination and application of knowledge and ideas.[5] The Council for Industry and Higher Education (CIHE) report *Industrial Competitiveness: Businesses Working with UK Universities* provides evidence to show that clusters of excellence with universities at their core are increasingly attracting multinational businesses who are seeking to recruit, to invest in research, and to find solutions to the business product, process and management issues they face.

Capacity and infrastructure in universities for business collaboration has continued to improve. Virtually all HEIs now have systems in place to engage with business and the benefits to the higher education (HE) sector have been tangible (see Table 4.1). For businesses and others, the real impacts are less easy to quantify, as they will be seen in the innovative new products, services, business models and policies that result from this engagement. (Table 4.1 shows the increase in the numbers of patents granted.) Over one-third of representatives on HEI governing bodies now come from commercial businesses.

There has been progress with many of Lambert's recommendations. Highlights include:

- the code of governance developed and adopted by universities;
- the development of a dedicated "third stream" of funding in England (the HEIF);
- the R&D tax credit is now worth over £600 million per year to business;
- guidance material and model contracts have been developed to cover intellectual property issues in five different collaborative and contract research scenarios, and these are now being used by a wide range of firms and universities; a further set of model agreements covering consortia arrangements is under development;
- the Higher Education Funding Council England (HEFCE) has announced that £60 million of the QR scheme will be used to reward applied research;
- UK technology-transfer organisations have developed close links with their US counterpart, the Association of University Technology Managers (AUTM); and
- Regional Development Agencies (RDAs) and the Devolved Administrations are taking an increased role in facilitating business–university links (see Chapter 10).

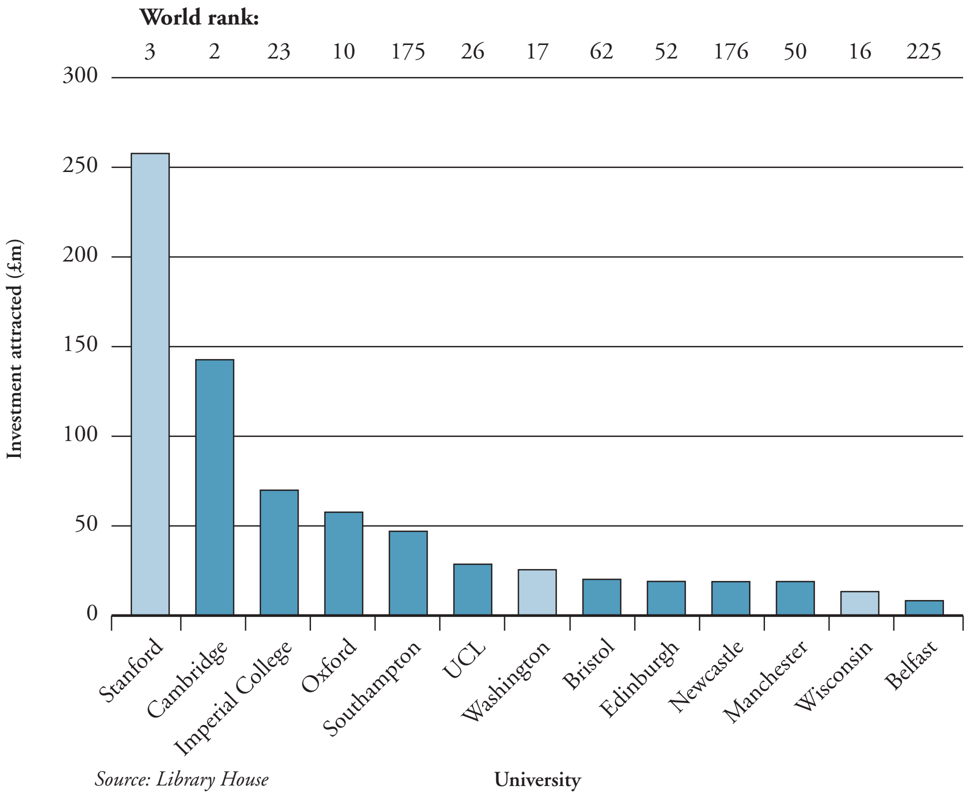
Another positive development (although not a specific recommendation) is the launch of the new Institute for Knowledge Transfer (IKT) in May this year, providing a focus to improve the quality of knowledge transfer professionals across the UK and to bring university, business and government KT professionals together.

[5] "What has changed since the Lambert Review?", a submission for the Review from the Council for Industry and Higher Education (CIHE), November 2006.

EXTERNAL INVESTMENT PER UNIVERSITY

4.6 A recent report by Library House concludes: "UK universities are now producing spin-out companies of equivalent number and quality to some of the USA's top institutions".[6] The report compared the spin-out portfolios of a cross-section of UK universities with those of three top US institutes: Stanford University, University of Wisconsin (the world's sixteenth best research university[7] that has a technology transfer operation dating back to 1925), and University of Washington (the world's seventeenth best research university,[8] located in a state that receives more than four times the venture capital finance per head as the UK). Using external investment attracted as a proxy for quality, Stanford University came out top, but most of the UK universities performed well against the other two US institutes (Chart 4.1).

Chart 4.1: External investment per university

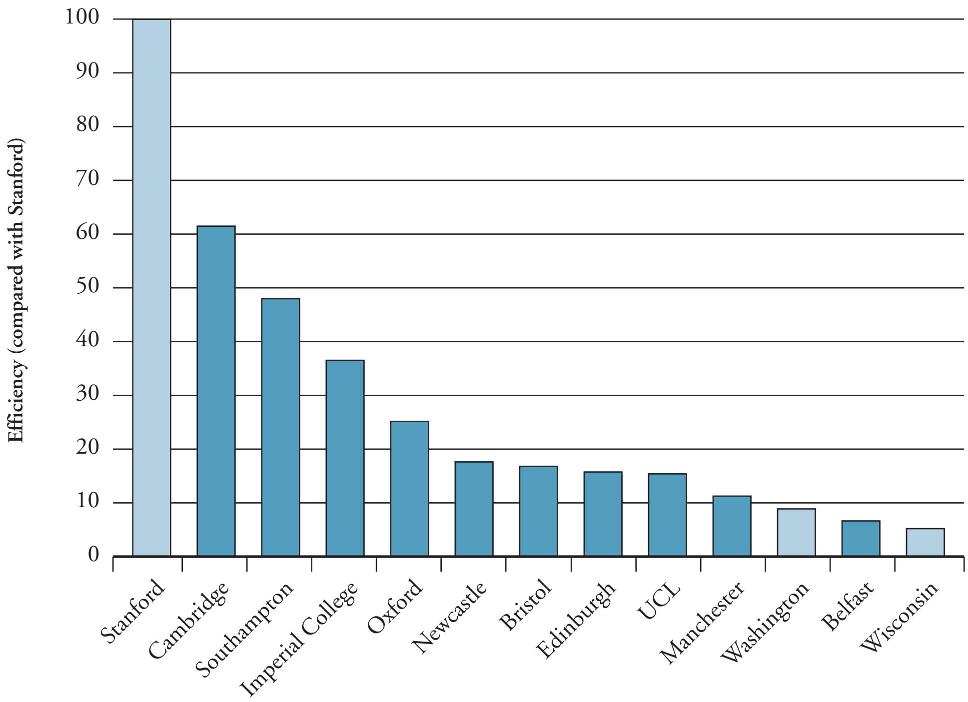


Source: Library House

4.7 The Library House report notes that the performance of UK universities in technology transfer is particularly striking when compared with research output (number of publications). By this measure, termed "venturing efficiency", the UK universities perform even better (Chart 4.2).

[6] *Spinning Out Quality: University Spin-out Companies in the UK,* Library House, March 2007.
[7] Shanghai Ranking System.
[8] Shanghai Ranking System.

Chart 4.2: Venturing efficiency



Source: Library House Analysis

4.8 "Public policy focus on translating research into business", the report concludes, "has been highly successful in reversing the UK's historical weakness in this area".[9]

4.9 The Library House report also notes, however, that there is an opportunity for further improvements in knowledge transfer from UK universities.

Recommendation 4.1

The Review believes that there are four ways to strengthen our performance in knowledge transfer:

1. More support through HEIF to business-facing universities, incentivising them to perform more knowledge transfer with small and medium-sized enterprises;
2. Drive up the knowledge transfer activities of Research Councils;
3. Increase the number of Knowledge Transfer Partnerships; and
4. Encouarage further education colleges to undertake more knowledge transfer.

STRENGTHENING OUR KNOWLEDGE TRANSFER POLICIES

The Higher Education Innovation Fund

4.10 Since 2001, the HEIF has provided support to universities to increase their ability to exploit the outputs of their research and engage with business. This has included support for the commercialisation of intellectual property, business development and brokerage, student enterprise and the incubation of new knowledge-intensive businesses.

[9] *Spinning Out Quality: University Spin-out Companies in the UK*, Library House, March 2007.

4.11 HEIF money was initially allocated on the basis of a competition. This had the advantage of getting universities to think seriously and creatively about knowledge transfer. However, it had the disadvantage that knowledge transfer staff could only be offered short-term contracts due to the unpredictable nature of the funding.

4.12 The Ten-year Framework in 2004 confirmed the Government's support for HEIF as a dedicated third stream of funding and announced a move to a more predictable funding mechanism. This has been delivered by the introduction in HEIF3 of a funding formula based on metrics as well as a competition. This has already enabled HEIs to offer careers in knowledge transfer to staff, rather than unpredictable short-term contracts.

4.13 The environment for collaborative working in the UK has improved significantly in the past decade, with greater levels of support for academics wishing to commercialise their research, a growing openness to working with industry and stronger support through technology transfer offices. However, for the most part academics are rewarded for research output rather than its application.

4.14 The work of interpretation and application into an industrial context is no less demanding intellectually, but it requires different skills and experience. There is a case to be made for new positions in university departments that are of equal status to academic positions and are embedded in that community (rather than in a separate office).

4.15 One successful example of this approach is the Principal Scientist role at Massachusetts Institute of Technology (MIT). These are individuals who have both academic and industrial credibility and typically appear to industry as practical academics. They take responsibility for much industry-facing work, enabling the tenured faculty to pursue their research and teaching.

Recommendation 4.2

Universities should initiate pilots with HEIF money for senior industry professionals to be embedded into departments to act in a similar manner to the Principal Scientists in MIT, acting in parallel to the scientific leader of major projects.

4.16 This Review believes that HEIF should now move to the next stage of development. While our knowledge transfer policies seem to be working well for our research universities, there is scope to increase knowledge transfer from business-facing universities to small and medium-sized enterprises (SMEs). The predictability of a formula would further help universities plan for the longer term.

Recommendation 4.3

HEIF4 funding should be allocated entirely on the basis of a formula, and the formula should be constructed so that the money that was allocated on the basis of a competition now goes largely to business-facing universities.

4.17 We have devised and discussed with DIUS and HEFCE a formula that gives less weight to the size of the university and more to income received from SMEs. This should result in the large research universities getting slightly more money in HEIF4, and many other universities getting larger sums, with an incentive for all to do more work with SMEs. We recommend that this formula be adopted for HEIF4.

Knowledge Transfer from Research Councils

4.18 In the past the Research Councils (RCs) have performed a considerable amount of knowledge transfer (see the box on the following page), but this has largely been ad hoc and on the basis of each RC developing its own programmes. This Review thinks that now is the right time to take this work a step further.

4.19 The RCs have drawn up a joint programme of knowledge transfer, focusing on five key areas: follow-on funds, a joint Business Plan Competition, knowledge transfer from their own research institutes, a Small Business Research Scheme to fund university researchers collaborating with SMEs, and joint funding with the Technology Strategy Board (TSB).

4.20 Building on the success of the RCs' existing collaborations with the TSB, Budget 2007 announced that the Director General of Science and Innovation will agree specific targets with each RC for the amount of collaborative R&D they will conduct jointly with the TSB. The RCs have agreed that the total resources to be committed by them to the new joint funding mechanism will be no less than £120 million over the CSR period. Individual targets for the RCs and the TSB will be finalised as part of the science budget allocations process later in the year. This represents a step change in the impact of RC and TSB support for business innovation and will maximise the capacity of investment from the science base to attract matching funding from other sources.

Recommendation 4.4

Specific targets in each of the five areas of knowledge transfer should be agreed between each Research Council and the Director General of Science and Innovation as part of the Research Council Delivery Plans. RCUK should take responsibility for common branding and alignment across the schemes, ensuring that this branding fits with the Business Support Simplification Programme (BSSP).

4.21 Although in its early stages, a new endeavour by two RCs, the small and medium-sized enterprise engagement vouchers, is a promising initiative. The Engineering and Physical Sciences Research Council (EPSRC), the Economic and Social Research Council (ESRC) and Advantage West Midlands support this innovative scheme in partnership with Aston University, which administers the scheme across all HEIs in the region. Based on a successful Dutch programme, the scheme funds vouchers to encourage SMEs and not-for-profit organisations to make their first engagements with universities. The scheme should be evaluated carefully. It could be a useful mechanism for encouraging SMEs to work with universities.

Knowledge transfer by the Research Councils

- The Arts and Humanities Research Council (AHRC) has established a strategic R&D collaboration with BBC New Media. This collaboration brings arts and humanities researchers together with BBC staff to address R&D needs in the areas of mobile/portable interactive devices, passive consumption/active engagement; user-generated content and managing media assets.
- Medical Research Council (MRC) funded trials in childhood lymphoblastic leukaemia (cancer of blood cells), the commonest type of leukaemia in children, have led to massive improvements in survival, so that four in five children with leukaemia now recover from the disease, compared with only one in five 25 years ago.
- The Biotechnology and Biological Sciences Research Council (BBSRC) and the Engineering and Physical Sciences Research Council (EPSRC) are co-funding a £10 million research programme in bioprocessing with 18 companies, who are contributing collectively £1 million. The aim is to address strategically important research problems that underpin the efficient production of biopharmaceuticals, which comprise over one-third of all new drugs in development.
- EPSRC has established 17 Innovative Manufacturing Research Centres (IMRCs), representing an investment of £80 million. IMRCs are expected to attract matched funding from industry partners. The IMRCs currently collaborate with over 1,000 companies, many of them SMEs.

Knowledge Transfer Partnerships

4.22 Knowledge Transfer Partnerships (KTPs) are a national cross-government activity sponsored by the TSB, a number of government departments, RCs and RDAs.

4.23 KTPs place recently qualified people (NVQ Level 4, HND, foundation degree, degree and higher degrees) in firms for one to three years to introduce a new product, service or process in partnership with a suitable university, college or research organisation. With over 1,000 partnerships running at any one time, KTPs provide fresh and trained minds for the businesses and practical experience for the graduates. The results are widely recognised, such that the Department for Innovation, Universities and Skills' (DIUS) spend of £18 million a year on KTPs leverages £12 million from other public sector bodies and £54 million from business.

4.24 Industry demand for KTP associates is high, and research has quantified the benefits. For every £1 million of government spend, the average benefits to companies as a direct result of KTP amounts to:[10]

- £4.25 million annual increase in profit before tax;
- £3.25 million investment in plant and machinery;
- 112 new jobs created; and
- 214 company staff trained.

[10] 1996 Quinquennial Review of the Teaching Company Scheme.

4.25 KTP associates also benefit: 60 per cent are offered and accept a permanent position within their host company on completion of the KTP project. On average, each associate project resulted in four new research projects being initiated and two research papers being published. Over 80 per cent of KTPs had plans for further collaboration following project completion. About 300–350 new KTP are funded each year and there is known demand for around 900.

Recommendation 4.5

Subject to the BSSP, the Government should build on the success of the KTPs by doubling their number. Responsibility for the KTP scheme was transferred to the TSB from July 2007, but the roll-out and funding of KTPs should be led by the RDAs (see Chapter 9).

4.26 However, the KTPs are not suitable for all universities or all businesses, and there is strong demand for a shorter, more flexible scheme.

Recommendation 4.6

Subject to the BSSP, a standard nationwide mini KTP scheme should be introduced in all regions to facilitate shorter, light-touch collaboration (3–12 months). For some time there has been a demand for shorter, less expensive mini-KTPs, and we believe that they could perform a useful function. They may also be of particular interest to the creative industries, service sectors and SMEs.

Knowledge transfer from Further Education Colleges

4.27 Knowledge transfer extends beyond the commercial exploitation of cutting-edge research by high-technology businesses. It can involve using established research knowledge in new ways or with new users, as well as interactions where the transfer is through consultancy, secondment, tailored training programmes, design input and technology or equipment sharing rather than research. This broader range of interaction can be particularly important for small or less technologically sophisticated businesses.

4.28 Similarly, knowledge transfer reaches beyond the classic STEM (science, technology, engineering and mathematics) subject areas. Financial services and creative industries are two buoyant and important areas of economic activity where there are considerable opportunities for learning providers to support business. Further education (FE) colleges are well placed to support business innovation and development by sharing knowledge and technology, and there are many who successfully do so.

4.29 The KTPs programme currently includes 37 FE partners, and funding is also available through English RDAs for initiatives to build business-support capacity in FE. For example, the London Development Agency is piloting a project providing pump-priming funds to support five FE colleges in establishing contacts with 50 businesses in each of their areas. RDAs have indicated that they would be prepared to increase this kind of funding for FE knowledge transfer activity in support of moves to raise the profile of this activity.

4.30 The development agencies of the devolved administrations also promote FE knowledge transfer (the Welsh Development Agency offers funding via the Knowledge Exploitation Fund). The Funding Councils for Scotland and Wales – which cover both further and higher education – are developing strategies to increase FE business support, and the Department of Education and Learning Northern Ireland (DELNI) includes increased FE business support and SME engagement in the aims for its planned FE sector reforms.

4.31 Research commissioned in 2005 by the DfES and the Learning and Skills Council (LSC)[11] also explored the potential for FE knowledge transfer in England and confirmed that: "FE providers possess the intellectual capital, equipment and facilities to provide low-cost support for innovation that could benefit local companies and the economy more generally". Employers taking part in the research thought that FE colleges might have distinctive advantages in business support, including local knowledge, a practical rather than an academic approach, readily accessible subject specialists and technical facilities and equipment. We agree that there is considerable scope for FE colleges to contribute to innovation, and enhance their reputation as high-quality business-support partners.

4.32 The creation of the new DIUS identifies FE more closely than ever with the Government's wider innovation strategy. We believe there is considerable scope to raise the profile of knowledge transfer in FE and build on the excellent work some colleges have done in this area. However, moves to encourage FE knowledge transfer on a wider scale must be seen in the context of a sector undergoing major reform. The priority for the adult education sector identified by the Further Education: Raising Skills, Improving Life Chances White Paper and endorsed by the Leitch Review is the drive towards increasing employability through skills provision led by learner and employer demand. This Review believes that there is scope for increased FE knowledge transfer to contribute to this agenda, but to do so it should sit within the new structures that are being put in place.

Recommendation 4.7

The Department for Innovation, Universities and Skills (DIUS) should develop a strategy to promote and support knowledge transfer within the wider FE reform agenda. Aligned with the BSSP, it should include:

- encouraging and supporting staff secondments to and exchanges with businesses as part of the FE workforce reform programme;
- funding further FE knowledge transfer projects and initiatives through the Regional Development Agencies;
- incorporating knowledge transfer capacity building in the criteria for the new employer responsiveness standard for Centres of Vocational Excellence;
- encouraging increased FE participation in Knowledge Transfer Partnerships;
- raising business awareness of FE knowledge transfer potential through Business Links and other business support routes;
- promoting FE's knowledge transfer role in advice from Regional Development Agencies and Regional Skills Partnerships to local employment and skills boards;
- using existing FE networks to share best practice in knowledge transfer and business support.

[11] *Talking the Right Language: Can Further Education Offer Support for Business Innovation?*, Learning and Skills Development Agency, 2005.

4.33 Once these measures are in place and demand-led arrangements are established, we recommend that DIUS reviews levels of FE engagement in knowledge transfer and considers the case for creating a dedicated fund for FE along the lines of the original HEIF.

4.34 Providing skills training to employers is, of course, a further knowledge transfer activity and is core to the mission of FE colleges. The supply of skills is discussed in detail in Chapter 7 of this Review, but we believe that FE colleges with knowledge transfer experience beyond training provision will be better equipped to meet businesses' skills requirements. They are also more likely to be seen by businesses as providers of relevant skills. In an LSC seminar in February 2007, the Chief Executive of CIHE, Richard Brown, noted: "For many businesses, the issues do not revolve around levels or qualifications. They are after solutions to business problems. What many see as the added value of higher education is the provision of bright and reflective minds that can make businesses succeed." By engaging in knowledge transfer, FE colleges will continue to establish themselves with business as an additional source of these "bright and reflective minds".

Public Sector Research Exploitation Fund

4.35 The Public Sector Research Exploitation (PSRE) Fund was set up following the 1999 Baker Report[12] to realise the economic potential of research in publicly funded laboratories, including the NHS. The fund has invested £50 million in a diverse range of organisations to commercialise their research, often for the first time.

4.36 PSREs are now beginning to generate significant volumes of commercial activity. In their latest annual reports, PSREs supported by the fund between August 2005 and July 2006 have:

- allocated proof of concept funding to over 150 projects to help develop them into marketable products; and
- used seed funds to establish at least 12 new companies, which themselves have attracted over £14 million of third party funds and now employ more than 90 new staff.

4.37 PSRE funds have also supported the NHS Innovation Hubs in England. These are designed to help translate ideas emerging from the NHS's R&D budget and the practical experience of its 1.3 million staff into commercial products and improved patient care. In 2005 (the latest year for which data is available), the NHS Innovation Hubs generated £1.5 million of revenue from licences and other IP and set up ten spin-out companies. Recent examples include:

- developing a paediatric imaging chair to ensure that high-quality images can be taken during kidney scans of children;
- a training manikin to help practitioners accurately place hypodermic needles in the spine region; and
- the *My Diabetes* information pack, which provides useful information to patients while also helping them to manage their condition.

[12] *Creating Knowledge Creating Wealth: Realising the Value of Public Sector Research Establishments: A Report to the Minister for Science,* Baker, J., August 1999.

Impact of the PSRE Fund

The commercialisation of research from the Science and Technology Facilities Council is managed by CLIK, a wholly owned subsidiary company. CLIK is currently involved in seven spin-out companies from STFC. Between them, these have received around £12 million of venture capital investment from various sources and employ around 40 people. In addition to the spin-out companies, CLIK is involved in around 25 potential commercialisation projects, which might result in licences, spin-out companies or sales opportunities.

Ploughshare Innovations Ltd, which has been established to manage the commercialisation of research from the MOD's agency, the Defence Science and Technology Laboratory, supports nine spin-out and joint-venture companies (of which three were formed in the past 12 months). Three of these spin-outs have received investments from the Rainbow seed fund, which was established to provide early stage capital for marketable ideas emerging from PSREs:

- P2i (Porton Plasma Innovations), which is developing cold pulsed plasma for applying oil- and water-repellant nanocoatings to, for example, textiles and medical devices;
- REMO Technologies, which is developing implantable and surface-mountable sensors for the wireless measurement of physiological parameters, such as temperature, muscle tone and heart rate; and
- ProKyma, which is developing biological sample preparation and diagnostics.

Recommendation 4.8

The Government should continue to support PSRE commercialisation. To increase the impact of the PSRE Fund, the Government should require PSREs with strong track records of commercialisation to lever in additional funding from other sources. The then-Office of Science and Innovation (OSI) consulted the community on this proposal and it has their support.

5 Intellectual property, standards and metrology

5.1 The effective commercialisation of research requires not only specific institutional arrangements to pass knowledge on from research establishments into wealth-creation and public policy-making, but also an infrastructure of intellectual property rights, standards and metrology, enabling advances in science and technology to be converted into innovations and new policies. Intellectual property rights (IPR), standards and metrology oil the wheels of the UK's innovation system.

INTELLECTUAL PROPERTY

5.2 In the UK, intellectual property (IP) is administered by the UK Intellectual Property Office (UKIPO) (formerly the Patent Office). This body is responsible for the award, registration and enforcement of IP in the UK. It also has a key role in policy formulation and responsibility for raising awareness of IP issues.

5.3 UKIPO covers all four of the main forms of IP: copyright, trademarks, registered designs and patents, each of which, as has been shown in Chapter 2, is of benefit to different parts of the economy and to different sorts of activity. The economic business model of the creative industries is, for example, very dependent on the knowledge, use and enforcement of copyright.

5.4 Technological change and the rise of emerging economies around the world present a new range of challenges and opportunities for the system of IPR in the UK. The Gowers Review recently examined the UK's IP system and made a number of recommendations for it to make a greater contribution to raising the country's level of innovation.

5.5 The first priority for UKIPO over the next few years must be the implementation of the proposals in the Gowers Review. A number of these are of great importance for the overall performance of our innovation system: raising awareness of our IP system, facilitating knowledge transfer, the enforcement of IPR, and work-sharing between UKIPO and other national offices. Chapter 2 has shown that our performance on IP is reasonable when the UK's level of R&D is taken into account. There are, however, plenty of opportunities to improve it further.

5.6 Enforcement, a particular concern raised by the Gowers Review, remains key. Counterfeit goods and piracy are damaging UK industries, and encouragement should be given to moves by UKIPO to implement Gowers' recommendations.

5.7 There are two other areas where this Review recommends that action is taken: patent informatics to inform planning and policy and the introduction of an EU Community Patent, the latter being also recommended by Gowers. A Community Patent is currently being debated by the European Union. It would allow individuals and companies to use a single, unitary patent across the whole of the EU.

5.8 The patent system promotes innovation in two ways. Granting a monopoly right provides the incentive to innovate by providing inventors with the necessary protection to capitalise on the effort, time and resources they commit to developing new products and services. In return, the inventor is required to disclose details about the patented invention, which is then placed on publicly accessible databases. These databases provide a rich source of information, which others can build on and use to develop further inventions and prevent duplication of effort.

The Gowers Review

The UK's performance on IP indicators will be affected by the structure of both the domestic system and international arrangements. The Gowers Review of Intellectual Property, which was published in December 2006, examined in detail the performance of the current IPR system in the UK. The Review came to the conclusion that the current system is broadly fit for purpose (i.e. to create incentives for innovation, without unduly limiting access for consumers and follow-on innovators), but that there is scope for improvement, focusing its recommendations for reform on the following three areas:

Litigation
Especially in the case of patents, costs of registration and litigation are seen as prohibitively high by the Review, with litigation costs starting at about £750,000. Costs are driven even higher when firms seek to use patents internationally, mainly due to translation, legal and other advisory fees. Other indirect costs are caused by lengthy award processes and highly complex systems, especially at the international level.[1]

Enforcement
The Review presented strong evidence that the enforcement of all types of IPR is insufficient. For patents, this is mainly due to prohibitively high costs of litigation, making it impossible for smaller firms to challenge infringements, especially on an international basis. For all other forms of IPR, hurdles to enforcement of IPR consist of a mixture of insufficient regulation, conflicting priorities for police to tackle IPR infringements and facilitated copying and distribution through digitisation and the Internet.

Flexibility
The copyright system in particular was found to be lacking in flexibility to accommodate certain uses of copyrighted material commonly perceived as legitimate and which do not damage the interests of the rights holder (e.g. format shifting of sound recordings or written works for private use or archival purposes). This applies in particular to "orphan works", which currently are not commercially available because the rights holder cannot be found. Some estimates suggest this affects up to 98 per cent of published work under copyright.

5.9 It is estimated that up to 80 per cent of all the applied technical knowledge that exists today is contained within patent documents and cannot be found elsewhere.[2] Historically, the information contained in patent databases has not been fully exploited, with estimates that up to 30 per cent of all R&D projects are merely a duplication of existing technology. This equates to an annual waste of about £20 billion.[3]

5.10 One reason why this technical resource is not more fully exploited is that patents themselves are complex legal documents, possessing their own terminology and associated systems, which are challenging to comprehend. The sheer volume of information available is also a factor.

[1] The Gowers Review quotes a finding from a business survey by the Confederation of British Industry that about 70 per cent of businesses were unaware that a UK patent did not secure their invention in other countries.

[2] *Usage Profiles of Patent Information Among Current and Potential Users*, European Patent Office, 2003, available from: http://www.european-patent-office.org/news

[3] PATINNOVA '94, Dritter Europäischer Kongreß über Innovation, Management und Patente 6. – 8. Juni 1994 Brüssel, Palais des Congrés. Personal communication from Eric Heusser, Präsident des Deutschen Patentamtes http://www.hi.is/~joner/eaps/wrd_ehau.htm

A single patent database, provided by the European Patent Office, contains about 60 million patents dating from 1836 onwards.[4] The volume of patent data is also increasing daily, with almost 1.6 million patent applications filed worldwide in 2004 alone.[5]

Patent informatics

5.11 Patent informatics has been developed to address the need for patent information to be more accessible. UKIPO is ideally placed, with the technological expertise and access to sophisticated search and analytical software tools, to enable full access and analysis of this resource.

5.12 The UKIPO has already undertaken analysis of patent data to prepare evidence as part of a report to the House of Lords Select Committee on Allergens[6] and a report on "electronic paper". Planned work includes more reports on key subject areas, at the instigation of the Knowledge Transfer Networks (KTNs). The results of such reports can aid the development of a Department for Innovation, Universities and Skills (DIUS)/Technology Strategy Board (TSB) framework policy in emerging technology areas. The Office is also exploring how it can use its ability to analyse patent data to provide information to the commercial sector to help with such things as trends in technology and monitoring competitor activity, which can help inform strategic planning. This information should also be used by the TSB in identifying technology priorities.

Recommendation 5.1

Government and business should be encouraged to make greater use of the enormous amount of technical information contained in patent databases to further innovation, avoid duplication of research and support informed decision-making. It is also recommended that UKIPO should continue to develop its expertise in patent informatics to provide information that can aid government and commercial bodies in strategic planning.

STANDARDS

5.13 Standards have an impact on every area of economic life, supporting safety regulations, assuring quality of produce and facilitating compatibility of products. New standards can emerge through a competitive market process, as occurred with the adoption of the VHS videocassette format over its rival, Betamax, or in the accepted use of the QWERTY format for English-language keyboards.

5.14 Because standards are a public good from which everyone will benefit, the incentive for suppliers to create standards can be reduced: if a supplier cannot claim all the benefit from introducing a standard – and by definition they cannot – the incentive to create a new standard is much reduced. The market alone, therefore, may not supply the right kind and the right number of standards. Governments have intervened to fill this gap, providing an increasing range of standards for a vast range of industries, products and processes. International organisations such as the International Organization for Standardization (ISO) provide a catalogue of internationally recognised standards. In the UK the catalogue is maintained by BSI British Standards, part of the BSI Group.

5.15 BSI British Standards, the UK's national standards body, represents the UK at all European and international standards organisations, operating on terms provided by its Royal Charter and a memorandum of understanding with government to provide a not-for-profit service.

[4] European Patent Office website: http://internet-p.epo.org

[5] *Statistics on Worldwide Patent Activities,* World Intellectual Property Organization, 2006. Accessed 15 May, 2007; available from: http://www.wipo.int/ipstats/en/statistics/patents/pdf/patent_report_2006.pdf

[6] House of Lords Select Committee on Allergens Report, submitted September 2006, available from: http://www.parliament.uk/documents/upload/st1patentoffice.pdf

The current BSI British Standards catalogue has 27,000 standards, with around 6,000 in development at any one time.[7]

Impact of standards on the economy

5.16 Recent empirical work has attempted to assess the extent to which standards benefit the economy. One team of researchers estimated that a reliable standards system had contributed 0.9 per cent towards the 3.3 per cent annual GDP growth in the West German economy between 1960 and 1990 – second only to investment in importance.[8] Research conducted by the DTI suggests that as much as 13 per cent of labour productivity growth from 1948 to 2002 was due to the portfolio of standards maintained by the then-BSI. Over one-quarter of annual technological growth can be attributed to BSI standards.[9] This growth is due to the role of standards in disseminating management practices, technology and other knowledge. It is therefore no surprise that the High Tech Strategy for Germany, published by the Federal Ministry of Education and Research in 2006, singles out the importance of a vigorous standardisation strategy, citing early standardisation as a key element in securing the rapid translation of research into commercial products and services.[10]

5.17 These results should be treated with care since the relationship between standards and innovation is complex. Many other factors interact with the standards system in driving innovation. Peter Swann compares building an infrastructure for standards to the "pruning and training of a young tree": in some places growth must be restrained, in others supported, to produce a healthy outcome overall.[11] Both the constraints and the supports are necessary: by doing both, standards provide a context for innovation. BSI British Standards lists the following advantages for innovation through the provision of effective standards:

- the establishment of common vocabularies, enabling innovators working in different locations to communicate with confidence about common subject-matter, without wasting time and effort;
- the acceptance of new technologies by the market-place, through the assurance of standards and related products;
- the consideration of health, safety or other aspects, as technology moves away from areas covered by existing arrangements; and
- the setting of a target for technologies to aim for, in terms of a performance specification.[12]

5.18 Table 5.1, which is based on returns from the EU Community Innovation Survey, shows that 64 per cent of innovation-active companies in the UK use standards and technical definitions as a source of information for innovation.

[7] *About BSI*, BSI, at: www.bsi-global.com/en/Standards-and-Publications/About-British-Standards/

[8] "Innovation, standardisation and the long-term production function: a cointegration analysis for Germany, 1960-1990", Jungmittag, A., Blind, K. and Grupp, H., in *Zeitschrift für Wirtschafts-und-Sozialwissenschaften*, 119, 1999.

[9] *Economics Paper #12: The Empirical Economics of Standards,* DTI, June 2005 p. 4.

[10] *High Tech Strategy for Germany,* Bundesministerium für Bildung und Forschung, 2006.

[11] *The Economics of Standardisation: Final Report for the Standards and Technical Regulations Directorate, Department of Trade and Industry*, Peter Swann, 11 December 2002.

[12] Adapted from British Standards Institution submission to the Sainsbury Review.

Table 5.1: Importance of sources of information, innovative enterprises only

Source type		Per cent rating "important"
Internal	Within your enterprise or enterprise group	81
Market sources	Suppliers	86
	Clients or customers	87
	Competitors	78
	Consultants, commercial laboratories, private R&D institutes	49
Institutional sources	Universities or other HEIs	29
	Government or public research institutes	31
Other sources	Conferences, trade fairs, exhibitions	65
	Scientific journals	64
	Professional and industry associations	67
	Technical, industry or service standards	64

Source: UK Innovation Survey 2005

5.19 There are clear examples of where the current standards system is effectively supporting innovation. The case studies below show how.

Case study: Nanotechnologies and standardisation

This is perhaps the best known area of standardisation supporting innovation. Real UK competitive advantage has been gained through strong leadership of the standards work programmes.

The strategy developed by the British Standards Institution (BSI) for nanotechnologies was to exploit standardisation as a mechanism to ensure that a global market, with a common understanding of terms and standards, would develop in an area where UK business was active. UK credibility was established through the publication of the definitions document for key nanotechnology elements PAS 71:2005 Vocabulary Nanoparticles, which was launched to industry acclaim, providing what one reviewer described as "a must-have vocabulary for all".[13] With DTI funding, high levels of national and international management support were provided. This supported a cross-divisional team of BSI staff which covered all aspects of the strategy, ranging from day-to-day programme management activity to planning and running of the part-funded ISO TC229 plenary meeting.

The establishment of the UK-held Secretariat and Chairmanship of ISO TC229, Nanotechnologies shows global recognition of the UK's capability and objective approach to standards development in the field of nanotechnology. The UK also holds the secretariat of the twin CEN committee (TC352), thereby ensuring a consistent approach in running the national, European and international work programmes.

Other activities have included the hosting of the UK Nanotechnology Forum, the launch of the BSI Nanotechnologies website (with links to MNT Forum), and successful submission by the UK for a new ISO technical specification. See box at end of chapter for details on Microsystems Technology and Nanotechnology network (MNT).

[13] Nanoparticles for All, *III-Vs Review*, 5 June 2005. Available fro: www.three-fives.com/competitive_complementary_news/June_c_c_news/060605NanoVocabulary_BSI.htm (accessed 16 April 2007).

Case study: Ultrasonics

EPL/87 is a committee which prepares, revises and amends British Standards related to the characteristics (including biological effects and associated limits) and method of measurement for electroacoustics systems and ultrasonic equipment. The public utility of the work undertaken by the committee is particularly evident in the medical sphere.

The committee is currently considering standards relating to diagnostic ultrasonic equipment and physiotherapy systems. Ultrasonics is a relatively new field, and standards documents currently under development include those dealing with areas of innovation such as underwater acoustics, pulse-echo scanners and hydrophones.

UK representatives' involvement has been important to a massive rationalisation of standards that will make the ultrasonics standardisation process much easier to implement. The UK team has also been instrumental in pushing the need for standardisation in high intensity focused ultrasound (a major worldwide growth area that is developing treatments for cancers and other conditions) to the fore. Currently, this is an area that is without regulation, a clear lead is needed to ensure safety standards can be developed and applied.

The UK is in the unique position of being seen as the lead nation in ultrasonic measurement science and is setting a high standard that the rest of the world follows.

METROLOGY

5.20 The National Measurement System (NMS) is the Department for Business, Enterprise and Regulatory Reform (DBERR)-funded infrastructure for the provision of measurement standards for the UK. Its main roles cover:

- representing the UK on the General Conference on Weights and Measures, the international committee that defines measurement units and fundamental constants, at least four of which, including kilogrammes, are due for redefinition in coming years;
- funding the maintenance and development of the national measurement standards, primarily at the National Physical Laboratory (NPL), but also at LGC Ltd (formerly the Laboratory of the Government Chemist) and TUV-NEL (formerly the National Engineering Laboratory);
- funding research into new measurement standards and techniques; and
- disseminating knowledge about measurement standards and techniques to user communities in academia, industry, regulatory bodies and the public sector.

5.21 At the heart of the NMS is the NPL, which undertakes about 80 per cent of government programmes to support the NMS infrastructure. Alongside the NPL are LGC Ltd, TUV-NEL and the National Weights and Measures Laboratory.

5.22 Like other standards, measurement standards are a prime example of a "public good", whose provision, potentially, is not optimally provided by a market. As discussed in the section on standards, a public good does not allow its provider to capture all the returns from its use; consequently, a market may underprovide the good, offering a rationale for government intervention. NPL is one of over 50 national measurement institutes (NMIs) performing this role and is recognised as being in the top three, alongside the National Institute of Standards and Technology (NIST) in the USA and the Physikalisch-Technische Bundesanstalt (PTB) in Germany.

For example, NIST benchmarks its performance in advancing and disseminating measurement knowledge against NPL, and PTB engages actively in collaboration on research and measurement standards.[14] NPL is the first or second most referenced external expert source on NIST and French national measurement institute websites.

5.23 In the UK, DIUS leads for the Government in funding measurement standards. Users of this service, or of goods and services underpinned by measurement standards, include private companies, government agencies (national and local), NHS trusts, public sector research laboratories and universities. Although its effects are often largely taken for granted, the total economic impact of the NMS is undoubtedly substantial. The total contribution of the NMS to UK GDP was estimated in a report for DTI at around £5 billion per year, or about 0.8 per cent of GDP.[15] The development of new standards and research into measurement techniques provide further means by which the NMS laboratories can boost UK productivity. The dynamic spillover effects from such research, as evidenced by citations in scientific journals and other forms of academic knowledge transfer, can be significant. An example of cutting-edge research undertaken by the NPL is given in the case study below.

Case study: Standardising "naturalness"

Synthetic materials offer numerous potential advantages over natural materials, such as lower cost, greater consistency and more flexibility of application. But consumers have often demonstrated a preference for natural goods, making decisions about a product's quality on this basis – quickly differentiating between natural and artificial products. If the process of differentiation between "natural" and "artificial" were better understood, reliable standards of "naturalness" could be offered, and products better meeting consumers' needs provided. Currently, however, such consumer differentiation is unquantifiable and subject to great uncertainty.

The NPL is leading a multidisciplinary research team looking at how physical characteristics of materials affect our judgements of those materials. The team is taking a series of complex measurements of different surfaces, linking specific physical characteristics (like roughness and reflectivity) to emotional and neurological responses.

To understand how a product is perceived by the human eye, the researchers are using a new instrument, called IRIS (image replicating imaging spectrometer), that uses pictures of the object to gather information about a surface's colour and texture. An artificial fingertip has been developed that can sense the differences between different surfaces, while insights from the field of psychophysics enable researchers to understand how humans differentiate between different physical properties of objects to create our perceptions of the world. When completed, the research project will provide a new understanding of how humans perceive quality in physical products, enabling benchmarking and better use of materials.

5.24 The UK instrumentation sector itself is of significant size, with an output of £8.1 billion each year. The NMS plays a key role in supporting this industry, providing necessary public infrastructure backed up by a history of world-class measurement support. This enabled the instrumentation sector to export £5.5 billion of equipment in 2004 (the last year for which figures are available), some £768 million more than was imported, making the sector a net contributor to

[14] For example, see page from NIST Annual Report at: http://books.nap.edu/openbook.php?isbn=NI000509&page=130

[15] *Review of the Rationale for and Economic Benefit of the UK National Measurement System*, PA Consulting, November 1999, pp. 2–18.

the UK's trade balance. Approximately 4,500 companies are engaged in the sector (of which 98 per cent are classed as small and medium-sized enterprises: SMEs, spending a total of £500 million per annum on research and development: above average, given the sector's size.[16]

Knowledge transfer

5.25 NPL has a long-established knowledge transfer expertise, and recent years have seen a progressive expansion of the skill base of its knowledge transfer team. NPL now has one of the largest scientific knowledge transfer teams in the UK, with over 30 knowledge transfer specialists working alongside more than 400 practising scientists, engineers and technologists.

5.26 Knowledge transfer has been achieved through secondments, consultancies for SMEs and joint industry projects under the Measurement for Innovators programme, initiated in response to DTI's 2003 Innovation Report. This established a series of targets for knowledge transfer that in all cases the NPL significantly exceeded by 2006 (Table 5.2).

Table 5.2: Measurement for Innovators programme performance

	Innovation Report target	Achieved
Co-funded projects with industry	15–25 p.a.	37
Product development projects	Up to 250	195
Secondments	20	110

Source: NPL

5.27 This is an impressive record of engagement with business, indicating the potential for metrology specialists to utilise their unique skill and knowledge sets to support private sector innovation. Other NMIs are developing similar programmes suited to their strengths, such as LGC Ltd's range of training courses, available off-site.

5.28 In response to market developments, NPL has established new capabilities in biotechnology and micro-nano technology and hosts two of the DIUS's new Nanotechnology Centres (CEMMNT and the Bio Nano Centre). It also manages two of DIUS's Knowledge Transfer Networks (KTNs) (Sensors and Location and Timing). In addition, NPL has established "Measurement and Standards for Emerging Technologies" forums across the KTN websites, providing access to online discussions and resources. NPL has identified a number of priority areas for future development, as detailed in Table 5.3.

[16] Details taken from *UK Instrumentation and EU Calibration Markets*, NPL, January 2006, with updated figures supplied January 2007. Output, export and import figures calculated from GAMBICA figures taken from PRODCOM, supplied by ONS.

Table 5.3: NPL – priority technical areas

Biotechnology	Nanotechnology
Biopharmaceuticals	Scanning probe microscopy
Biodiagnostics	Carbon nanotubes for metrology
Bioprocessing	Nanoparticle characterisation
Biomaterials	Standards for nanotechnology
Communications networks	**Mathematical modelling**
Signal propagation and information transfer	Experimental design, modelling and uncertainty evaluation
Complex waveform analysis	Molecular modelling and FE computational techniques
Uncertainties in communication networks	
Environmental measurements	**Advanced materials**
Air-quality monitoring	Composites and light alloys
Data analysis and modelling	Surface engineering
Airborne particle and chemical analysis	Emerging materials
New techniques	Lifetime prediction and sustainability analysis

AIMtech

5.29 Drawing on existing on-site support for KT, AIMtech is a proposed industrial incubator to be located at the NPL's Teddington site. It would provide start-ups in measurement technology with managed access to the NPL's facilities and scientific expertise. The NPL is particularly well-placed to provide incubator facilities, having long experience in knowledge transfer, a critical mass of technical and scientific facilities and expertise, and capacity on-site to provide appropriate accommodation in an existing building. By building on existing facilities, DIUS and SEEDA funding can be effectively leveraged, boosting start-ups' chances of success.

Recommendation 5.2

DIUS should fully endorse the setting up of a new, world-class incubator facility on NPL's Teddington site (AIMtech) to help measurement and instrumentation start-ups.

5.30 It is clear from the foregoing that metrology and standards are critical components of the innovation ecosystem and help bring new technology to commercialisation and widespread uptake. This has been recognised among our leading competitors.

Recommendation 5.3

In developing its strategy for supporting the development and dissemination of key technologies, the TSB should systematically consider the role of metrology and standards as part of its portfolio of targeted interventions and ensure that this strategy is widely communicated through the relevant KTNs. In allocating resources to these activities, the TSB will clearly wish to develop management metrics of successful outcomes and maximum impact.

5.31 However, standards must be translated into an international setting in order to ensure that global markets develop in areas of UK capability.

Recommendation 5.4

Working with the TSB, DIUS should take a more proactive approach towards the development of European and international standards in areas of UK strength.

Recommendation 5.5

An Emerging Industries Co-ordinating Committee should be established by DIUS to bring together representatives from the TSB, the Research Councils, The National Measurement System, the UK Intellectual Property Office and the British Standards Institute to co-ordinate support for emerging industries, such as regenerative medicine, as has been done in recent years for microsystems technology and nanotechnology.

5.32 In the early stages of a disruptive new technology, the Government can play an extremely valuable role in stimulating research, establishing communication networks among the different players, and encouraging the development of the enabling metrology and standards.

Microsystems Technology and Nanotechnology

The UK was at the forefront of nanotechnology development in the early 1980s, but five years ago was in severe danger of falling behind. The Government, therefore, commissioned a strategic review of nanotechnology research and industry in the UK from John Taylor, the then-Director General of the Research Councils.

As a result of this review, in July 2003, the Government announced a cash injection of £90 million over six years, with £50 million earmarked for the creation of a network of open access manufacturing facilities. A micro and nanotechnology network (MNT) was also set up.

The MNT network identified four key areas where the UK is among the leaders: nano-materials, nano-medicine, nano-metrology and nano-fabrication. The focus was business pull as opposed to technology push. One of the first actions undertaken was the creation of road maps for each of the key areas. Following on from this, the people working in these areas were encouraged to create Focus Groups. A good example of the way in which Focus Groups have developed is the measurement club which now boasts more than 400 members.

The development of nanotechnology is strongly influenced by the ability to measure and characterise materials and devices at the micro and nanoscale. The National Physics Laboratory (NPL) has considerable capabilities in this area and has adopted a strategic approach to international standards formation in nanotechnology by adopting a proactive approach to international standards discussions in this area. The UK chairs the recently formed ISO Committee for the standardisation of nanotechnologies and NPL has been instrumental in the Committee's establishment and strategic direction. The UK has also played a key role in developing a European strategy for nanotechnology standards.

Evidence from published company accounts indicates that the UK's micro and nanotechnology industry had a turnover of £23 billion for the financial year 2004–05, and employs around 43,000 people, supporting a further 400,000 jobs in industries making significant use of MNT in their products. Its products include wound dressings developed by Smith and Nephew which incorporate silver nano-particles which reduce the risk of infection and enable wounds to heal more quickly, and Pilkington's K-Glass which is a low-emmisivity (low-e) glass with high thermal barrier properties due to a thin film (about 50 nanometres in thickness). Low-e coatings reduce the amount of heat radiation from glass, thereby reducing heat loss from buildings.

The UK is now firmly on the front of the wave, and independent studies indicate the U.K. is progressing strongly to be the fourth dominant country in nanotechnology in the world over

6 The supply of venture capital

6.1 The availability of finance to transform research into commercial applications is critical to the functioning of a successful innovation system. Established companies will complete some of this research and commercialisation; however, smaller, fast-growing technology firms also play a vital role in delivering innovation and supporting economic growth more generally. The "catalytic effects" of small and medium-sized enterprises (SMEs) in the innovation process are important.[1]

6.2 New high-technology businesses can face particular difficulties in securing the necessary finance to develop from proof of concept through to commercialisation. Capital requirements for these businesses can be very high, and returns much-delayed, but entrepreneurs may have few assets available for collateral beyond their own knowledge capital. Business plans are often untested and immediate managerial experience limited, both factors tending to deter conventional investors.[2] Few friends or family members will able to supply sufficient capital and be sufficiently open to risk to provide adequate funding over an extended period of time. As a result, risk capital provided by venture capitalists and business angels may be the best available form of finance.[3]

6.3 However, venture capital functions best with other forms of financing working alongside it. A successful entrance onto the listed public markets, for example, requires that early-stage private funding is available; however, that early-stage funding may only be forthcoming when a clear (and profitable) exit is available to "pull" the system along. These linkages between forms of finance create the possibility of co-ordination failure between different markets.

6.4 Many of the public sector schemes now in place rely on government bearing some of the risk of early-stage investment, most frequently through the use of tax-favoured investment vehicles, such as the Enterprise Investment Scheme and Venture Capital Trusts. There are also schemes in which government provides matched funding for risk capital investments, such as Enterprise Capital Funds. These and other programmes are considered in detail later.

6.5 It is important to recognise that the supply of capital is only one element in developing successful high-technology companies. Elsewhere in this report, we have stressed the importance of demand for innovative goods and services. As a rule of thumb, a reliable order for a new high-technology firm is worth about ten times the same value of venture capital investment.[4] Chapter 8 details ways in which government can help support new, innovative companies through innovative procurement and a reformed Small Business Research Initiative scheme.

[1] See, for example, European Commission, *Raising EU R&D Intensity: Improving the Effectiveness of Public Support Mechanisms for Private Sector Research,* 2003, p8.

[2] Moore, B., "Financial Constraints to the Growth and Development of Small High-Technology Firms" in Hughes A. and Storey, D.J. (eds.), *Finance and the Small Firm,* 1994.

[3] One study found that SMEs pursuing innovative growth also have the lowest debt:equity ratios, indicating the importance of equity financing. See Jordan, J., Lowe, J., Taylor, P., "Strategy and Financial Policy in UK Small Firms", *Journal of Business Finance and Accounting* 25, 1998.

[4] Foundation of Science and Technology conference, 5 June 2007.

6.6 The UK venture capital market is, by European standards, large and flourishing. It is supported by a number of government interventions, such as the Enterprise Capital Fund programme, a recent promising initiative to help boost small firm investment. The growth of the Alternative Investment Market in the last decade provides venture capitalists with the prospect of an earlier exit through an Initial Public Offering (IPO), and hybrid spin-out/licensing companies have emerged to bridge the gap between university knowledge creation and start-up.

6.7 We would like to see the venture capital market grow but do not recommend any major new initiatives at this stage. It is important to understand the impacts of government's latest policies first. We make a number of small recommendations, including the introduction of a national proof-of-concept scheme through the Business Support Simplification Programme. Together with our proposals for the reform of the Small Business Research Initiative, the new formula for the Higher Education Innovation Fund, and the support of the Regional Development Agencies for incubators, high-technology clusters and business-readiness services, this should provide a significant boost for investment in early-stage high-technology companies.

UK VENTURE CAPITAL: SIZE AND SCOPE

6.8 Venture capital generally covers investment in newer and earlier-stage companies and constitutes a relatively small proportion of the total risk capital investment market. But it is this early-stage risk capital investment that is important for high-technology innovation. The UK accounts for approximately one-third of the total European venture capital market (Table 6.1).

Table 6.1: Selected EU venture capital investments, 2006

Country	Investment value (million euros)	Deals completed
UK	1,784	515
France	875	195
Spain	491	67
Ireland	439	30
Germany	428	207
Europe total	**5,553**	**1,434**

Source: Library House

Equity gap

6.9 The UK's high-technology sector is the most actively invested in by the European venture capital community.[5] UK venture capital investment in all technology companies (early- and later-stage) has not recovered to the heights of the dotcom boom, stabilising at around £600–700 million per year – but this is approximately double the pre-1996 average.[6] The ebbing of high-technology investment after the dotcom bubble left behind a larger and more secure financial infrastructure for innovative investment in general. This "learning effect" is one important spillover from the bubble. Nonetheless, previous reports have indicated the existence of an "equity gap" of between £250,000 and £2 million, where companies (particularly newer companies) find barriers to accessing growth capital.[7] The following box details the likely causes of this gap.

[5] *The Ball's in Our Court: UK Technology at a Critical Juncture*, Deloitte, 2005, p. 15.
[6] *The Economic Impact of Private Equity in the UK*, BVCA, 2005, Appendix E.ii.
[7] *Bridging the Finance Gap: Next Steps to Improving Access to Growth Capital for Small Businesses,* HM Treasury and Small Business Service, December 2003.

Causes of the equity gap[8]

- **Information asymmetries:** potential investors can find locating promising investments a difficult and costly process since they are not fully informed about all potential investments. These information problems are likely to be particularly great for early-stage companies using innovative technology or techniques since there is generally less existing market information upon which to base investment decisions.
- **Transactions costs:** where the costs of negotiation and contracting are significant, smaller investments appear much less attractive. This affects those entrepreneurs looking for smaller sums of money.
- **Perceptions of risk and reward:** where expectations about an investment's future potential are incorrect, investors will allocate a sub optimal amount of investment. If high-technology investments are perceived as riskier than they are, they will receive too little funding.

6.10 These issues are more often a problem for early-stage and high-technology firms.[9] The innovation cycle itself, requiring extended periods of product research and development, with frequent (and often relatively large) capital input, can create problems for financing (see Table 6.2). For example, small biotechnology firms, with typical product development cycles of 10–15 years, are particularly vulnerable.[10] One study of UK SMEs found that firms with relatively high R&D expenditure were more likely to report financing constraints precisely as a result of perceived greater risks,[11] and due diligence requirements have been found to be differently applied by venture capitalists between technology and non-technology investments.[12] This may, of course reflect the length of product development and an investor's target period over which to make a return.

Table 6.2: New technology development times (years)

Stage/industry	Innovation	Proof of technology	Proof of market	Exploitation	Total length
Life science therapeutics	2	5.8	0.5	0	8.3
Biotechnology services and processes	1	0.75	1	0.8	3.55
Diagnostic innovation	1	1	0.5	0.5	3.0
Life science medical devices	1.5	2	1	0	4.5
Life sciences – veterinary	2	2	1	–	5
Microelectronics	0.8	2	1.5	1	5.3
Optoelectronics	–	2	1	–	3
Creative digital industries (large devices)	–	2	0.25	–	2.25
Creative digital industries (mobile)	0.75	0.5	0.25	–	1.5
Energy	1.5	1	1	1	4.5
Other emerging technologies	1	1.75	2.6	1.5	6.8
Drug development timeline	5	9	1	–	15
All industries average	–	–	–	–	**6 to 8**

Source: Scottish Enterprise, Proof of Concept Programme Evaluation: Final Report

[8] Taken from HM Treasury, ibid., Box 2.2.

[9] See "The Financing of Technology-Based Small Firms: A Review of the Literature", Bank of England, *Bank of England Quarterly,* Spring 2001, for a summary.

[10] *High-Technology New Firms: Variable Barriers to Growth,* Oakey, R.P., 1995.

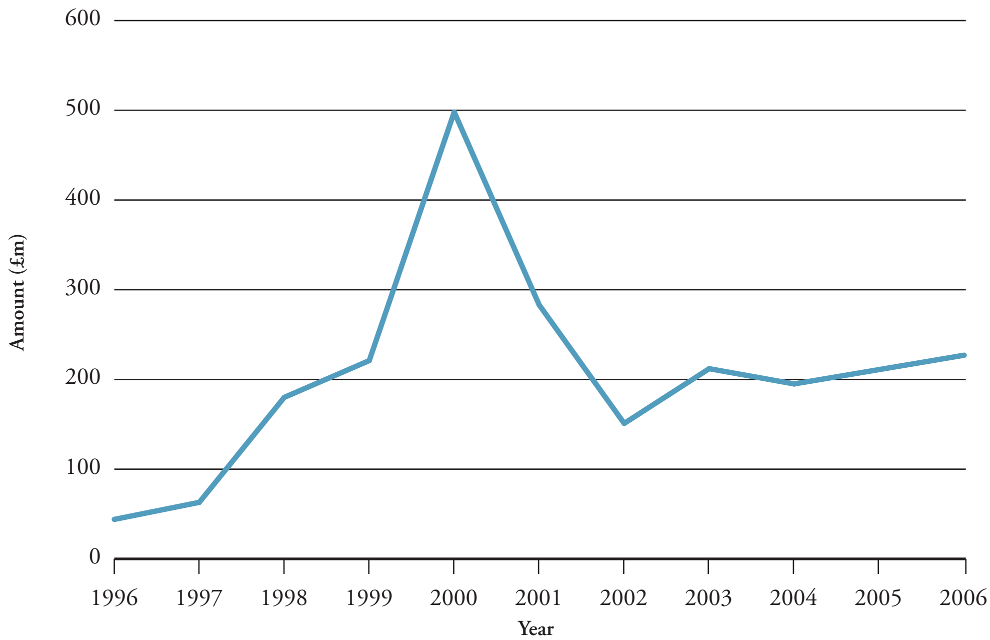
[11] "Financial Constraints on the Growth of High-Technology Small Firms in the UK", *Applied Financial Economics* 7, Westhead, P. and Storey, D.J., 1997.

[12] See, for example, "Do UK Venture Capitalists still have a Bias Against High Technology Investments?", *Research Policy,* Lockett, A., Murray, G. and Wright, M., 31:6, 2002.

EARLY-STAGE VENTURE CAPITAL INVESTMENTS

6.11 The overall amount of funding for early-stage high-technology companies[13] has fallen but remains higher than in the 1990s. The value of funds flowing into these companies in the UK has slid significantly from its 2000 peak of around £500 million, stabilising in recent years around £200 million (Chart 6.1).

Chart 6.1: Value of venture capital investment in high-technology early-stage companies



Source: BVCA

6.12 However, legitimate concerns remain around the smaller and riskier end of the venture capital market. Early-stage high-technology investment is not, at present, producing high returns,[14] and as a result capital is flowing towards the larger end of the market, where low interest rates have enabled cheap, leveraged investment with relatively less risk and a greater prospect of good returns. Most institutional investors have shifted funding to the later stages of development, where a company's track record and scalability imply a higher potential for growth.[15] Significant recent growth in early-stage venture capital has not boosted early-stage high technology. The proportion of early-stage venture capital investment flowing into high-technology firms fell substantially in 2006, from 67 per cent of all funding in 2005 to 23 per cent in 2006 (Chart 6.2).[16]

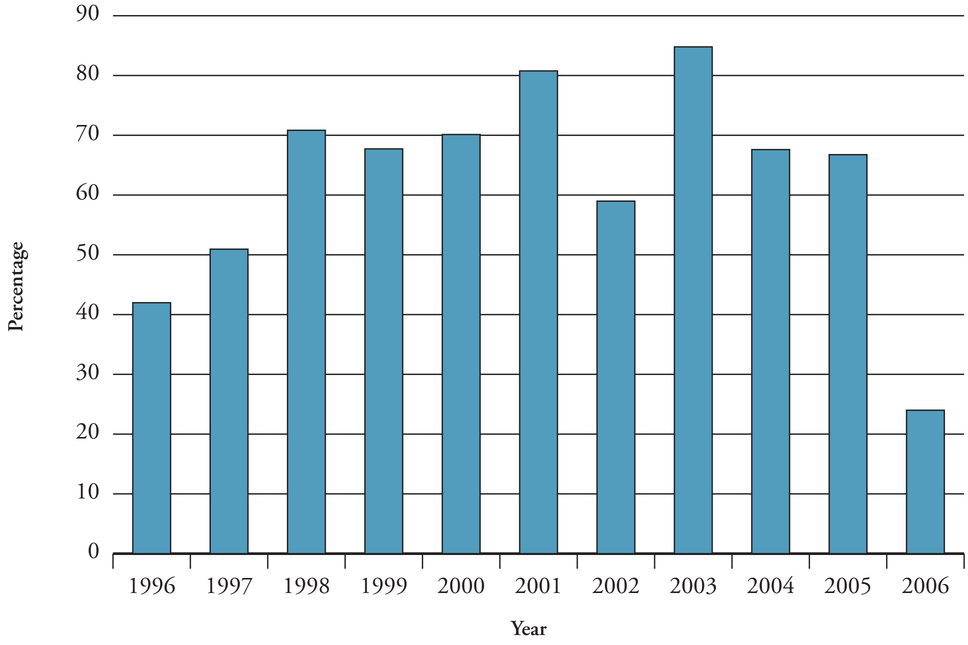
[13] Defined by BVCA, whose figures have been used in this report, as including communications, computers (hardware, software, semiconductors and Internet), biotechnology, health industries (pharmaceuticals, health services and instruments) and two generic categories of "other electronics related" and "other".

[14] PwC/BVCA data suggest that returns on post-1996 funds up to this year are averaging –1.9 per cent.

[15] Submission from Design Council, CBI, NESTA, EEF, UNICO, IFM.

[16] BVCA figures.

Chart 6.2: Percentage of all early-stage venture capital financing received by technology companies



Source: BVCA

6.13 Alternative financing models, described below, have emerged and become important ways to meet the demand for capital. As described in Chapter 4, on knowledge transfer, this demand (emerging in the form of spin-outs from our universities) is of an increasing quantity and quality.

BUSINESS ANGELS

6.14 The term "business angel" was coined to describe the activities of individual investors who specialise in providing finance to new starts and early-stage firms in return for an (often substantial) equity stake. They are typically wealthy individuals, usually with significant prior managerial or entrepreneurial experience.[17] They differ from venture capitalists in generally being sole investors, often reliant on their own finance, rather than managing a fund; it is, however, increasingly common for business angels to group themselves in networks and syndicates to search for and make investments.

6.15 The advantages of business angel investment are similar to those for venture capital more generally: an angel can provide both the finance and the business experience where both might otherwise be lacking.[18] In addition, angels can fill a gap in early-stage financing, since venture capital funds will often not consider investments below a threshold (typically around £250,000), since search and due diligence costs can be lower for informal investors. There is some evidence of complementarity between the two forms of finance, venture capitalists providing expansion capital to firms that had earlier received angel finance.[19]

[17] "Informal Venture Capital in The UK", Mason, C.M. and Harrison, R.T. in Hughes, A. and Storey, D.J. (eds), *Finance and the Small Firm,* 1994. They found that 70 per cent of angels have founded more than one business.

[18] *The New Economy: Beyond the Hype – The OECD Growth Project,* OECD, 2001, pp 74–76.

[19] "The Financing of Entrepreneurial Firms in the UK: A Comparison of Business Angel and Venture Capitalist Investment Procedures", van Osnabrugge, M.S., Hertford College, Oxford, cited in Bank of England, The Financing of Technology-Based Small Firms: A Review of the Literature, *Bank of England Quarterly,* Spring 2001.

6.16 The Government introduced business asset taper relief in 1998, allowing significant relief from capital gains tax on longer-term business asset holdings, and has created a favourable environment for private wealth-holders to invest in new firms.[20] The Enterprise Investment Scheme, introduced in 1994, provides significant tax reliefs for private investors in small businesses and offers attractive incentives for business angels.

6.17 The amounts invested by business angel networks in the UK have more than doubled, from £14.1 million in 2003 to £28.9 million by 2005.[21] Though uncertainty exists over numbers, in 2000 there were estimated to be 20,000 to 40,000 business angels in the UK, making 4,000 to 6,000 investments annually, with a total value of between £0.5 and £1 billion. Angels are less inclined to invest in technology than formal venture capitalists, with 24 per cent of angel finance going to technology sectors, compared with 44 per cent of venture capital in the same survey period.[22] Only 5 per cent of angels are technology specialists.[23]

6.18 UK angels typically invest in a very small proportion of the opportunities they see.[24] This could reflect the low quality of many proposals, the lack of "investor readiness" of these businesses, the very significant risks involved in business angel activity, or a combination of these factors. It might, of course, simply reflect lack of money, but surveys tend to suggest that angels have substantially larger sums available for investment than are actually committed.[25]

THE ALTERNATIVE INVESTMENT MARKET, THE MAIN EXCHANGE AND INITIAL PUBLIC OFFERINGS

6.19 The Alternative Investment Market (AIM) was established by the London Stock Exchange in mid-1995 to provide a means for smaller and growing companies to access capital on a public market, potentially bringing them improved liquidity and access to more significant investment funds. The regulations for entry and trading on the market are less stringent than on the conventional stock exchange, with companies requiring no specific trading history or minimum size before listing. The intention was to provide a bridge between the types of finance often available to early-stage companies and those available for established firms.

[20] *Benchmarking Business Angels,* European Commission: Enterprise Directorate, November 2002, "Best practice case 3", p. 23.

[21] British Business Angels Association, *BBAA Statistics 2005;* BBAA at www.bbaa.org.uk Note that this is the amount invested through BBAA participating networks, not the total amount of angel activity, so is indicative only.

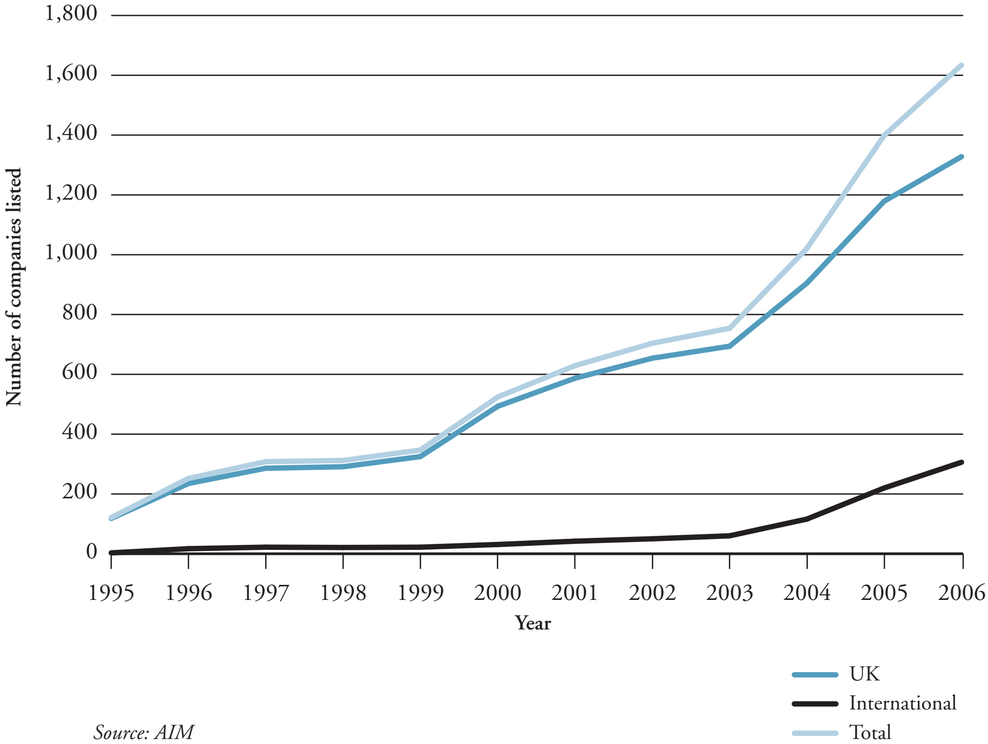
[22] "The Financing of Entrepreneurial Firms in the UK: A Comparison of Business Angel and Venture Capitalist Investment Procedures", van Osnabrugge, M.S., Hertford College, Oxford, cited in Bank of England, "The Financing of Technology-Based Small Firms: A Review of the Literature", *Bank of England Quarterly,* Spring 2001.

[23] Figure given in Bank of England, "The Financing of Technology-Based Small Firms: A Review of the Literature", *Bank of England Quarterly*, Spring 2001, p. 73.

[24] *Benchmarking Business Angels,* European Commission: Enterprise Directorate, November 2002, p. 11.

[25] "Supporting the Informal Venture Capital Market: What Still Needs to be Done?", Mason, C.M. and Harrison, R.T. Report to the DTI, cited in Bank of England, "The Financing of Technology-based Small Firms: A Review of the Literature", *Bank of England Quarterly,* Spring 2001.

Chart 6.5: AIM listings, 1995–2006



Source: AIM

6.20 Currently, 1,639 companies are listed on AIM, covering a very broad range of sectors (Chart 6.5). AIM has played an important part in supporting the growth of early-stage companies, providing investors with a clear exit strategy.

6.21 AIM attributes much of its success to the use of nominated advisors, or Nomads, who are appointed to every company listed and assist them through the processes of listing, trading and potentially eventual delisting and transfer to the main market. There are parallels between their role and that offered by some venture capitalists and business angels, in that Nomads attempt to advise and support their nominated companies, although their role is considerably more circumscribed by trading regulations and more clearly linked to the administrative processes of market registration and managing trading.[26]

[26] *AIM: The Most Successful Growth Market in the World,* London Stock Exchange (n.d.).

6.22 It has been suggested that some companies are encouraged to list too early in their life, with AIM acting as a substitute for venture capital funding. Nonetheless, recent signs are encouraging. A critical determinant of liquidity on a market is the presence of institutional investors able to deliver the very large capital sums that technology companies require for later-stage growth. Institutions have increased their share of the value invested in AIM from 35 per cent of the total in 2003 to nearly 67 per cent by the third quarter of 2006.[27] This suggests an improvement in AIM liquidity and the strengthening of the IPO market.

techMARK and the main market

6.23 The main London exchange is one of the world's leading stockmarkets, with an average daily traded value of £6 billion.[28] To facilitate and promote trading in high-technology shares, the London Stock Exchange maintains the techMARK index, consisting of high-technology companies listed on the main market. Conventional indices, such as the FTSE100, bracket firms by their size to give an average performance. techMARK differs in using a basket of firms selected by their output, enabling high-technology companies to be tracked against their peers and so allowing their performance to be more adequately assessed, promoting investment. By creating liquidity for high-technology investment at the very top end of the market, this should provide the backward linkages into smaller markets. The total IPO market was strong in 2006: over £17.7 billion was raised through public offerings, up 35 per cent from 2005. However, of this only 2 per cent was used to fund high-technology companies.

New models for university spin-outs

6.24 The past decade has seen a rapid increase in the number and quality of high-technology spin-out companies from UK universities (see Chapter 4 on knowledge transfer for further details). Evidence suggests that, whilst they have learned quickly in the past ten years, the performance of UK universities' Technology Transfer Offices (TTOs) is mixed, with substantial variation between the best and worst performers. Universities in regions with high R&D levels and GDP appear to be more efficient at technology transfer, implying that there are considerable cluster effects from university and high-technology company location.[29] Where these cluster effects are lacking, universities may find effective technology transfer a difficult task, especially given the relative inexperience of many offices.

6.25 In recent years, a number of hybrid operations have emerged to help bridge the gap between university knowledge creation and start-ups. There are now at least four distinct hybrid spin-out/licensing companies operating in the UK, including Intellectual Property Group (IG Group, formerly IP2IPO), bioFusion and ULive. In addition, the UK arm of Angle, a US specialist in intellectual property commercialisation, has signed a deal with the University of Reading to

[27] *Institutional Investors in AIM 2006*, Growth Company Investor in association with Teather and Greenwood, Summary available at www.londonstockexchange.com/NR/rdonlyres/E416463D-CB0B-4949-B33E-8F7DAFD3DAAA/0/InstitutionalInvestors4pp2006.pdf

[28] As of December 2006. "Exchange Completes Record-Breaking Year with a Spring", London Stock Exchange, 9 January 2007. Available at www.londonstockexchange.com/NR/exeres/F330C221-C907-40F5-9AA0-22CC7F41E70E.htm

[29] *Assessing the Relative Performance of UK Technology Transfer Offices: Parametric and Non-Parametric Evidence*, Rensslaer Working Papers in Economics #0423, Chappel, W., Lockett, A., Siegal, D, and Wright, M., December 2004. IP Group rapidly transfered into AIM and then onto the Official List, with less than three years between its first AIM listing in October 2003 and admission to the full London Stock Exchange list in mid-2006.

commercialise its intellectual property. All operate a similar, well-defined business model, signing long-term contracts with universities (or university departments) for exclusive access to their intellectual property. In effect, the partner university hands over an exclusive licence for its property, removing them from direct input into the commercialisation process.

IP Group

6.26 IP Group, established in 2001, helps its university partners establish routes to commercialisation for their intellectual property, whether through the creation of spin-outs or licensing. It now works with ten partner universities and, as of 31 December 2006, had established 53 portfolio companies from its partnerships, of which eight have listed on AIM, one on PLUS markets and two have sold to trade. In 2004, the IP Group acquired a dedicated venture capital company, Top Technology Ventures, and in summer 2006 launched IP Venture Fund (in collaboration with the European Investment Fund) to work as a traditional seed-finance provider alongside its core function as a facilitator between academics and entrepreneurs. Modern Biosciences, Modern Water and Modern Waste were all set up as subsidiaries to search out innovation opportunities within their broad, thematic areas, rather than marketing technology as it emerges in partner universities. IP Group rapidly transferred into AIM and then on to the Official List, with less than three years between its first AIM listing in October 2003 and admission to the full London Stock Exchange list in mid-2006.

bioFusion

6.27 bioFusion was established in 2002 to promote technology transfer from UK universities. In January 2005, it signed a £500 million deal with the University of Sheffield to promote high-technology spin-outs based on the university's intellectual property, granting bioFusion exclusive access to the university's intellectual property for ten years. bioFusion performs the same function as IP Group: matching up university intellectual property with finance, and with managerial and marketing experience, to create new companies and support their initial growth. In January 2007, bioFusion signed another ten-year deal with Cardiff University, on the same terms as the original Sheffield contract. At present, bioFusion maintains 24 companies in its portfolio, with rights to an estimated £114 million annual research spend across the two universities.

6.28 It is too early to fully assess the long-term prospects for such public–private sector partnerships, but most expect the "trend for innovation" in this field to continue.[30] Survey evidence from Library House into university technology transfer suggests that those universities who have outsourced their TTO operations are "very happy" with their deal; those whose TTOs remain in-house are more sceptical. These results are not too surprising. It is noticeable that a consensus among technology transfer managers appears to regard TTO outsourcing as more suitable for smaller universities with more limited deal flows. Library House concurred that "IP commercialization companies do seem to have at least the potential to deliver efficient technology transfer in partnership with small and medium universities".[31]

[30] See, for example, Quester's Report, *Building Viable University Spin-Outs,* October 2006.

[31] *Spinning Out Quality: University Spin-Out Companies in the UK*, Library House, March 2007.

THE ENTERPRISE INVESTMENT SCHEME

6.29 The Enterprise Investment Scheme (EIS) was established in January 1994 as the successor for the Business Expansion Scheme (BES), to encourage investment into small higher-risk companies. Subject to some restrictions, it provides investors in such companies with a range of tax reliefs, covering income tax and capital gains tax.

6.30 The amounts invested since the introduction of the EIS have been significant, and a substantial volume of capital has flowed through the EIS into new start-ups and early-stage companies (Table 6.3).

Table 6.3: Number of EIS companies and amount invested, financial year

	New companies	All companies	Number of subscriptions	Amount invested (£ million)
1996–97	474	651	11,809	94.3
1997–98	532	725	11,387	113.4
1998–99	1,036	1,267	15,341	294
1999–00	1,639	2,104	29,347	613.5
2000–01	2,376	3,311	45,709	1,061.0
2001–02	1,684	2,854	25,478	758.5
2002–03	1,336	2,452	27,613	666.4
2003–04	1,133	2,157	28,088	624.7
2004–05[a]	1,109	2,066	31,281	585.9
2005–06[b]	634	1,463	23,691	462.7
Total[c]	**12,902**	**20,285**	**262,097**	**5,418.70**

Source: HMRC figures
[a] *Provisional figures*
[b] *Provisional figures*
[c] *Total includes incomplete figures for 2006–07*

6.31 The measure has had some impact on the sectors where the risk capital market failures are claimed to be greatest – principally by incentivising the provision of risk capital to early-stage technology companies. Table 6.4 indicates that 55 per cent of new EIS share issues over 2005–2006 were for technology companies, as defined by the standard Trade Classification Numbers. Over the lifetime of the scheme, nearly one-quarter of EIS shares by value have been issued for technology companies at any stage of their life.

Table 6.4: EIS investment by sector and company age (percentage value invested)

	Percentage of investment in companies new to EIS	Percentage of all 2005–06 investment	Percentage all investment over lifetime of scheme
Technology	55	23	23.9
Manufacturing	25.5	13.4	14.1
Business services	19.5	14.8	11.7
Wholesale and retail		13.7	10.4
Entertainment and personal care		10.6	11.8
Hotels, bars and catering		7.5	8.8
Chemicals and pharmaceuticals		5.3	4.3
Transport		3.5	4.9

Source: HMRC figures

6.32 However, this Review has received submissions detailing the particular difficulties the speed of use requirement causes for some early-stage high-technology companies.[32] Standard EIS investment requires that companies begin trading within two years of receiving funding for the investor to receive the available tax reliefs, and that 100 per cent of money raised is spent within two years. Investors should not, however, be forced to invest too quickly, and biotechnology companies in particular work on much longer timescales: after initial investment, a typical business plan will require early-stage investment over a four to five year horizon, often running to very large sums, before trading takes place. The Bioscience Industry Association reports that two-thirds of its members claim this causes difficulties in acquiring funds.[33]

Recommendation 6.1

The conditions of the EIS scheme concerning the time constraints for the start of trading and the expenditure of money raised should be reviewed.

VENTURE CAPITAL TRUSTS

6.33 The Venture Capital Trust (VCT) scheme was started in April 1995. It is designed to allow individuals to invest indirectly in small, higher-risk companies by buying shares in a VCT that holds a portfolio of investments in smaller, unquoted companies. VCTs have a number of tax advantages designed to reduce the risks of investment in smaller firms. Like under the EIS, VCT investors can claim significant reliefs on their income and capital gains tax in relation to gains made.

6.34 VCTs have raised about £3 billion since the scheme's inception across a series of managers and vintages. Changes in regulation and tax policy have impacted on the amount raised each year with no long-term trends developing. For example, 2005–06 tax year saw the largest amount raised at £790 million, however this fell to £270 million 2006–07.[34]

[32] See for example Oxford Technology Management submission to this Review.
[33] BIA submission to this Review.
[34] Allenbridge Tax Shelter Report, 2007.

6.35 The tax incentives for investing in VCTs make a large difference to the performance of the funds for an individual high-rate paying investor. The average weighted performance of the VCTs from the 2001–02 tax year is 1.45 per cent per annum internal rate of reform (IRR), compared to FTSE all-share performance of 8.87 per cent per annum and AIM of 6.34 per cent. However, with the income tax reduction at purchase then the figures look more compelling. With a 20 per cent income tax relief the performance increases to 5.74 per cent, 8.41 per cent at 30 per cent relief and 11.58 per cent with a 40 per cent relief.[35] There is also no capital gains tax to pay subject to below conditions. These figures also hide the large differences between specific managers before the tax benefits are taken into consideration; the 2000–01 tax year had one fund returning 7.41 per cent whilst at the other end of the scale a loss of 19.71 per cent before 2004 when the fund was merged.

6.36 There has been a tendency in recent years towards an increase in the size of each investment. This may reflect the trend in venture capital more generally, as smaller investors become more wary of high-risk investment following the dotcom crash.

6.37 There has been a movement away from high technology to more risk-averse portfolios. There is again a large variety in managers, with some technology investments going into applying current science and some mixing high science investments with asset-backed investments to provide steadier returns.

6.38 The EIS and VCTs have been reasonably effective implements for channelling funds into new and early-stage companies, with some success in providing finance for high technology and other innovative sectors. Nonetheless, the assessment here is incomplete without the counterfactual: had they not existed, would the pattern of investment have differed?

The cost-effectiveness of the EIS and VCTs

6.39 Research commissioned from PACEC by HMRC suggests that for both the EIS and VCTs the bulk of funds raised would not have been raised without the schemes' existence. Although difficult to assess, PACEC estimates that around 57 per cent of EIS funding, and 82 per cent of VCTs' would not have been invested without the schemes (and the tax-privileges) in place. They estimate the tax foregone as being up to 66p for every additional £1 of EIS funding raised, and 41p of every additional £1 of VCT funding. In addition, there is qualitative evidence to suggest that the presence of both schemes enabled new firms to benefit from the managerial experience the EIS and VCTs mobilised alongside additional capital.[36]

6.40 Long-term investment may be needed to build and grow a high-technology business. There is scope for further refinement. The market pressures that push investors towards less-risky and shorter-term investments were identifed earlier in this chapter: a market failure exists in which and investors cannot always optimally price the risks involved in high-technology investments. Relatively small amounts of finance committed by private individuals, who – in addition to the finance capital – can bring valuable market and management experience to a new high-technology firm, are important.

6.41 The current system of reliefs available to business angel investors, principally in the EIS, was devised over a decade ago to deal with a generic market failure in the provision of finance for smaller, higher-risk firms and has proved broadly successful in that objective. But there are specific difficulties facing some new and early-stage high-technology companies.

[35] Allenbridge Tax Shelter Report, 2007.

[36] *Research into the Enterprise Investment Scheme and Venture Capital Trusts*, PACEC, April 2003 at www.hmrc.gov.uk/research/summary.pdf. Accessed 12 February 2007.

Young Innovative Enterprises

6.42 The EU has recently introduced a definition of Young Innovative Enterprises (YIEs), potentially allowing the creation of schemes to support new high-technology businesses that comply with state-aid rules. Tax reliefs and other forms of assistance can be provided. YIEs are companies up to six years old and investing a minimum of 15 per cent of their expenditures on R&D, and are therefore of particular interest to this Review.

Recommendation 6.2

Consideration should be given by government to utilising the Young Innovative Enterprises (YIE) definition to provide targeted support for investment in new high-technology businesses.

"FUNDS OF FUNDS" AND ENTERPRISE CAPITAL FUNDS

6.43 A "fund of funds" is a way to diversify risk among private equity investments. By pooling numerous discrete investments, the uncertainties attached to each can be spread out, in a manner similar to conventional portfolio investment. Placing the fund under expert management further reduces the risks involved. Of course, by diversifying risk (and paying management fees), potential returns are reduced: nonetheless, for more risk-averse investors, a fund of funds may be an ideal way to move into discrete, private equity investment. An example of a highly successful, government-backed fund of funds is given in the case study below.

The Yozma high-technology fund

The Yozma programme was established in 1993 to attract foreign investment into Israel's high-technology industry. Ten venture capital funds were established, each with $20–$25 million of total capital, the Israeli Government providing approximately 40 per cent of the capital. Each fund was charged with investing in high-technology companies A substantial inventive was also provided by giving investors the option to buy out the Government's share at a fixed price after five years.

A total of $210 million was under fund management at the scheme's close, and Yozma made 15 direct investments in high-technology new businesses, of which nine led to successful IPOs. Nine of the ten funds exercised their option to buy out the Government share, indicating the scheme's success. Yozma has been attributed with playing a major role in establishing the thriving Israeli venture capital industry, now worth over $10 billion with 80 separate venture capital funds.

Critical to the success were the presence of government funds, which provided credibility, and the significant incentive effect provided by the five-year option to buy.[37]

6.44 The UK High Technology Fund was established by the then Department of Trade and Industry (DTI) in 2001 as a 13-year fund of funds aiming to encourage investment, especially by institutional investors, in high-technology venture capital. Part of the impetus for this came from the Myners Report into institutional investment, which noted the apparent disinclination for UK institutional investors to put money into smaller venture capital deals. A sum of £20 million was allocated by the DTI, with £106 million eventually being invested by 23 private sector institutional investors, mainly within the UK. The entire £126 million fund was managed by Westport Private Equity after a competitive selection process.

[37] Taken from *The Emergence of Innovative Clusters: Lessons from the Israeli experience*, Teubal, M., June 2006. Available at www.trabajo.gov.ar and *Yozma Program,* Israel Venture Association. Available at www.iva.co.il/content.asp?pageId=37

6.45 Two principal conditions were placed on the Fund: first, it needed to meet an IRR of 10 per cent: if less than this was earned, up to £20 million could be paid back by the DTI. This arrangement removed a substantial part of the risk for private investors. Second, investments from the Fund had to live up to the Fund's name by investing in UK high-technology businesses.

6.46 The Fund's lifetime has not yet expired, so it is too early to make a conclusive assessment. By UK high-technology standards, returns to the Fund have been impressive: but they have (as is usual for the sector) taken a long time to mature, meaning the Fund is unlikely to reach its 10 per cent hurdle rate. The Fund has stimulated interest in the asset class, and encouraged institutional investors to stay in that asset class, while Westport has demonstrated the commercial viability of such ventures by launching its own, privately financed fund of funds. By encouraging institutional investors into early-stage venture capital, a well-supported fund of funds can both increase the supply of capital to needy early-stage companies and help sustain a well-informed and effective venture capital community. It should be recognised by the Government, however, that returns to such investments will not be immediate, requiring a long-term commitment to deliver funding. Funds' success measures should reflect this.

6.47 Enterprise Capital Funds (ECFs) were established following the *Bridging the Finance Gap* consultation. The first round of funds, Pathfinder, launched in 2006, was backed by £81 million of Government money. In an ECF the Government will provide up to twice the amount of private investment raised but will take a lower share of the profit of each fund. This gearing enables investors in successful funds to achieve a higher return on their investment than they would otherwise. By enhancing the private investors' potential return in this way, the Government hopes to improve the attractiveness of equity gap funds to investors.

6.48 Restrictions on investments made using ECF money are intended to ensure monies are targeted where there are market failures: no single investment can exceed £2 million and only qualifying SMEs with high growth potential are eligible. The involvement of professional fund managers and private investors ensures that investments are made on sound commercial terms.

6.49 The Pathfinder competition for ECFs sought to test the attractiveness of the model for UK investors. It attracted 45 bids, many of which had strong private investor backing. The independent Capital for Enterprise Board eventually recommended that five funds be awarded ECF status. Those funds are targeting investments in: sustainable technology, life sciences and high-technology firms; firms at an early stage of development; and more generally in SMEs with high growth potential. A second-round competition closed in February 2007, with successful funds to be announced later in the year.

6.50 This Review considers that ECFs are a promising means to deliver very-early-stage financial support, encouraging venture capital into the asset class. Initial reports indicate that they are effectively fulfilling the role played elsewhere by dedicated technology funds of funds and should continue to receive support.

PROOF-OF-CONCEPT FUNDING

6.51 Many potential business ideas and incipient technologies emerge from academic research, but since most research funding is directed at the publication of new knowledge, it is not used to further develop the technologies or business ideas. At the same time, private investors and institutions can be wary of investing in very high-concept projects, perceiving the risks to be too high to justify their commitment.

6.52 There is therefore a case for proof-of-concept funding provision by public sector institutions such as the Government or Regional Development Agencies (RDAs). Feedback from businesses, advisors and venture capitalists suggests that the most effective form of support for early stage innovators (particularly in the technology sector) is the proof-of-concept model.[38] Successful funds have worked closely with participating universities, and some have attracted small amounts of private financing.

Scottish Enterprise proof-of-concept

6.53 One of the most successful examples of such a scheme is Scottish Enterprise's Proof-of-Concept Fund, established in 2000 to provide funding for researchers in Scottish universities, research institutes and the NHS. In total, £50 million has been set aside for the Fund, with £39 million from the Scottish Executive and £11 million from the European Regional Development Fund. So far, £30 million has been paid in seven funding rounds to 172 projects (from more than 750 applications); however, alongside the money, the fund has also provided mentoring and some business support for researchers, helping to ease the move towards commercialisation. To date, 27 new companies have been formed, with ten more in the pipeline, and 23 licences have been granted from proof-of-concept funded projects.

6.54 Table 6.5 shows the outcomes after seven rounds of funding.

Table 6.5: Outcomes from Scottish Enterprise proof-of-concept fund

Status	Number	Finance provided by Scottish Enterprise (£ million)	Finance leveraged (£ million)
Spin-outs/Start-ups	27	4.8	21.0
Stand-alone licences	5	0.6	0.5
Collaborations	7	1.1	5.4
Progressing to commercialise	31	5.2	5.5
No commercial outcome	41	5.8	1.5
Total	**111**	**17.5**	**33.9**

Source: Scottish Enterprise

6.55 According to a PwC evaluation of the Fund, over its first six rounds (2000–05), over £124 million of extra value-added was created from around 184 proof-of-concept projects, creating 500 jobs. Eighty per cent of these, in PwC's estimation, would not have existed without the additional funding. The fund attributes its success to rigorous budgetary control over projects and to active commercialisation support, with dedicated project management groups overseeing each successful application.

[38] Submission from Design Council, CBI, NESTA, EEF, UNICO, IFM.

6.56 Although there have been some criticisms of the Fund, not least when an early spin-out, Essient Photonics, collapsed in 2003, its demonstrable success has prompted calls for UK-wide schemes to match what some RDAs are already attempting. One Northeast, for example, provides finance for the North East Proof-of-Concept fund, offering loans up to £60,000 to technology SMEs and those "within the North-East's research base".[39] The scheme is linked to regional Centres of Excellence, which are business- and university-led support networks that provide laboratories and office space to develop early-stage technologies. Universities in London have established the Heptagon Fund, covering life science proof-of-concept in colleges with substantial life sciences engagement,[40] and the Emerald fund, covering creative industries' proof-of-concept development.[41]

Recommendation 6.3

A nationally agreed specification for proof-of-concept funds should be developed subject to the Business Support Simplification Programme (BSSP), drawing on current best practice. It should cover:

- rigorous project management and budget control over funded projects;
- well-defined outcomes and objectives for the fund;
- carefully specified application criteria and independent assessment of commercial potential;
- a strong focus on strengthening "investor readiness"; for example, access for entrepreneurs to managerial and investment expertise through a dedicated mentor; and
- awards to bring access to facilities (e.g. linked to Enterprise Hubs and Centres of Excellence) to support concept development.

6.57 The specification could be run through the RDAs (see Chapter 10), who would provide resources for the three elements: funding, mentoring and facilities. Science and Innovation Councils should oversee the programme along BSSP nationally agreed lines.

[39] See description at *North East Proof of Concept Fund* at www.onenortheast.co.uk/page/proofofconceptfund.cfm. Accessed 19 March 2007.

[40] These are Queen Mary, University of London (lead), King's College London, Royal Veterinary College, St Georges Hospital Medical School, School of Pharmacy, Birkbeck University of London, London School of Hygiene and Tropical Medicine and Institute of Cancer Research.

[41] Colleges involved in Emerald are London Metropolitan University (lead), London South Bank University, City University, Goldsmiths University of London, University of Greenwich, University of East London, Middlesex University and Ravensbourne College of Design and Communication.

7 Educating a new generation of young scientists and engineers

DEMAND AND SUPPLY OF SCIENCE, ENGINEERING AND MATHEMATICS (STEM) SKILLS

7.1 Business relies on world-class skills to innovate and compete, and evidence suggests that the UK's productivity gap with countries such as France and Germany is partly linked to the relatively poor intermediate skills of workers in the UK.[1] It is not possible to predict future economic conditions with certainty, but we can be sure that demand for skills will grow inexorably. In a world in which the UK's competitive advantage will depend increasingly on innovation and high-value products and services, it is essential that we raise the level of our science, technology, engineering and mathematics (STEM) skills. Policy-making in many areas of government also requires a supply of creative young scientists and engineers.

7.2 Compared to other OECD nations, the UK has a reasonable stock of STEM graduates.[2] However, a closer look at the situation reveals some potential problems ahead.

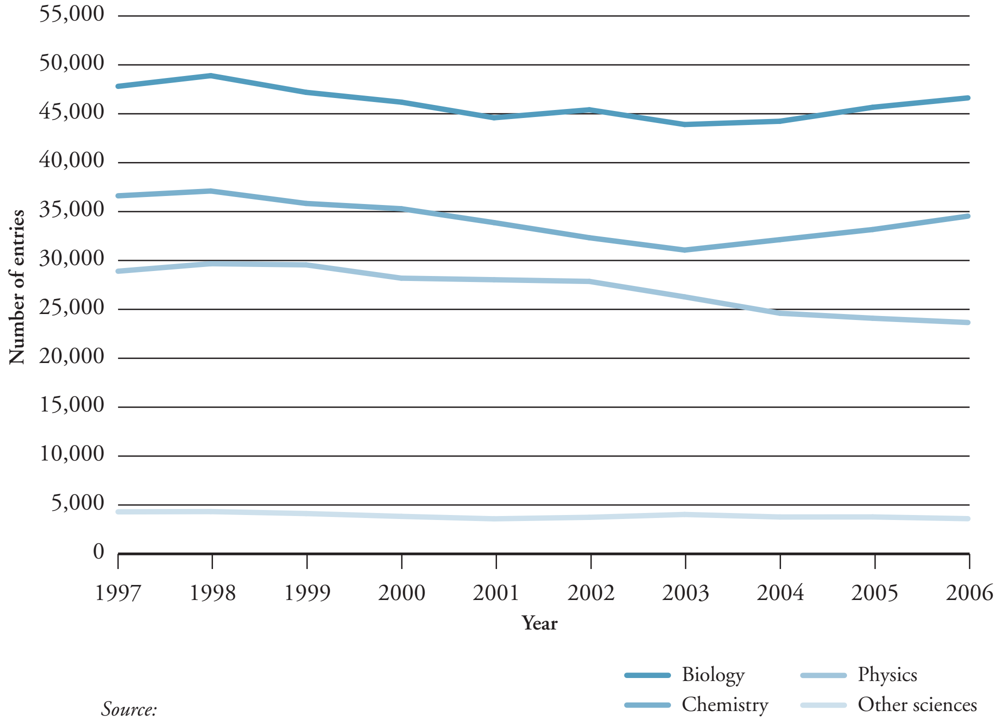
7.3 If we break down the headline figures of graduates, a mixed picture emerges, with a worrying decline in certain key subjects, including chemistry, engineering and technology. At the same time, the numbers of graduates in forensic science, psychology and sports science have increased very rapidly in recent years.

7.4 Looking to the future, the pipeline of STEM students is a concern. In the past three years there has been a recovery in the number of students taking A-level biology and chemistry. As a result the 10-year picture shows only a modest decline. In the case of A-level physics we are looking, however, at a 20-year decline. The number of students taking A-level mathematics fell in 2001–02 and is now recovering.

[1] *Prosperity for All in the Global Economy: Review of Skills*, Leitch, S., December 2006.

[2] *Economics Paper No. 16: Science, Engineering and Technology Skills in the UK*, DTI, March 2006.

Chart 7.1: A-level entries for science subjects at schools and colleges



Source:

7.5 The UK also has a poor level of intermediate and technician-level skills. In OECD comparisons of 30 countries, we score eleventh on "high" but only twentieth on "intermediate" skills.[3] The Leitch Review noted that in spite of improvements over the past decade, the proportion of adults in the UK lacking at least a Level 2 qualification is more than double that of the best performing countries. This is a serious concern and the Leitch Review proposed a number of major reforms to tackle the situation.

7.6 The Ten-year Framework (July 2004) and Next Steps document (March 2006) announced measures to address the STEM skills challenges and signs of progress are now emerging. The total number of people recruited to train as science teachers in 2006–07 was 3,390 (compared with 3,060 in 2001–02). In mathematics the total number starting to train as teachers was 2,290, compared with 1,860 in 2001–02.

7.7 However, there are significant shortages of qualified teachers in key subjects, and it is clear that more needs to be done urgently. Our analysis suggests that solutions can be found and this chapter outlines specific ways to achieve a step change in the supply of STEM skills.

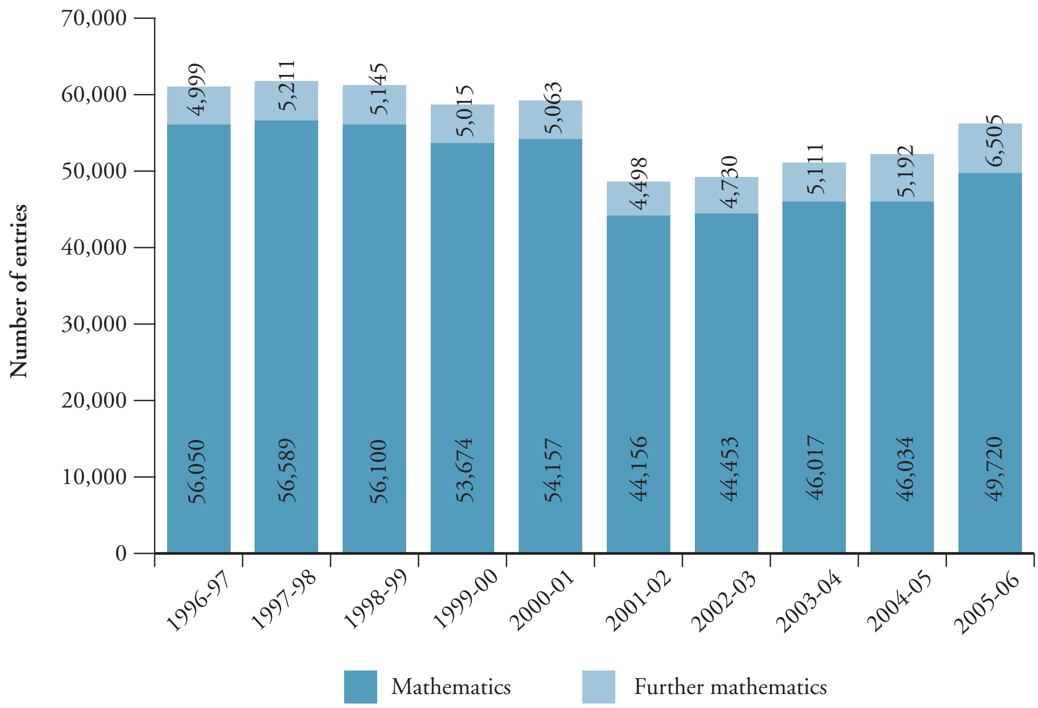
[3] *Prosperity for All in the Global Economy: Review of Skills*, Leitch, S., December 2006.

SCHOOLS

7.8 Students' experiences at an early age have a significant impact on their future choices and there is widespread concern that pupils are turning away from STEM subjects following their experiences at school. At A-level the take-up of key subjects is a cause for concern. A detailed analysis reveals that there are a number of different factors in play.

7.9 In the case of A-level mathematics, the decline is being addressed and there is a simple explanation for the pattern. Factors associated with the change in the curriculum in 2000 dissuaded significant numbers of students from choosing to go on to study A-level mathematics. The problem was identified and, in September 2004, the curriculum was revised. The results in Chart 7.2 speak for themselves: this was not a case of students disliking a difficult subject, but an error in the AS syllabus. Of particular interest is the rise in the number of students taking further mathematics, which has risen sharply after steps were taken to make access to the course more widely available.

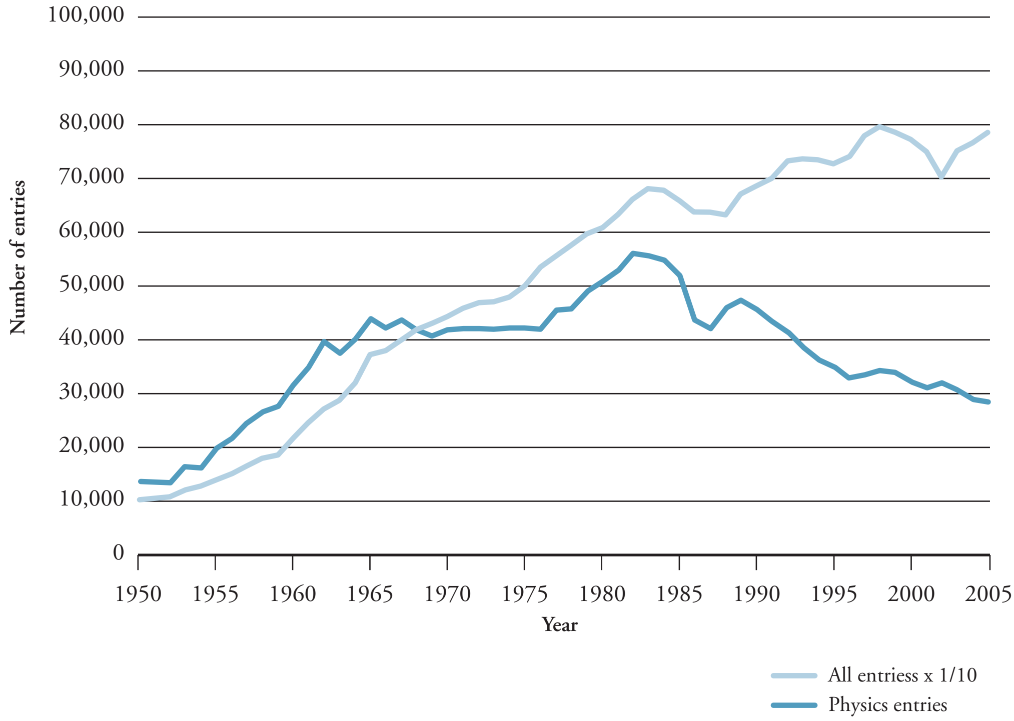
Chart 7.2: A-level mathematics and further mathematics
Number of 16–18 year old entries



(1) 2005/06 figures are provisional

7.10 The take-up of A-level physics, however, has undergone a 20-year decline (see Chart 7.3). In 1990, with the introduction of Double Award Science as part of the National Curriculum, it became compulsory to study science until the age of sixteen. However, Chart 7.3 shows that in the late 1980s the take-up was beginning to improve, but then from 1990 a rapid decline began which has, as yet, not been turned around. A decreasing number of qualified physics teachers is likely to have contributed to the decline.

Chart 7.3: The 20-year decline in pupils studying A-level physics



Sources: Education in England and Wales, Report and Statistics 1951-1977; Statistics of Education School Leavers CSE and GCSE 1978-84, Inter-Awarding Body Statistics for England, Wales and Northern Ireland, Joint Council for Qualifications 1985-present.

7.11 There are five areas where this Review believes that action is critical to improve the situation in schools: the qualifications of teachers; the school curriculum; careers advice; laboratories and practical work; and STEM enrichment schemes. We also believe that care must be taken with the introduction of the second mathematics GCSE in 2010.

IMPROVING THE NUMBER OF QUALIFIED STEM TEACHERS

7.12 Teacher quality is clearly fundamental to pupil attainment. Smithers and Robinson (2005) have demonstrated that the qualification of physics teachers was the second most powerful predictor of pupil achievement in GCSE and A-level physics after pupil ability (measured by prior attainment).

7.13 However, the Roberts Review (2002) reported that almost one-third of the head teachers surveyed in the UK felt that a shortage or inadequacy of teachers was hindering the learning of pupils in mathematics, and almost one-quarter held the same view with regard to science. This compared with around one-tenth in OECD countries.

7.14 The Next Steps document set out the ambition by 2014 to achieve: 25 per cent of science teachers with a physics specialism, 31 per cent of science teachers with a chemistry specialism and 95 per cent of mathematics lessons in schools to be delivered by a mathematics specialist.

7.15 A number of initiatives were taken by Department for Education and Skills (DfES) to improve the situation: new incentives of £1,000 per recruit to attract more physics and chemistry teachers, increased Golden Hellos and training bursaries, and a Student Associate scheme to give science and mathematics students at university a taste of teaching to encourage them into the profession.

7.16 However, there is clearly still a long way to go. According to the National Foundation for Educational Research (NfER) (2006),[4] less than one-third of those teaching the physics element of Double Science have a degree in physics or have specialised in it through Initial Teacher Training (ITT).

7.17 We therefore welcome the fact that the then-DfES developed plans to reach the target numbers of qualified STEM teachers by 2014.

Recommendation 7.1

Progress in achieving this plan will be monitored by the Department for Children, Schools and Families (DCSF) on an annual basis and corrective action will be taken if it looks as if the targets will not be met. This Review recommends that this could include financial incentives being offered to teachers during their first five years to address critical retention issues.

If experience shows that, with the expenditure of further funds, the target dates can be brought forward, we recommend that the necessary resources are made available. Clearly the shortage of qualified teachers must be rectified as soon as possible.

ACHIEVING THE PLAN

Teacher recruitment and retention

7.18 Recruitment to science ITT has improved significantly over the past five years, with especially strong growth in physics and chemistry. The Government is broadly in line to meet the demanding 2014 targets, so long as recruitment growth is maintained and teacher retention does not worsen. However, the gains of the past few years are fragile, and efforts to build on them are made more difficult by the fierce competition among employers to recruit new graduates.

7.19 Teach First has been recruiting top graduates to teach in schools in challenging circumstances since 2003. By 2009, it will expand from its current base in London, the Midlands, and Manchester to cover schools in Liverpool and in Yorkshire and the Humber. Around 80 per cent of Teach First placements are for teaching in shortage subjects, including STEM. Building on the success of Teach First in recruiting high-quality teachers in these areas, the Government recently announced that it would consult on a new "Teach Next" programme to promote mid-career routes into teaching, especially for people from industry and the sciences.

7.20 New routes such as the employment-based Graduate Teacher Programme are also buoying up physics and chemistry recruitment. To secure recent gains, and make even faster progress towards the 2014 targets, people with degrees in subjects that are related to, but beyond, pure physics or chemistry need to be attracted to teaching. They will then require adequate training to enable them to be good teachers in these subjects. Successful programmes exist for this purpose, but are not yet being fully exploited.[5]

[4] *Mathematics and Science in Secondary Schools Research Report 708*.

[5] There are a large number of degree subjects that could be sourced for physics or chemistry enhancement. These include forensic and archaeological science, astronomy, geology, oceanography, geographical and environmental sciences, engineering subjects, naval architecture, metallurgy and minerals, materials and maritime technology.

7.21 Since 2004 the Training and Development Agency (TDA) has supported pre-training enhancement courses in mathematics, physics and chemistry. Over 1,100 trainees have now completed these courses, with a full 90 per cent going on to ITT. Evaluation showed these trainees to be excellent teachers who are often among the first to find jobs.

7.22 To meet the targets in the Science and Innovation Framework for 25 per cent of science teachers to have a physics specialism and 31 per cent to have a chemistry specialism by 2014, it would be necessary to recruit more than 1 in 5 graduates (21 per cent) in each subject each year. By targeting graduates in related subjects and using enhancement courses to update their knowledge, we would only need to recruit 1 in 33 graduates (3 per cent).

7.23 In order to increase the number of subject-enhancement places, and involve a wider range of universities in the provision, the TDA is introducing new, more flexible types of courses. As a first step, from 2007–08 it will fund extended postgraduate courses ranging from 18 months to 2 years. The additional input focuses on chemistry, mathematics and physics. An additional bursary of £7,000 is paid for the extension.

7.24 As a second step, the TDA is proposing to bring together all subject-enhancement work in a modular programme, linked to individual needs. This would allow the level of enhancement in physics, chemistry and mathematics to be increased from the current planned level of 1,000 places to 1,500 places a year, securing faster progress towards the 2014 targets. This proposal should be considered if targets for the DCSF plan are not being met.

7.25 Even if recent recruitment successes are maintained, skilled teachers leaving the profession could still threaten progress. Retention is a major challenge for schools, especially for those in challenging circumstances, and can have a direct impact on pupil attainment. The NfER has shown that the length of time in post of heads of science departments can have a significant impact on GCSE attainment. It found that schools in the lowest band of GCSE achievement had the largest representation of heads of science departments with less than five years' experience.

7.26 The figures on retention are a cause for concern. For example, almost half of all physics teachers leave within their first five years of teaching. The problem can become self-perpetuating. A shortage of science teachers and the high rate of turnover tend to result in rapid promotion of science teachers. Anecdotal evidence suggests that this accelerated career progression can leave some teachers with insufficient support or experience to perform their role.

7.27 The NfER found strong evidence that a pilot of early professional development "made a very positive impact on participating teachers". The Institute of Physics (IoP) has also been working to provide support for science graduates through the Physics Enhancement Course (see the following box).

Institute of Physics Mentoring Scheme: The Physics Enhancement Course

The scheme consists of three phases: an initial intensive six-month course designed to strengthen subject knowledge, a PGCE course at any centre or school-based training and a follow-up mentoring programme for the first two years of teaching after qualifying. The mentoring has been relatively light touch, making regular contact with participants to check on progress and informing them of opportunities that might be of interest, but tailored to suit individual needs. The sense of community that has been fostered by this scheme appears to be important. Of those that attained Qualified Teacher Status in 2006, from the second pilot cohort, over 92 per cent entered the teaching profession, compared to 84 per cent that entered through traditional ITT courses in England.

Feedback from participants has been very favourable: "The support made available to me from the IoP during my first year of teaching has been wonderful. The range of courses they provide has been very impressive, contact from my local representative about up-coming local events, regular contact from the IoP mentor asking how the year has been going and offering support and advice. The conferences and training days have been a fantastic networking opportunity and have provided lots of useful tips and ideas from the trainers but also from colleagues that you meet up with. All in all, knowing that you have the support of a dedicated and experienced team has made the first year better for me and also better for the kids, as all the things I learn at the events that I think are fun the kids think are great. My head of department (a chemist) has said that he wishes there was a similar scheme available for him."

Recommendation 7.2

A mentoring scheme should be rolled-out nationally along the lines of the IoP scheme to increase support for newly qualified science teachers. We believe that the relevant professional bodies would be keen to support such a programme.

Financial incentives

7.28 In view of the shortage of physics and chemistry teachers and the fact that attractive alternative job opportunities are in many cases available to them, it is essential that there is sufficient flexibility in the pay system to attract and retain them.

7.29 The independent School Teachers Review Body (STRB) believes that there is sufficient flexibility in the pay system to address local teacher shortages in priority subjects, and that the problem lies in the fact that the flexibilities are not used. The STRB believes that the answer to this problem lies in effective support for local managers, a sharper framework of accountability and effective school budgets. This Review strongly supports the greater use of pay flexibility to address local teacher shortages in priority subjects.

7.30 The STRB has also recommended that teachers receive a financial incentive for completion of accredited courses in priority subjects designated by the DCSF.

7.31 This will help to meet stretch targets for teacher recruitment. Current arrangements allow teachers to have the opportunity to undertake continuing professional development (CPD) for accredited disciplines in school holidays should they wish to do so, and be paid for undertaking CPD outside the school day. Teachers should be encouraged to take this route if it is not possible to release them during term time.

Recommendation 7.3

In line with the STRB's recommendation, financial incentives should be introduced to encourage the take-up of conversion continuing professional development courses to help meet stretch targets for teacher recruitment.

Recommendation 7.4

The self-evaluation form that schools complete prior to inspection should prompt schools to set out any difficulties in recruiting and retaining staff, with specific reference to mathematics and science teachers. This will allow Ofsted inspectors to have a more informed discussion with head teachers to agree how to tackle any shortages.

Continuing professional development for teachers

7.32 The STRB has stressed that the most important tool in addressing teacher quality issues is their CPD. In equipping teachers better for their job, CPD also increases their job satisfaction and boosts retention.

7.33 More needs to be done to improve the general culture towards CPD in schools. Much CPD takes place within schools: this has the advantage that it can be focused on specific school needs, and it can minimise disruption. However, the majority of school-based CPD is often of a generic kind rather than subject-focused.

7.34 While we accept the importance of school-based CPD, we believe that out-of-school, subject-focused CPD has an important role to play in enhancing the subject knowledge and teaching skills of science teachers. The teachers we consulted as part of the Review told us about the difficulty of getting out of school to engage in CPD, but also emphasised the need for a sustained programme of CPD. We were told that "twilight" sessions have very limited effect and heard calls for teachers to have access to sabbaticals. We believe that serious thought should be given to the content and delivery of CPD so that teachers are further convinced of its importance and are better able to attend the programme.

7.35 CPD is provided through a range of providers, including the Science Learning Centres, Secondary National Strategy, the Specialist Schools and Academies Trust, subject associations, Higher Education Institutions (HEIs) and local authorities and this fragmentation of provision may be a barrier to take-up. There are many CPD initiatives and resources for teachers of mathematics and science but information about these is scattered across different organisations' websites and is often hard to find. The Review believes that more can be done to improve the accessibility of CPD. The framework of ten schemes detailed below will help in this.

7.36 Other barriers to take-up of CPD include lack of incentives for teachers to participate, cost, and varying attitudes of teachers and head teachers to CPD. Evidence submitted to the House of Lords noted that many schools struggle to find or pay for supply teachers to cover staff undergoing external CPD.

Science Learning Centres

7.37 The network of Science Learning Centres provides subject-focused CPD for science teachers and complements school-based training, providing access to equipment and expertise that is often unavailable at school level. In 2006–07 all the Science Learning Centres met their teacher training targets and many exceeded them, and we should build on this success.

7.38 We believe that the initial success of the national and regional Science Learning Centres provides an opportunity to improve the quality and relevance of CPD for science teachers, and to increase its uptake. External evaluation shows that 92 per cent of participants would recommend the course they attended, and there is early evidence of impact on teachers' subject knowledge, teaching skills and ability to engage learners more effectively.

Recommendation 7.5

DCSF should commit to the long-term funding of the Science Learning Centre network. The National Science Learning Centre should be given a leadership and co-ordinating role for the network, and resources should be made available to pay for supply cover costs for schools that have a shortage of well-qualified science teachers. Industry, the professional scientific institutes, and the Wellcome Trust are keen to provide support for the network of Science Learning Centres. A high level advisory group should be set up for the network with each of these organisations represented, as well as teachers and government.

CURRICULUM CHANGES

7.39 The curriculum should provide all pupils with sufficient understanding of scientific and mathematical principles and should also inspire young people to study STEM subjects further. Schools began teaching the new Key Stage 4 programme of study for science in September 2006. Additional training and support is being provided by the Science Learning Centres, the Secondary National Strategy, the Association for Science Education and the Specialist Schools and Academies Trust. The Qualifications and Curriculum Authority (QCA) is undertaking a wide-ranging evaluation of the changes made to the Key Stage 4 curriculum from September 2006. An interim report is expected in Autumn 2007. The QCA has convened meetings of independent scientists and engineers to advise on how the new Key Stage 3 curriculum can stretch the most able pupils and will be involving them in the evaluation of Key Stage 4 later in the year.

7.40 The revised National Curriculum programmes of study for Key Stage 3 have been published and will be introduced into schools for first teaching from September 2008. The new curriculum is based on the need for all young people to acquire relevant subject knowledge, skills and understanding, including high-level skills in literacy, numeracy and scientific understanding. The new science curriculum brings Key Stage 3 into line with the changes which have already taken place at Key Stage 4.

7.41 The chance of getting an A or B at A-level chemistry in the maintained sector is increased by 76 per cent for pupils who take three separate science GCSEs rather than studying double science. As a result of this and other evidence, the Government introduced an entitlement for all pupils achieving at least level 6 at Key Stage 3 to study triple science GCSE, which will come into effect from September 2008.

Recommendation 7.6

Government should continue its drive to increase the number of young people studying the three sciences as separate GCSEs.

Recommendation 7.7

The school profile, which provides valuable information for parents, and the accompanying guidance should be amended to encourage schools to provide information about whether they offer triple science.

IMPROVED CAREERS ADVICE

7.42 Good careers advice is critical for pupils to be able to understand the opportunities available to them and to raise their aspirations. Careers advice should be firmly rooted in the labour market (present and predicted future) and careers advisors should have excellent knowledge of both these trends and of the learning routes to get there. There is a widespread consensus across the UK private and public sectors that the careers advice on offer in this country is severely lacking. The Government has taken some measures to try to address the issue: for example, the 14–19[6] and Youth Matters[7] White Papers set out reforms of information, advice and guidance. However, much more needs to be done.

7.43 The existing Connexions service focuses on the most disadvantaged pupils and the National Audit Office (NAO) has highlighted that more could be done to improve access to advice and guidance for all young people. They also found that in two-thirds of schools sampled, staff delivered careers education without any formal qualifications in the field.[8] Research has shown that three-quarters of careers advisors had no qualification in mathematics or science beyond GCSE. These findings were all confirmed by the recent House of Lords report *Science Teaching in Schools*.

7.44 In addition to being insufficient and of inconsistent quality, existing careers services provide advice too late to students. Evidence shows that pupils decide what to study at a young age, often before they are 14 years old.[9] Yet the existing school and university careers guidance system is largely configured to provide advice close to the formal decision ages (16, 18 and beyond). Careers opportunities are closely related to subject choice, yet the two are not well integrated.

7.45 There is evidence[10] that a range of agencies influence students when thinking about future options, and that parents and subject teachers can have a greater influence on choice than the formal careers guidance system. However, students and parents often have a poorly informed view of science and engineering jobs and their rewards. They have a narrow view of the range of careers that are open to those who choose STEM subjects, limited to those in the immediate STEM field (scientist, engineer) and overlooking the fact that STEM qualifications open the door to a wide range of well-paid jobs in, for example, banking, the media and business. It is therefore important that careers advisors have a good knowledge of these options.

[6] *White Paper: 14–19 Education and Skills*, DfES, February 2005.

[7] *Youth Matters*, July 2005.

[8] NAO Connexions Service, *Advice and Guidance for All Young People*, 31 March 2004.

[9] For example, "Taking a leading role", a survey of 1,141 scientists and engineers conducted by the Royal Society, found that 63 per cent of them first began thinking about working in STEM by the age of 14.

[10] For example, evidence is given in *Factors Affecting Students' Choice of Subject*, prepared by the DfES Research and Analysis Division for the STEM Strategy Group.

7.46 Better awareness of the wide range of worthwhile careers opened up by school STEM subjects can lead more students to opt for STEM subjects at 14 (GCSE and the future specialist diplomas), 16 (A-level and other Level 3 qualifications) and 17 (higher education). Improved awareness of the range of STEM careers, and the contribution they can make to enhancing human well-being and to addressing major global challenges, could also help to counter the imbalance in STEM participation by under-represented groups, particularly girls in physics and engineering, and some ethnic minority groups in specific STEM areas.

7.47 Pupils themselves recognise the problem. An ICM survey showed that two-thirds of university students across the UK[11] wished that they had been given better careers advice at school. The NfER report *How Do Young People Make Choices at 14 and 16* also observed that young people would like more detailed, clear information on options for Key Stage 4, particularly on subject content. The report also highlighted the importance of teacher involvement in the decision-making process.

7.48 The Review welcomes the development of the "Careers from Science" initiative, which aims to provide an effective source of careers guidance for pupils, teachers and parents. The structure of the website and its associated teaching activities, designed to guide pupils from 11-19 from the subjects they enjoy to a multitude of diverse careers, will help to address any misconceptions and will illustrate the wealth of well-paid, exciting opportunities available to those with STEM skills. Material from the website will also link to CPD initiatives for teachers. The Science Council will run the initiative in partnership with stakeholders across the STEM community.

7.49 However, a website alone will not solve the problem. A widespread marketing campaign of presentations and leaflets to schools, parents, teachers and children will be necessary to make the website known. And, more broadly, careers guidance needs to become a core part of our education system, built into the training of teachers and the everyday activities of students and teachers.

Recommendation 7.8

STEM careers advice should be built into the school curriculum. To support this, teachers need to be given greater support in delivering careers advice and therefore we further recommend that careers advice is built into CPD for teachers.

7.50 Many organisations are already painfully aware of the problems associated with careers guidance, and are ready to help. And partnerships with key stakeholders, including employers, universities, learned societies and Research Councils, are important to demonstrate to young people some of the exciting and inspiring opportunities that studying science can lead to, and are an important part of careers advice. Many businesses, for example, are already involved in organising company visits, mentoring schemes and in producing learning materials. Expansion of extra-curricular activities, such as the Science and Engineering Ambassadors programme (see box on page 14), in which industry employees come into schools and universities, will also help bring STEM careers to life. As will an annual update on the destination of leavers from higher education (HE), which this Review recommends be produced.

[11] ICM Survey 2006, undertaken for the Association of Colleges National STEM Careers Co-ordinator.

7.51 However, schools can often be overwhelmed by the opportunities available to them, or, more worryingly, unaware of them. The Review welcomes the recent DfES announcement of a package of actions, including the appointment of a National STEM Careers Co-ordinator.

7.52 Large companies in particular have indicated their strong support for improving careers advice and we recommend that the new co-ordinator works closely with them to take advantage of their enthusiasm to help.

Recommendation 7.9

When the National STEM Careers Co-ordinator takes up the new post in April 2008, he or she should be attached to the Science Learning Centre network and be responsible for driving forward the careers advice agenda and co-ordinating activities to ensure that a uniform approach, which is accessible to all, is adopted.

7.53 The reformed careers advice service in schools should ensure that it caters for vocational as well as academic opportunities, to help address the serious shortages of skilled workers facing UK industries, such as construction and manufacturing, and the low apprenticeship completion rates. Businesses value these apprenticeships highly and yet a survey by the Engineering Employers' Federation (EEF/SEMTA) showed that only one in five pupils were advised to apply for apprenticeships and 83 per cent of students were given little or no information on apprenticeships. Addressing this issue will be vital to boost the numbers of skilled workers and to ensure that the new diplomas do not become a second-class choice for the disaffected.

Recommendation 7.10

The policy advice from the DCSF to schools should indicate the sort of careers advice and timing that students should expect to receive.

BETTER LABORATORIES AND PRACTICAL WORK

7.54 The DCSF is funding Project Faraday to review the Building Schools for the Future (BSF) exemplar designs for school laboratories and to ensure they reflect the latest thinking on what is required to ensure effective interactive teaching. The aims of Project Faraday are to:

- support, through excellent and appropriate facilities, the drive to improve attainment levels in science, encourage more young people to take science at higher levels and help to reverse the recent decline in numbers taking science at A-level and at universities;
- explore the ways in which the whole school building and its grounds, not just the laboratories themselves, can enable and enhance innovative and interactive methods of teaching science;
- develop design ideas that can act as "exemplars" for science provision, to inspire and inform all future building projects; and
- fully reflect the requirements of the new science curriculum.

7.55 The DCSF has appointed three teams, each comprising designers, educationalists and ICT specialists, to develop exemplars designs for science facilities. Each of the teams has been partnered with two secondary schools (chosen for their innovative approaches to science teaching and learning) which are being rebuilt. The teams are working with the school staff and pupils to develop inspirational designs for science facilities and interactive "experiences". These six schools will become demonstration projects, supporting and inspiring others in their areas. A further seven (smaller scale) science building projects will bring the total to 13 demonstration schools, at least one in every government region.

7.56 The design ideas emerging from the project are being overseen by a steering group of external experts to ensure that they meet our educational ambitions. The group includes representatives from the DCSF curriculum policy team, the ASE, BECTA, the Wellcome Foundation, the SSAT, science bodies such as the Royal Society, local authorities and schools. The designs were presented for comment to the wider science community at a conference on 10 May 2007 and CLEAPSS (an advisory service providing support in science and technology for a consortium of local authorities and their schools) will be advising on detailed design issues, such as health and safety, before the schemes are finalised. A book showing the exemplar designs will be published in autumn 2007. The first built projects will be completed at the end of 2008.

7.57 However good the quality of school laboratories, it is of even greater importance that science teachers have the knowledge, skills and confidence to carry out high quality practical work. Where these are lacking, for example in those teaching outside their main subject specialism, CPD focussed on practical skills is needed.

RATIONALISING AND IMPROVING ENRICHMENT SCHEMES

7.58 Extra-curricular activities can play an important role in enthusing young people and demonstrating the exciting opportunities that studying science can open up. Some of the current schemes are very successful (see the following box on the Science and Engineering Ambassadors programme). However, at the current time far too many schemes exist. Each has its own overheads, few have more than a local coverage and teachers find it difficult to make sense of the vast amount of literature with which they are bombarded. Companies also do not feel they get value for money from the funds they put into these schemes.

Science and Engineering Ambassadors programme

The Science and Engineering Ambassadors (SEAs) programme began in 2002 to excite young people about the role STEM plays in everyone's lives and to inspire the potential scientists and engineers of the future. Within five years nearly 17,000 schools have engaged with the programme, and over 17,500 STEM-qualified volunteers have been involved in over 1,000 different organisations as an SEA. The programme is operated nationally by STEMNET (the Science, Technology, Engineering and Mathematics Network), working with its network of local organisations acting as SETPOINTs.

The programme provides training and Criminal Records Bureau checking to enable these volunteers to work with schools, colleges and teachers in a range of ways, such as acting as role-models and assisting teachers in delivering activities that enhance and enrich the STEM curriculum.

> "The Ambassador has provided me with support and encouragement which contributed significantly to my personal and professional development. He has acted as a useful sounding board, helping me to recognise my achievements and build my confidence to take on new challenges. This has allowed me to obtain a clearer picture of my role as a teacher of physics within secondary education." Ailsa Galbraith, Parkmans High School, Renfrewshire

Increasingly, STEMNET is working with organisations at a strategic level to make participation in the SEAs programme part of their own education, outreach and Corporate Social Responsibility activities. This has proved very popular and successful with a wide range of STEM employers, covering everything from the automotive industry to pharmaceuticals and from healthcare and medical scientists to defence research.

> "Enthusing students with inspirational and topical STEM projects, outside of the formal classroom environment, is essential to develop a perception of STEM as a set of rewarding, exciting and socially important careers. I believe that STEMNET contributes to this need admirably through its Ambassadors scheme, which QinetiQ strongly supports. I look forward to exploring how we in QinetiQ can contribute, both corporately and individually through the actions of our Science and Engineering Ambassadors, to benefit the next generation of STEM practitioners through these clubs." Dr Martin Thomas, Director of STEM Outreach, QinetiQ

DIUS has tasked STEMNET with registering 18,000 SEAs by March 2008.

7.59 DCSF and the Department of Innovation, Universities and Skills (DIUS) have decided to fund no more than ten national schemes of STEM support for schools (excluding national teacher supply measures) and to work with industry to rationalise the number of schemes on offer to teachers. This work is being taken forward by the National STEM Director.

7.60 The Review welcomes the proposal of DCSF to work within a framework of ten schemes within which will be clustered, publicly funded initiatives to support STEM teaching. The following box lists the proposed schemes, which have been developed by the National STEM Director by reference to the Ten-year Framework and Next Steps documents. This framework of schemes was considered in a workshop held by the Review on 1 May 2007 and attended by funders from the private and charitable sectors as well as government representatives. The commitment of all three sectors to work within the framework is key to simplifying the STEM landscape for the benefit of teachers and funders alike.

Schemes to raise standards and increase equality and diversity

Continuing professional development of teachers and lecturers

S1. Improving teaching and learning through CPD for maths teachers.

S2. Improving teaching and learning through CPD for science teachers.

S3. Improving teaching and learning by engaging teachers with engineering and technology.[12]

Enhancing and enriching the curriculum, both inside and outside the classroom, to motivate students towards STEM

S4. Enhancing and enriching the science curriculum.

S5. Enhancing and enriching the teaching of engineering and technology across the curriculum.

S6. Enhancing and enriching the teaching of mathematics.

S7. Improving the quality of advice and guidance for students (and their teachers and parents) about STEM careers, to inform subject choice.

S8. Widening access to the formal science and mathematics curriculum for all students, including access to triple science and second mathematics GCSE.

S9. Improving the quality of practical work in science.

S10 Developing a scheme to build capacity within the national, regional and local networks.

7.61 The adoption of such a framework of schemes will simplify the landscape for schools and colleges. Guided by the STEM Community Portals, teachers will be able to locate more readily the support they need, and it will be easier for funders to identify where overlaps and gaps in provision lie. With more systematic evaluation in place, it will be possible to identify which initiatives work well and which do not, so that over time it will be possible to concentrate funding on a smaller number of proven initiatives.

Recommendation 7.11

DCSF and DIUS, in partnership with stakeholders in other sectors, should adopt and develop the framework of ten schemes and the associated infrastructure, including:

- the network of national and regional Science Learning Centres;
- STEMNET, with its team of Science and Engineering Ambassadors;
- the National Centre for Excellence in Teaching Mathematics (NCETM);
- the science and mathematics strands of the National Strategies;
- the network of Specialist Schools with STEM specialisms;
- the STEM Community Portals.[13]

[12] Technology here is confined to technology with a strong element of science and engineering, e.g. electronics.
[13] These would bring together the many high quality portals providing STEM support to make it easier for teachers to find the support they need.

Recommendation 7.12

Subject to a detailed evaluation of the pilot science and engineering clubs, we would like to see a science and engineering club in all secondary schools within the next five years.

Recommendation 7.13

A National Science Competition, which could include a number of different prizes, should be established as part of Science Week, bringing together existing contests to maximise their impact, with a well-publicised (ideally televised) final taking place during Science Week. All school science and engineering clubs should be eligible for entry.

Mathematics

7.62 Given the responsiveness of A-level mathematics entries to changes in the AS mathematics curriculum, there is no room for errors with the changes to GCSE mathematics. This is particularly important given the impact that mathematics attainment has on progression to A-level physics. The odds of choosing A-level physics for a pupil with an A* in GCSE mathematics are over ten times the odds of a pupil with a C or below taking A-level physics.

7.63 In March 2006 the QCA was asked by the then Secretary of State to design and develop a second mathematics GCSE for introduction from 2010. There will continue to be an optional second mathematics GCSE for those with an interest in broadening their knowledge and skills in the subject. The plan is not to make the second mathematics GCSE a prerequisite for those who wish to study mathematics at A-level, nevertheless in practice it is likely that those seeking to progress to A-level mathematics will want to take both GCSEs. It is too early to predict uptake and provision of the second GCSE.

7.64 The Review welcomes the move to give pupils the option to increase the amount of mathematics they study in schools but is concerned that in practice very few schools will offer both GCSEs and take-up will be minimal.

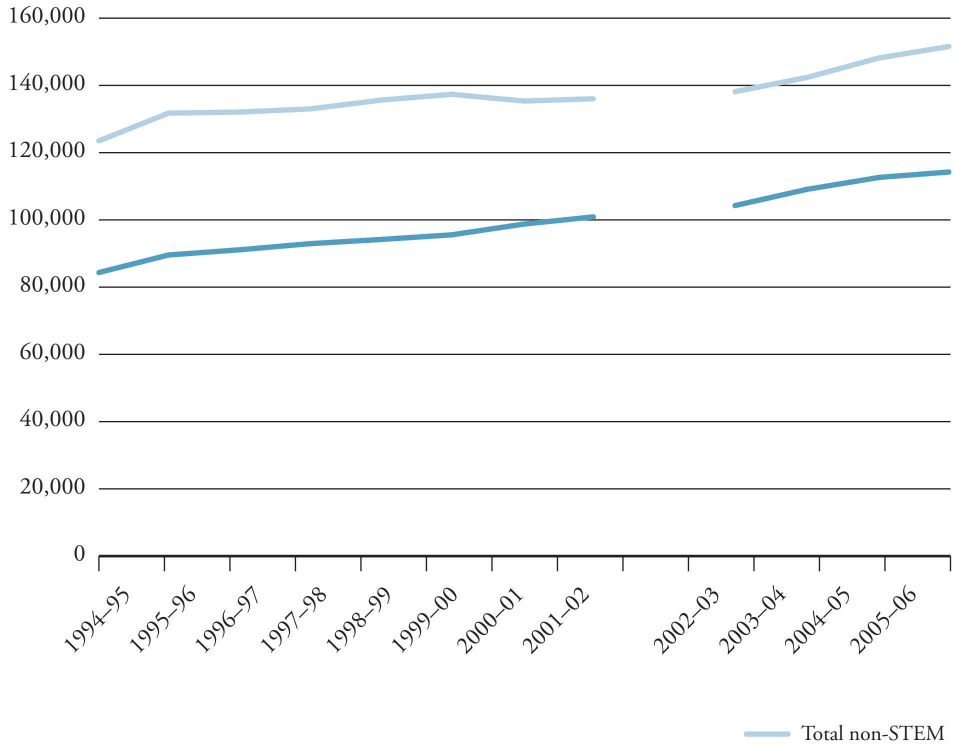
Recommendation 7.14

All pupils who would benefit should have the option to study the second mathematics GCSE and schools should find ways to make it available to them.

Trends in first-degree participation in STEM subjects

7.65 The analysis of individual STEM subjects is complicated by a reclassification of combined degrees and coding systems in 2002–03. Nonetheless, as shown in Chart 7.4, the trend of students qualifying in STEM skills appears to have increased both before and after the break in 2002–03. The increases are both in absolute terms and as a percentage of total graduates. For the purpose of this analysis we have used the figures for UK domiciled students.

Chart 7.4: First-degree qualifiers in UK HEIs, UK-domiciled, excluding the Open University



Source: HESA commissioned statistics[1]

7.66 The DIUS and Higher Education Statistics Agency (HESA) jointly publish an annual national statistics publication on the number of entrants, students and qualifiers in STEM subjects, and data under the new classification are now available on a consistent basis for four consecutive years.

7.67 Taking the re-classification into account, the number of STEM graduates has increased by about 30 per cent from 1995–96 to 2005–06. Growth is not uniform, however, with the decline in some key subjects a cause for particular concern (chemistry), while the flows of graduates from others have appeared fairly flat (biology, engineering, agriculture and physical science overall).

Table 7.2: UK domiciled, first-degree qualifiers in UK HEIs, excluding the Open University[1] 1994–95 to 2005–06

Academic year / Subject area	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	Change 94–05	Change 02–05
Medicine and dentistry	5,320	4,993	5,408	5,499	5,494	5,517	5,559	5,622	5,619	6,446	6,778	7,006	32%	25%
Subjects allied to medicine	10,834	12,206	14,236	15,813	17,047	17,745	19,674	21,550	22,355	23,486	26,359	27,884	157%	25%
Biological sciences	13,924	15,856	17,067	18,242	18,958	20,113	20,266	19,891	22,269	23,425	24,944	25,309	82%	14%
of which														
Biology	3,898	4,297	4,587	4,266	4,171	4,369	4,415	3,926	4,156	4,230	4,333	4,136	6%	0%
Sports science (2002–03 onwards)									3,648	4,858	5,518	6,054		66%
Psychology [2]	5,515	6,389	6,656	7,061	7,436	8,033	7,843	7,936	8,323	9,074	10,076	10,710	94%	29%
Other biological sciences	4,510	5,169	5,825	6,915	7,351	7,710	8,008	8,028	6,142	5,264	5,017	4,409	–2%	–28%
Veterinary sciences	437	437	487	469	501	494	520	568	505	605	636	633	45%	25%
Agriculture and related subjects	1,843	2,091	2,236	2,162	2,220	2,204	2,219	2,192	1,951	2,235	2,073	1,971	7%	1%
Physical sciences	13,658	14,180	14,472	13,486	12,943	12,932	12,933	12,164	11,769	11,238	11,454	11,671	–15%	–1%
of which														
Chemistry	3,914	3,975	3,610	3,193	3,454	3,174	3,104	3,000	2,760	2,552	2,526	2,323	–41%	–16%
Physics	2,398	1,931	2,321	2,175	2,225	2,211	2,325	2,178	2,054	1,997	2,073	2,143	–11%	4%
Archaeology as a physical science (up to 2001–02)	231	226	328	376	362	398	361	397						
Forensic and archaeological science (2002–03 onwards)										361	501	719	1,136	214%
Other physical sciences	7,114	8,048	8,212	7,742	6,903	7,149	7,142	6,589	6,594	6,188	6,135	6,069	–15%	–8%
Mathematical sciences	4,562	4,688	4,308	4,492	4,992	4,801	4,796	4,643	4,670	4,666	4,401	4,440	–3%	–5%
Computing science	8,129	8,958	8,946	9,584	9,924	10,842	12,273	13,600	15,646	16,929	16,619	15,517	91%	–1%
Engineering and technology	17,992	18,652	17,285	16,840	15,948	15,142	14,979	15,194	14,049	14,447	14,065	13,655	–24%	–3%
Architecture, building and planning	7,650	7,502	6,683	6,344	6,170	5,774	5,540	5,480	5,429	5,620	5,313	6,156	–20%	13%
TOTAL STEM	84,349	89,562	91,128	92,933	94,199	95,564	98,758	100,904	104,262	109,097	112,641	114,242	35%	10%
TOTAL NON-STEM	123,513	131,754	132,082	133,011	135,672	137,358	135,358	136,033	138,146	142,382	148,194	151,563	23%	10%
Grand total	207,862	221,316	223,210	225,944	229,871	232,922	234,116	236,937	242,408	251,479	260,835	265,805	28%	10%

(1) Figures for the Open University are excluded due to changes in reporting practice over time

(2) Psychology in 1994–05 to 2001–02 includes C8 Psychology (not solely as a social science) and L7 Psychology (without a significant element of biological science)

From 2002–03 this includes the single category C8 Psychology

NOTE: The subject classification system changed between 2001–02 and 2002–03

Source: HESA Student Record 1994–95 to 2005–06

7.68 There is of course a time lag when looking at data on qualifiers. The time series on entrants provides a picture of more recent trends. The long-term falls in the number of entrants to first-degree physics, chemistry and engineering have flattened out in the more recent past and mathematics is now on the increase, although there has been a decline in computer science.

7.69 Concerns about course closures in 2004 prompted the Government to commission HEFCE to review the position of "strategically important subjects" (STEM subjects are strategically important because of their economic importance; other subjects included in the definition are modern and minority languages and area and cultural studies). The review set up an ongoing advisory group to monitor and report to HEFCE on the position of these strategically important subjects.

7.70 The number of first-degree STEM students has increased in recent years, both in absolute and percentage terms. We are, however, concerned that there may be a significant mismatch between STEM subjects taken by students and the job opportunities that are likely to be available to them, and that this mismatch may be disappointing for them and may lead to shortages in the economy. This is why we recommend that there should be a major increase in the provision of careers advice in schools (paragraphs 7.42 – 7.53).

7.71 Furthermore, we believe that there is a major gap in information provision and that students, universities and governments should be able to make their decisions on the basis of the best possible up-to-date information. We also believe that more students will take STEM subjects at university when they see the many options that open up to them as the result of taking a STEM subject at university, and the excellent rewards that they can as a result receive.

7.72 Graduates in all subjects gain benefits in terms of employability and earnings premia over those without degrees, and there is evidence that STEM graduates see higher than average benefits (in PwC's February 2007 study for Universities UK, chemistry, physics and engineering graduates attracted a rate of return of 15 per cent, compared with the average of 12 per cent for all degrees). STEM skills are valued by all employers as a proxy for more general skills (e.g. numeracy and reasoning), and as a result STEM graduates tend to have a wide range of exciting jobs open to them.

Recommendation 7.15

To address the lack of information on the supply and demand of STEM skills, HEFCE should transform the Strategically Important and Vulnerable Subject Advisory Group into an Advisory Group on Graduate Supply and Demand and extend its remit to include responsibility for publishing an annual report describing: undergraduate subject trends; recent graduate jobs and salaries; and the subjects where employers and government departments believe that there are, or are likely shortly to be, shortages of graduates with key skills. The Review welcomes the extension of the group's membership to include an industry and a STEM business representative.

7.73 HESA and DIUS jointly publish the undergraduate trend data. The Sector Skills Councils should be able to provide the demand data and the Destination of Leavers from Higher Education survey can provide information on graduate jobs and salaries. The Review welcomes the pilot survey, reporting in autumn 2007, which is tracking graduates three and a half years after leaving university, and we encourage a longer time period than the usual six months to be used in future to ensure the survey data are robust.

Cost of higher education teaching

7.74 While the numbers of students taking relevant subjects at A-level are significant factors determining the flow of science and engineering graduates, the teaching facilities at universities are also key. If STEM students are to be excited by their teaching they need to be able to use up-to-date equipment and have good teaching staff.

7.75 The Roberts Review (2002) concluded that the cost of equipment and SET teaching staff had increased relative to other subjects and that these costs were greater than allowed for in the funding available at that time to maintain the quality of laboratories and retain good teaching staff.

7.76 In November 2006 HEFCE announced additional funding of £75 million over three years to support the teaching of chemistry, physics, chemical engineering and mineral metallurgy and materials engineering. This increases the teaching grant for these strategically important subjects by about 20 per cent. Taken together with the increases in income from student fees since 2006–07, HEFCE estimate that a sum of up to £2,500 per student may now be available to add to the support calculated in the studies done by the Royal Society of Chemistry and the Institute of Physics, substantially reducing or eliminating the deficits identified.

7.77 HEFCE has recently completed a consultation on proposals for changes to its funding method. There are no immediate plans to change subject weightings, but HEFCE will use the implementation of the Transparent Approach to Costing for Teaching (TRAC(T)) to improve its understanding of relative subject costs. The data from TRAC(T) are expected to be available by summer 2008, allowing HEFCE to implement any changes to the weightings from 2009–10. The Review encourages DIUS and HEFCE to make certain that money is available to continue the additional funding if the need for it is identified by the TRAC(T) data.

Further Education

7.78 The Further Education (FE) system includes 385 FE colleges (which provide education for 14–19 year olds as well as adult learners) and over 1,000 work-based learning providers, as well as personal and community learning providers. It offers academic and vocational courses and is particularly well placed to contribute to the Government's science agenda by addressing skills gaps at technician level and responding to business needs. An estimated 250,000 out of a total FE learner body of around 6 million have STEM subjects in their learner outcomes. Over 23 per cent of students entering for mathematics A-level, and a similar percentage of those entering for science subjects, are studying at FE colleges.

7.79 Work has been undertaken to extend the FE system's provision of vocational training and to improve recruitment and CPD to raise teaching quality. Centres of Excellence in Vocational Teacher Training will launch in September 2007, and a CPD entitlement is being introduced for FE staff. Incentives offered in schools, such as bursaries and Golden Hellos for science and engineering subject teachers, have been extended to FE, and work is underway to introduce a series of new strategic recruitment processes to attract both graduates and people with substantial business experience into FE teaching.

7.80 The drive to improve the relevance of qualifications and quality of teaching in FE are part of a wider move towards developing vocational skills training. Following the White Paper *Further Education: Raising Skills, Improving Life Chances*, and the Leitch Review report in December 2006, FE is adopting a model which will base all adult FE provision on learner and employer demand, with funding following demand through Learning Accounts (learners) and Train to Gain accounts (employers), rather than central planning and allocation by the Learning and Skills Council (LSC).

7.81 Train to Gain allows individual businesses to call on skills brokers, trained by the LSC and with expertise in business support, to assess their business needs and suggest providers to meet training needs. As well as this service for individual businesses, employers have a more collective input to FE provision via:

– Sector Skills Councils, which have a role in curriculum design and approval of qualifications, in particular diplomas and apprenticeships;

– Regional Development Agencies, which produce statements of regional skills needs and sector priorities;

– Centres of Vocational Excellence (CoVEs) and National Skills Academies, which produce high-quality specialist training to meet specific sector and industry needs. Under the demand-led system, new standards are being introduced to ensure that providers applying to set up CoVEs are business-facing across the range of their provision.

7.82 Moving away from centralised planning might be a risk to provision of "vulnerable" subjects where learner demand might be low. But the twin focus on learner and employer demand should help to promote study of science, where demand from employers is strong.

Recommendation 7.16

SEMTA, the Science, Engineering and Manufacturing Sector Skills Council, should liaise with subject associations to ensure that messages about science employment needs and prospects are communicated to students.

Engineers for Enterprise

7.83 Engineers coming into companies in the future will need more than just technical skills, but at present there is a perceived lack of comprehensive and integrated preparation in technology, innovation, design and management skills among engineers. Anecdotally, it also appears to us that many engineering students graduate with little desire to take up an engineering career. Many countries recognise a problem with the narrowness of existing science and technology education. Japan, for example, aspires to have "bilingual engineers" with capabilities in technology and business.

7.84 The Royal Academy of Engineering has recently produced an excellent report entitled *Educating Engineers for the 21st Century*. This makes a number of important recommendations about how engineering education in our universities should develop in line with the real and constantly evolving requirements of industry, as well as motivating students to become engineers on graduation.

Recommendation 7.17

A leading member of the engineering profession should be asked to set up a working group of experts from academia and industry to review current approaches to engineering education. The group should develop, with a number of leading engineering universities, an experience-led engineering degree which integrates technical, operational and business skills.

8 Government departments

8.1 It is simplistic to think that all policies on science and innovation should be decided at one level in government. The majority of decisions need to be taken at a national level, but some important decisions will be best taken at a regional level, and others at an international one.

8.2 At a national level, the Department for Innovation, Universities and Skills (DIUS) needs to take a leadership role in upgrading our knowledge and skills and creating the best possible conditions for companies to produce new high-value-added goods and services and move into new high-value-added industries.

8.3 The Department for Business, Enterprise and Regulatory Reform (DBERR) is also clearly involved in any industrial restructuring, and the DBERR Business Relations Division provides a strong link to industry. The success of policies for science and innovation will largely depend on close collaboration between DBERR and DIUS. In order to encourage collaboration, this Review suggests that the two departments establish early on a mechanism at official level for co-ordinating their activities.

UK Trade and Investment

8.4 UK Trade and Investment (UKTI) has a key role to play in raising the level of innovation in the economy, and has adopted a new approach to both inward investment and export promotion. Its inward investment activities are now focused on bringing high-value-added jobs to the UK. And in terms of export promotion, UKTI is now more focused on opening up new export markets for fast-growth, high-value-added companies.

8.5 With global competition in all parts of the value chain, the UK needs the organisational capacity to attract foreign direct investment (FDI), particularly in R&D. Co-ordination between government agencies is a key factor for companies choosing a country for their R&D, to ensure rapid decision-making, to allow companies to quickly to establish their operations and to facilitate access to willing partners such as universities. Singapore has proven highly effective in attracting FDI. Two key elements underpin its successes:

- The careful co-ordination of all parties relevant to a potential development (e.g. the national development agency, research funding bodies, universities, technology parks, etc.). Companies feel that they are dealing with a single "Singapore Inc" rather than having to negotiate separate deals with a range of organisations and institutions. This ease of doing business adds significantly to the attractiveness of the country as an FDI location. The Singapore Economic Development Board plays a lead co-ordination role for FDI.

- There is a clear national strategy and unity of purpose among Singapore's agencies and institutions in underpinning and developing key prioritised industrial sectors. Companies considering investing in such a sector (e.g. biotechnology) gain significant added comfort from additional interventions supporting the larger environment for their investment.

Regional Development Agencies

8.6 At the regional level, the Regional Development Agencies (RDAs) have an important role to play in raising the level of R&D and innovation in their regions. Chapter 9 argues that the strategies of the RDAs, if they are to make a major contribution to improving the economic performance of their regions, need to focus more on science and innovation. This Review recommends that an active co-ordination is developed between UKTI and the Technology Strategy Board (TSB), with support from the RDAs as appropriate, for promotion of the UK as a location for R&D. There should be explicit targets to improve the ease of access to relevant information for companies wishing to locate R&D in the UK and to speed up decision-making.

8.7 All government departments can make a significant contribution to raising the level of innovation in the companies with which they interact, but many of the opportunities that exist to do so are not being seized. Innovation needs to be more clearly written into the objectives of departments.

8.8 DIUS itself has control over many of the key policy levers that are of critical importance in raising the level of innovation in the economy. It allocates the money to Research Councils (RCs) and universities, it has responsibility for the UK Intellectual Property Office (IPO), metrology, standards and the Design Council, and it covers trans-departmental science policy and international strategic and technological collaboration.

8.9 In the TSB, DIUS has also created a means of supporting user-driven research in industry. If this Review's recommendations are followed, the TSB will be able to provide valuable technological leadership for the DBERR, the RDAs, UKTI and other government departments.

8.10 Today, there are a myriad of schemes to support business, run by many different organisations. This is inefficient and confusing for industry. A major Business Support Simplification Programme (BSSP) has been initiated by DBERR. The consultation process has highlighted the importance of introducing a body to manage business support and to ensure that the proliferation of business support does not recur.

8.11 The BSSP consultation envisages a "single, cross government oversight of business support, involving a partnership of representatives from all key stakeholders. These representatives would include major central government funding departments, Regional Development Agencies and local authorities".

8.12 The Review is concerned that without the involvement of business people, such a body may not be effective in ensuring that only BSSP-endorsed products are on offer; that BSSP products are run only according to nationally agreed specifications; and that new products do not proliferate again in future.

8.13 As described in the following chapter, market failures do not vary in their nature between regions. There is no logic in creating specific R&D grants or proof-of-concept schemes for different parts of the country. Funding bodies will want to put varying amounts of money into these different schemes based on the needs of their locality or region, but business-support products will be most effective if the decentralised funding and management of schemes takes place within a national framework.

Recommendation 8.1

Business people should play a major role in the new business support management body. This body will evaluate, endorse and manage the business support products, according to government criteria on the proper expenditure of public money.

8.14 Finally, there is a considerable danger that government activities in support of innovation and economic restructuring are neglected under the pressure of short-term political and operational problems.

Recommendation 8.2

The Director of Innovation in DIUS should be tasked each autumn to produce an Innovation Report on the innovation activities of DIUS, including the Technology Strategy Board, other government departments and the Regional Development Agencies.

8.15 This Innovation Report should cover, among other things, the support given to user-driven research by the TSB and the performance of Knowledge Transfer Networks. It should also show the funding given by RDAs to encourage innovation in the regions under the four categories of: user-driven research; knowledge transfer; support for high-technology clusters around universities; and support for fast-growth, high-value-added businesses.

8.16 The report should also cover the innovation activities of other government departments, including the publication of their science and innovation strategies and their funding of R&D, and whether any money has been directed from R&D budgets to support other activities. The Innovation Report would be valuable both in highlighting the support given by the DIUS to encourage innovation and in allowing industry to see whether all branches of government are delivering on their commitment to it.

Science and innovation policies across government departments

8.17 While DIUS should take the lead role in government in supporting science and innovation, this Review believes that government departments can play a part by encouraging innovative procurement solutions and through the funding of R&D. The USA has demonstrated the extent to which defence R&D can be used to stimulate innovation in the economy,[1] and we believe that similar opportunities exist for the civil departments in the UK to stimulate innovation in their areas of responsibility.

8.18 Attempts have been made in recent years to raise the level of support for science and innovation in government departments. Some progress has been made. Chief Scientific Advisors (CSAs) have been appointed to most departments and a number of departmental Science and Innovation Strategies have been developed. But the results are, so far, disappointing. We believe that the Government is, at best, missing a significant opportunity to stimulate innovation and, at worst, is inhibiting innovation through its policies and behaviour.

[1] See, for example, its role in initiating the high-technology cluster of Silicon Valley: "Cold War Armory: Military Contracting in Silicon Valley", Heinrich, T., *Enterprise and Society,* 3, 2002.

Recommendation 8.3

Innovation should be made a core part of the mission statement of each government department and embedded in Departmental Strategic Objectives. Progress in stimulating innovation should be measured in the annual Innovation Report produced by the DIUS.

8.19 The R&D budgets of government departments need to be better managed and not used to support operational activities in times of difficulty. There are also four key areas where this Review believes departments should concentrate their efforts and where significant improvements could be made. These are user-driven R&D, procurement, Innovation Platforms, and the Small Business Research Initiative.

THE MANAGEMENT OF DEPARTMENTAL R&D BUDGETS

8.20 The Cross-Cutting Review of Science and Innovation in 2002 made recommendations on how to improve the effectiveness and value for money of civil research commissioned by government departments. The Review highlighted the risk of raids on departmental R&D budgets and stressed the importance of identifying these budgets early on in the Spending Review process. It argued that departments, the Chief Scientific Advisor to the Government and HM Treasury all have a role to play in establishing and maintaining departmental R&D budgets.

8.21 However, the mechanisms for identifying and protecting departmental R&D budgets remain inadequate, and this Review is concerned about the level of funding. As shown in Table 8.1, against an overall ambition to raise levels of R&D in the UK, civil and military departmental R&D spend have declined as a percentage of GDP over the past decade and in real terms over the past few years. In both cases, the GDP intensity of funding has been unstable.

Table 8.1: Total departmental expenditure on R&D

Total civil departments	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
£ million	1,282.4	1,246.3	1,351.3	1,474.3	1,594.8	1,849.4	1,929.2	1,666.0	1,597.0
% GDP	0.1558	0.1436	0.1470	0.1533	0.1727	0.1748	0.1727	0.1403	0.1210
Total defence	**1997–98**	**1998–99**	**1999–00**	**2000–01**	**2001–02**	**2002–03**	**2003–04**	**2004–05**	**2005–06**
£ million	2,314.0	2,140.0	2,272.0	2,240.0	2,057.1	2,734.0	2,676.6	2,576.3	2.406
% GDP	0.2812	0.2465	0.2472	0.2328	0.2049	0.2584	0.2396	0.2170	0.1823

Source: SET statistics 2007

8.22 At a time when the impact of science and technology on our society and economy is growing, this decline of R&D funding causes concern for this Review for two reasons. First, we are concerned that we are significantly reducing our capacity to have a high-level scientific input made into key policy decisions. Given the high costs and benefits that these key policy decisions involve, this could turn out to be a very serious economic mistake (see Table 8.2).

Table 8.2: Identified risks from declining public R&D funding

Identification of infectious disease: The Foresight Detection and Identification of Infectious Diseases (DIID) project highlighted the opportunities to develop four key technologies to manage this risk. For example, the development of a handheld device to identify a disease at the bedside or in the field. The technology could be used for humans or animals, but there is no funding stream for the two government departments with an interest to co-operate. There have been similar problems on the other three technologies that requires collaborative response across departments.	**Risk:** The modellers working on the Foresight report estimated that if there were an effective detection system in place, based on these four technologies, in a future foot-and-mouth outbreak it would reduce the costs from £5 billion to £50 million.
Public health: The actions of a number of departments affects the nation's health – CLG, DfT, DIUS, DCMS as well as the Department of Health. At the moment, the emphasis is on treating health problems rather than preventing them. Cross-departmental research on public health can help with preventative measures.	**Risk:** Health problems are created, which lead to a significant increase in the costs of healthcare. An example is obesity, which already costs £1 billion a year, and costs are likely to double over the next ten years unless we change the current trends.
Investment in infrastructure: The UK already heads the EU in league tables on levels of congestion, and the contribution of transport to CO_2 emissions is the one area that is still increasing. The Foresight project on intelligent infrastructure systems highlighted that a sustainable transport solution requires close co-operation between decisions on investments in information systems, transport infrastructure, design of urban areas and land use.	**Risk:** The solution to sustainable transport might be missed as departments each pursue their separate objectives. There is also a risk that departments could undermine each other as they legitimately seek to meet their own objectives – for example in the location of new schools and hospitals, with complex and unintended consequences for transport infrastructure.
Nanotechnologies: Applications of nanotechnologies are multiplying rapidly and there is the potential for the transformation of many areas of industry and society, such as manufacturing and healthcare. There will be both opportunities for and threats to almost every industrial sector. To make the most of the opportunities, co-ordinated government research is needed to determine if there will be any adverse effects of manufactured nanomaterials on human health and the environment.	**Risk:** There are respected predictions of a global market in nanotechnology worth over $1 trillion within a decade. The UK has a strong academic background in nanoscience and nanotechnology and is highly rated internationally as a research partner. Failure to address adequately the health, safety and environmental research issues associated with the new nanomaterials will jeopardise the UK's share in this rapidly developing market. Public acceptance, which is related to perceived risks and benefits, could be undermined and would not be easily won back.

Source: Prepared for the Review by the Chief Scientific Advisors' committee

8.23 Second, we believe that significant opportunities are being missed to support innovation in the companies with which government departments interact, and that by not stimulating innovation through the £150 billion of goods and services they buy each year, government departments could be significantly slowing down the rate of innovation in the economy.

Recommendation 8.4

A more robust mechanism should be put in place to identify and protect departmental R&D budgets. Chief Scientific Advisors should work closely with their departments and HM Treasury spending teams early on in the Spending Review process to agree amounts and priorities for R&D spend. Once this has been agreed, a department should consult with the Government CSA and HM Treasury and must show a sound justification if it wishes to reduce its level of spend.

8.24 The Cross-Cutting Review also highlighted the need for stronger co-ordination in cross-cutting areas. This Review believes that insufficient progress has been made in interdepartmental collaboration. A number of policy areas inevitably cut across the boundaries of government departments, and it is extremely wasteful if the R&D programmes that are funded to support decisions in these policy areas are not properly co-ordinated.

Recommendation 8.5

The Chief Scientific Advisors' Committee (CSAC) should identify cross-cutting areas of research on an annual basis and appoint a Chief Scientific Advisor to each of the priorities to co-ordinate resources and funding across relevant departments.

8.25 A light touch approach is recommended, in which each CSA reports back on progress at quarterly CSAC meetings.

USER-DRIVEN RESEARCH AND DEVELOPMENT

8.26 In recent years it has been claimed by some government departments that their R&D budgets should only be used to help with the formulation of policy. It is this Reviews' firm belief that for civil departments to spend £1.66 billion per year, which is about 70 per cent of the RCs' budget and 0.6 per cent of GDP, solely on the formulation of policy is not economically sensible. It is also not an accurate reflection of what is currently taking place.

8.27 Valuable user-driven R&D is being undertaken in some departments. The Ministry of Defence (MOD), the Department of Health and the Energy Technologies Institute can all provide some encouraging examples.

User-driven R&D in defence

8.28 Innovation is vital for the MOD to be able to counter threats from potential enemies, maintain superior military capability and operate with high-technology allies. By the nature of its business, the MOD is an early adopter and user of cutting-edge technology. Over 98 per cent of the MOD's research and technology (R&T) budget is focused on developing science and technology solutions to military and security capability needs. A strong correlation has been found between MOD's investment in R&D and the quality of equipment 10–15 years later.[2] MOD has also found innovative ways, through research, to perform their mission more cost effectively, for example it has brought about a reduction in its heavy armour assets.

[2] "The Effect of Defence R&D on Military Equipment Quality", Middleton, Burns, et al., *Defence and Peace Economics*, April 2006.

8.29 Military research can also have spillover effects for the civil sector. It has led to the development of much of the underpinning technology for mobile phones, night-vision goggles, sensors and vaccines. The digital plate at the back of digital cameras came from work in the nuclear field, and the first liquid-crystal display was invented at the MOD research laboratories in Malvern.

DARPA **8.30** In the USA the Department of Defense research programmes have played a significant role in stimulating discovery and drawing the resultant technology through into the economy. The Defense Advanced Research Projects Agency (DARPA) was set up after the shock of the Sputnik launch to take on high-risk research to keep the USA a generation ahead of any possible competitor. It is best known for programmes which led to the Internet, stealth aircraft, unmanned aircraft and VLSI electronics, but underneath that are numerous innovations that would have struggled to find their way into production without such an ambitious early-adopter customer. Defence research spending in the USA has increased steadily for the past 15 years and enjoys bipartisan support largely because it is seen to deliver both security and economic benefits. In the UK, by contrast, defence research expenditure has declined over the same period.

8.31 This Review thinks that decisions on the level of defence research expenditure should be taken on the basis of what is necessary to make sure new equipment is fit for purpose.

User-driven R&D in energy

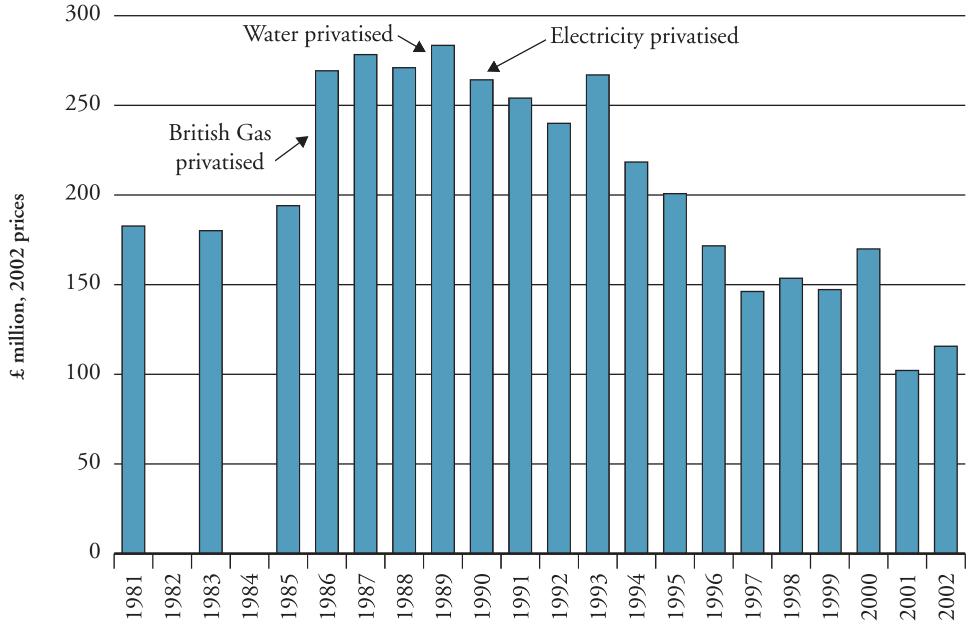
8.32 Since privatisation, R&D spending in the UK energy sector has fallen sharply. For example, British Gas, in the years before its privatisation in 1989, typically spent around £70 million per year on R&D. Its principal inheritor company spent £15 million in 2003.[3] Chart 8.1 shows total R&D expenditure by the energy sector.[4] R&D spending across the energy, gas and water supply product group fell in real terms from £183 million in 1981 to £116 million in 2002 – a decline of 37 per cent.[5]

[3] House of Commons Select Committee on Science and Technology, Fourth Report, para. 70. These are nominal figures: the real terms fall has been even sharper.

[4] Taken from *Economics Paper No. 11: R&D Intensive Businesses in the UK,* DTI, March 2005, p. 16.

[5] Ibid., p. 15.

Chart 8.1: R&D performed by the energy sector



Source: ONS. Data include water supply.

8.33 This decline is not unique to the UK: other European countries, post-liberalisation, have experienced a similar pattern of decline. R&D spending now accounts for just 0.4 per cent of turnover, on average. However, the decline in the UK was "by far the largest of all OECD countries",[6] a fact attributed by the Performance and Innovation Unit to "increased competition [shortening] the time horizons for R&D expenditure creating a focus on short-term commercial goals rather than long-term investment".[7] R&D in the nationalised utilities contained a substantial "public good" element, which could be paid for by charging higher prices to consumers. Privatisation and regulation introduced strong pressures on price, forcing companies to cut costs elsewhere.

[6] House of Commons Select Committee on Science and Technology, Fourth Report, para. 71.

[7] *Resource Productivity: Making More with Less*, Performance and Innovation Unit, 2001, Annex J, p. 107.

DBERR Energy Group

8.34 The Stern Review noted that policy to support innovations and the development of low-carbon technologies will be a key response to mitigating climate change. The DBERR Energy Group, in conjunction with the RCs, is investing heavily with industry in low-carbon energy technologies, addressing the market failure caused by the high costs and risks associated with energy technology innovation. Funding is available for research proposals in a range of renewable energy sources, including wind, tidal and photovoltaic power. Future Energy Solutions manages direct grants to those developing renewable energy sources, while the new Collaborative R&D Business Support Product has replaced the New and Renewable Energy R&D Programme to provide more focused support for collaborative R&D.

8.35 Other programmes include the Energy Technology Institute (ETI), which is planned to be launched this year with a budget of up to £1 billion over the next decade for R&D into non-nuclear low-carbon energy. The ETI draws on private as well as public funding. In addition, the UK Energy Research Centre (UKERC) was established in 2004 following the 2002 Energy Review. With funding of £13.8 million over 2004–09, its objective is to provide a focus for energy research in the UK and for international collaboration. Without such public support new energy technologies are unlikely to develop at all or within the timescales necessary to reduce the risks of climate change.

8.36 In June 2006, the Government announced the creation of a new cross-government fund to invest in low-carbon energy technologies and energy efficiency. The Environmental Transformation Fund (ETF), led by Department for Environment, Food and Rural Affairs (DEFRA), DBERR and Department for International Development (DfID), will open in April 2008. Budget 2007 announced Comprehensive Spending Review (CSR) funding of £800 million for the international element of the ETF to support development and poverty reduction through environmental protection in developing countries, including action to tackle climate change. Details of the domestic window are due this year.

Carbon Trust

8.37 Finally, other organisations are also active in funding parts of the innovation chain. The Carbon Trust, an independent company funded by government, works with research institutions and industry to identify and help accelerate innovative low-carbon technologies. Grants of up to £250,000 are available to help develop low-carbon technologies, with 40 per cent matched funding. Over £13 million has been committed to applied research since 2001, leveraging £21 million of further funding to support research into improvements to combined heat and power plants, electricity generation from wave power, and hydraulic transmission mechanisms, among other projects.[8]

User-driven R&D in health

8.38 Health R&D is an area of UK strength, promoting both health and economic gains. This strong health research base plus a national health service offer great potential to attract R&D investment from the pharmaceutical, devices and biotechnology industries, which form a major part of our knowledge economy. Over recent years the Government has taken a number of initiatives to ensure that the UK remains a location of choice for these health research industries. These initiatives include: the creation of the UK Clinical Research Collaboration (UKCRC); a new strategy for research in the NHS in England, Best Research for Best Health (BRfBH); and the establishment of MRC Technology (MRCT).

[8] *Grant Funded Projects*, Carbon Trust, at www.carbontrust.co.uk/technology/appliedresearch/succesfulprojects.htm. Accessed 11 June 2007.

OSCHR 8.39 In December 2006, following a major review by Sir David Cooksey, the Government established the Office for Strategic Co-ordination of Health Research (OSCHR). OSCHR sits between the Department of Health and the DIUS. The role of OSCHR is to achieve better co-ordination of publicly funded health research and more coherent arrangements for translational research by:

- alignment of MRC, NIHR and other government-funded health research agencies with a single integrated strategy;
- effective cross-working between agencies, retaining clarity for the research community;
- elimination of unnecessary duplication and redundancy; and
- enhancement of capacity for translational and public health research.

Enhancing user-driven R&D will be a major theme in the work of OSCHR.

8.40 These are all important initiatives, which should be built on.

Recommendation 8.6

Other government departments should follow the MOD's example in focusing some of their R&D spend on encouraging innovation in the companies with which they interact.

8.41 In particular we see many opportunities within the Home Office on security, within DEFRA on environmental issues and within DfT on transport issues. This Review believes that there is as much need for government policies in these areas to be supported by innovative products and services, as in the area of defence.

PROCUREMENT AND INNOVATION

8.42 The Government currently spends approximately £150 billion per year on procurement. This includes an estimated 55 per cent of all the spend in the UK on information technology (IT) services and systems, and more than 30 per cent of all construction spend. Its purchasing policies, therefore, have a huge impact on the level of innovation in the economy, and it is essential it acts as an intelligent customer. Demand for new products and services is critical to promoting innovative activities.[9] The £150 billion represents over 12 per cent of UK GDP, and to the extent that it discourages innovation it is an innovation deadweight on the economy.

8.43 Surveys of businesses reveal a widespread feeling that government is not meeting the needs of innovative procurement. The Engineering Employers' Federation concluded from its 2005 survey of business attitudes: "The conduct of government procurement was more likely to be seen as negative rather than positive for innovation. Companies saw public procurement in the UK as risk-averse, slow, and bureaucratic." The following year, the Confederation of British Industry (CBI) found that 70 per cent of surveyed companies disagreed with the claim that "Current government procurement policies foster innovation", and only 9 per cent thought government was an early-adopter of new technology.[10] Business perception, therefore, is that government does not actively pursue innovative purchasing.

[9] *Demanding Innovation: Lead Markets, Public Procurement and Innovation*, Georghiou, L., NESTA Provocation #2, 2007.

[10] *Innovation and Public Procurement: A New Approach to Stimulating Innovation* CBI/QinetiQ, October 2006, p. .

8.44 The then DTI's 2003 Innovation Report raised the possibility that government's procurement budget could be used to support more innovative activities. This was followed by publication of an Office of Government Commerce (OGC) guide to best practice.

8.45 The OGC has listed some of the ways in which procurement can miss out on some of the potential benefits of innovation:

- Inadequate warning: The public sector is not always good at communicating long-term plans to the market; as the start of the formal tender process is often the first indication a supplier receives of a complex requirement, the timescales can be too short for innovative solutions to be developed.
- Risk aversion: The public sector may seek to stimulate supplier innovation through short-term pilot projects but often does not carry through the ideas into longer term procurements; there is a tendency to opt for low-risk solutions, low-margin players and mature technology – innovation is not routinely welcomed or rewarded.
- Client capability shortfalls: Organisations that act as capable clients are better able to harness supplier innovation through effective procurement.

8.46 Difficulties are also caused by the plethora of regulations, objectives, guidelines and criteria that government procurers face when making purchasing decisions. This regulation reflects legitimate government priorities and goals, such as environmental concerns and local economic development, alongside a necessary concern to protect public money, but not all of them are well-suited to good procurement decisions.[11] Furthermore, given competing demands on procurement, the tendency is for purchasers to play safe, and stick firmly to well-established practices and products. This have the merit of simplicity and ease of application; however, it does not necessarily deliver the best outcome.

8.47 Value for money is defined by HM Treasury as: "Optimising the cost of delivering a service over the full life of the contract rather than minimizing the initial price".[12] Nonetheless, as George Cox noted in his 2005 review of business creativity, the issue is not whether a proposal offers value for money, but whether even "greater value could be obtained from a more innovative solution". The challenge is to encourage government procurers to think creatively beyond what is immediately available.[13] Furthermore, a single procurement purchase may influence future supply-side behaviour, and hence can stimulate better value for money in the long run as suppliers respond creatively to procurement demands, and so reduce costs and improve processes.

8.48 Studies have shown that the risks associated with innovative procurement can be substantially reduced by enabling government procurers to develop close relationships with suppliers.[14] If suppliers are engaged early in the procurement process, they can better hope to meet even the complex needs of innovative demand; combining this early-stage involvement with a clear contracting structure based on well-defined outcomes will allow suppliers to provide feasible project plans and better estimate the likely risks associated with any particular procurement

[11] See, for example, *Public Spending for Public Benefit*, Sacks J., New Economics Foundation, 2005.
[12] Quoted in *Cox Review of Creativity in Business: Building on the UK's Strengths,* Cox, G., November 2005, p. 34.
[13] Ibid., p. 34.
[14] *Innovation and Public Procurement – Review of Issues at Stake*, Edler, J., et al., Study for the European Commission ENTR/03/04, 2005.

contract. A recent report by HM Treasury identified these two elements as crucial to the future success of government procurement in general.[15] For innovative procurement, the requirements are still more pressing.

Recommendation 8.7

Government should urgently press ahead with the Transforming Government Procurement agenda to improve procurement capability. This requires the OGC to develop outcome-based specifications in procurement, and to ensure that innovative procurement is placed at the heart of the government procurement function. It also places a responsibility on the OGC to raise the level of capability of government purchasing.

8.49 There are a number of places where government departments can find examples of good practice. In the MOD, considerable efforts have been made to promote innovative defence purchasing. A Defence Industrial Strategy and a Defence Technology Strategy have been developed through discussion with industry to inform MOD thinking and to make MOD needs clear to the supplier base.

8.50 The MOD has also introduced the Grand Challenge, inspired by DARPA's robot-controlled vehicle race, which aims to find technology that will enable ground troops in urban areas to detect threats, with initial assessments of proposals made in summer 2007, and final trials the following year.[16] The use of a competition format and the open-ended nature of the specified task make this procurement exercise unique in UK procurement, and it is an example of how creative procurement can seek to meet complex new demands for technology.

8.51 In a similar vein, the Competition of Ideas attempts to source innovative new solutions for defence and security issues in four broad, themed areas: prediction of intent, protection, automatic object recognition and ad hoc networking.[17] Although more formal than the Grand Challenge, the Competition of Ideas again moves away from direct specifications of tasks towards a theme-based approach to procurement.

8.52 The MOD employs a number of other initiatives to stimulate innovation in their suppliers:

- overall closer alignment with industry to identify where innovation occurs in the supply chain;
- reviewing existing commercial models, in co-operation with industry, to change the risk and reward balance to boost investment in R&D;
- developing an innovative culture and rewards for innovators;
- bringing in industry secondees;
- using road-mapping to engage stakeholders, including industry, clarify activities and linkages and build coherence across capability, research and procurement; and
- intellectual property rights for work funded by MOD are usually vested with suppliers, with MOD retaining "user rights" for defence purposes.

[15] *Transforming Government Procurement,* HMT, January 2007.
[16] See MOD "Grand Challenge" website, at www.challenge.mod.uk/faq.asp. Accessed 2 April 2007.
[17] See MOD "Competition of Ideas" website at www.ideas.mod.uk/. Accessed 2 April 2007.

8.53 There are no good reasons why other government departments and agencies should not adopt a similar approach for at least an element of their procurement decisions. Predicting future challenges and demands and adopting a theme-based approach should enable more proactive procurement decisions, with government departments working closely with suppliers at an earlier stage in the procurement process.

Recommendation 8.8

Government departments should consider using outcome-based specifications as part of forward procurement programmes like the Grand Challenge and the Competition of Ideas to stimulate innovation. Early discussions with some government departments have indicated that there is appetite to do so.

Innovation Platforms

8.54 The TSB is aiming to work with departments to encourage the use of Innovation Platforms as a sophisticated supplier relations tool. They will help to join up research spending with procurement through government better identifying and communicating its long-term challenges to business. This engagement will allow government to better understand what solutions suppliers could develop where there is a public sector demand. This Review believes that the use of Innovation Platforms should be an effective way of stimulating innovation in suppliers where a government department faces a major societal challenge that requires innovation to help solve it. We would, therefore, urge government departments to introduce these where there is a need. The way that the TSB is planning to operate Innovation Platforms is described in more detail in Chapter 3.

SMALL BUSINESS RESEARCH INITIATIVE

8.55 Small and medium-sized enterprises (SMEs) are often best placed to provide the most innovative solutions to problems due to their ability to focus narrowly, pursue new and different ideas, take quick decisions and respond to changing circumstances. In the USA, SMEs have driven the growth of the high-technology economy.[18]

8.56 The Small Business Research Initiative (SBRI) was launched in 2001 with the aim of boosting innovative government procurement from SMEs.[19] It established a target of 2.5 per cent of external government R&D to be spent with SMEs, and created a website allowing R&D-spending departments to advertise contracts. In March 2005, the 2.5 per cent target was made mandatory in an effort to encourage departmental spending with SMEs.

Small Business Innovation Research

8.57 It aimed to reproduce, as far as possible, the highly-successful US Small Business Innovation Research (SBIR) programme. This was established in 1982, at a time when a "failure to translate [the USA's] research prowess into commercial advantage" was held to be undermining US competitiveness.[20] SBIR was introduced, with some controversy, as a wholly new initiative that was structured towards creating innovation and delivering new, commercialised products to market.

[18] *Entrepreneurial Dynamism and the Success of US High-Tech,* United States Congress, Joint Economic Committee Staff Report, October 1999.

[19] Note: in a manner consistent with the EU procurement directives.

[20] "America's Industrial Resurgence: An Overview", Mowery, D.C., in Mowery, D.C. (ed.), *U.S. Industry in 2000: Studies in Competitive Performance,* 1999, p. 1.

8.58 It is generally agreed that the SBIR has played an important part in sustaining the demand for new – and often radically new – products and services that are vital to support innovative activity.[21] Each year, on average, over 4,000 awards are made under the scheme to US small businesses, worth over $2 billion in total.[22] Furthermore, SBIR funding can act as a lever for future capital investment: with a guaranteed government contract and the likelihood of future commercialisation of products, much of the risk of early-stage high-technology investment is reduced.

8.59 The UK SBRI has so far failed to achieve anything like the success of the US scheme, even allowing for the different legal frameworks and smaller budgets it operates under. Almost every department claims to spend more than its 2.5 per cent allocation, and have done so since before the mandatory target was introduced. But the introduction of this target appears to have made no difference to departmental behaviour. SMEs are asked to tender for specific pieces of research, many of them concerned with the development of policy, rather than being asked to bring forward research projects in scientific or technical areas where the government department wants to see research take place. There is no active engagement with suppliers beyond the completion of a contract. As a result, the scheme has done little more than reproduce existing practice – with an additional bureaucratic burden.

A new SBRI scheme

8.60 The SBRI has the potential to transform the financing of innovative SMEs, but it needs radical reform in order to achieve this. David Connell and Anne Campbell have presented a well-developed set of proposals for reforming the current SBIR system.[23]

[21] See, for example, "The Government as Venture Capitalist: The Long-run Impact of the SBIR Programme", Lerner, J., *Journal of Business,* July 1999. Lerner finds a strong positive relationship between SBIR awards and growth of high-technology firms.

[22] Figures cited in *Secrets of the World's Largest Seed Capital Fund*, Connell, D., Cambridge Centre for Business Research, 2006, p. 2.

[23] These are presented in their most complete form in Connell, '*Secrets*', op. cit.

Recommendation 8.8

The SBRI should be reformed, adopting the following principles of the successful US SBIR scheme:

- departments should focus on active engagement with innovative businesses and act as intelligent customers to fulfil their departmental objectives;
- departments should specify up front, in a simple and standard format, and update on a fixed and regular basis, the technological areas in which they would like to see projects, in a simple, standard format;
- SBRI contracts should adopt a two-phase structure, tendering a second, larger award after successful completion of a smaller, early-stage development, so as to minimise risks associated with innovation;
- SBRI awards must take the form of contracts, not equity loans or grants; this will ensure that departmental objectives are clearly identified and met, and will enable the award of an SBIR contract to act as a "seal of approval", reassuring future investors and customers of the firm's value;
- SMEs should retain the intellectual property associated with any new technology, boosting incentives for high-quality small businesses to bid for SBIR awards; and
- to maximise the SBIR's effect, award availability should be restricted to products and services meeting the HM Treasury's R&D tax credit criteria; this would exclude humanities and social science research and consultancy, for which the scheme was never intended.

Technology Strategy Board and the management of the new SBRI scheme

Recommendation 8.9

In order to ensure this time that the new SBRI scheme achieves its objectives, this Review recommends that a central administrative role be given to the TSB. Government departments should be required twice a year to notify to the TSB in a standard form those technological areas where they would like to support projects. The TSB would then be responsible for publishing twice a year, at fixed dates, a list of the projects notified to it by government departments so that SMEs are readily able to find them. The awarding of contracts should also be administered by the TSB, with assessment of proposals being made jointly with the relevant government departments.

8.61 It is appreciated that as this will mean government departments having to fund projects they have currently not been paying for, and that this will put pressure on their budgets.

Recommendation 8.10

SBRI targets for extramural departmental R&D should build up over three years, from 1.5 per cent in the first year to 2 per cent in the second year and 2.5 per cent in the third year.

REGULATORS

8.62 Since privatisation of the utilities and communications sectors, there has been an improvement in the efficiency and effectiveness of customer service. However, these sectors are facing tough new challenges and we are concerned that a lack of investment in R&D in the price-regulated utilities sectors since privatisation may mean that they are not best placed to meet the challenges their sectors face.

8.63 We have consulted the Regulators on this issue and it is evident that innovation is given a varying degree of attention in these organisations. It is important that Regulators give due consideration to long-term customer needs, but the Review is concerned that if Regulators focus solely on short-term prices without considering innovation, this could be at the expense of capability and long-term value for future consumers.

8.64 It can be argued that the nationalised industries over-invested in R&D, but a real term reduction of R&D in utilities product group, which excludes telecommunications, from £183 million in 1981 to £116 million in 2002 (a fall of 37 per cent[24]) is a concern. R&D spending does not necessarily translate into innovation and privatised companies may be spending research money more effectively than nationalised industries. Nonetheless, the scale of the decline suggests that whatever efficiency improvements have been introduced, investment in innovation has almost certainly reduced. This is particularly worrying given the pace of technological change in the past two decades. Regulators may have had some impact on this decline as significant chunks of the sector are subject to direct price regulation, including water supply, the National Grid and the distribution of natural gas.

Ofcom

8.65 Ofcom is the regulator for the communications sector, with responsibility for regulating telecoms, broadcasting and the radio spectrum. One of Ofcom's duties, as outlined in the Communications Act 2003, is to consider innovation.

8.66 Ofcom commissioned a review of innovation in January 2006.[25] The review highlighted that, in the long run, innovation is the mechanism by which choice and value can be delivered to the citizen-consumer, Ofcom's highest duty, and recommended that innovation be given a significant weight in policy formulation. Its report argues that innovation can best be stimulated by giving the market freedom to innovate by regulatory withdrawal and technological neutrality, and by creating the incentive to innovate through competition. Where intervention is necessary, the report supports outcome-based regulation. It recommends that Ofcom encourages innovation in three ways:

1. by promoting competition;
2. by exploring potential future developments in the communications industry to keep regulation responsive to sector need;
3. by carrying out research and development in specific areas.

[24] ONS figures for electricity, gas and water supply business group.
[25] *The Role of Encouraging Innovation,* Cleevely, M., Jan 2006.

8.67 Ofcom says that it supports the findings of the report and recognises that innovation delivers wide-ranging benefits to consumers. Ofcom has conducted major strategic reviews of telecoms, spectrum and public-service broadcasting to consider how these sectors are likely to evolve and to identify the key issues requiring regulatory action. This enables Ofcom to target regulation more effectively and to remove any regulations that are no longer needed. The strategic review of telecoms led to targeted regulation of BT to promote competition from other operators. BT agreed to set up a separate business, Openreach, in order to provide all communications providers with equivalent wholesale products. This has stimulated increased competition and innovation at the retail level, with consumers benefiting from lower prices and new services, including higher-speed broadband, and has led to the removal of regulation around price control on voice calls.

8.68 Ofcom has its own programme of research and development, focusing on new and emerging technologies and assessing the extent to which regulation may need to change to allow them to develop. For example, it is examining cognitive radio technology in advance of its likely commercial introduction.

Ofwat

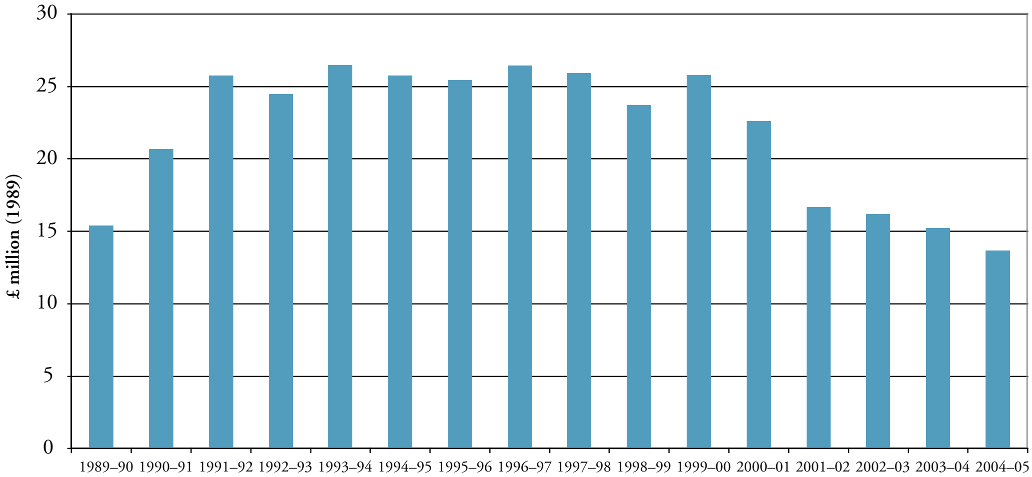
8.69 Ofwat is the economic regulator of the water and sewerage industry in England and Wales and sets price limits for each of the companies. Since privatisation 18 years ago, the market has comprised a number of regional and local vertically integrated water and wastewater companies with a monopoly position.

8.70 One of Ofwat's primary duties is to protect the interests of consumers, wherever appropriate by promoting effective competition. Ofwat's interpretation of this duty is reflected in its vision "for a water industry that delivers a world-class service, representing best value to customers now and in the future". Promoting innovation is not a specific duty for Ofwat, however innovation is an important part of protecting the interests of customers in the future, and Ofwat's duties were amended in 2003 to add emphasis to competition and sustainability.

8.71 R&D spending by water companies was equivalent to only 0.3 per cent of industry turnover in 2004–05.[25] This is likely to be related to the fact that, unlike other utilities, there is little or no competition in the water industry. Relative to the utilities sector as a whole, real spending by water companies on R&D remained relatively stable throughout the 1990s, declining sharply and continuously after the end of the decade (see Chart 8.2). There are two major reasons for this: first, the implementation of a series of EU directives on water quality required significant exploratory expenditure (for example in setting up pilot plants and schemes) throughout the decade, boosting R&D spending; second, the price regulation imposed by the regulator resulted in a 12 per cent drop in regulated consumer charges in 1999. Unlike capital and operating expenditures, it is relatively easy to cut costs in R&D without immediate impact, and so water companies were driven to reduce R&D spending in order to maintain profit margins.

[25] Figures from Ofwat, *Financial Performance and Expenditure Report*, September 2006, Table 4.

Chart 8.2: Water companies' real expenditure on R&D



8.72 UKWIR is the industry body, established by water companies, that conducts research of common interest within the sector. Surveying the pattern of R&D spending, a UKWIR study concluded: "there is a misalignment of expectations between the supply-chain, the water companies, the regulators and government which is limiting the sector's ability to fully exploit its capacity for technological innovation to sustainably meet the future needs and challenges of UK and world markets".[26]

8.73 The same report also found that incentives to innovate are limited to reducing leakage and maintaining water quality, with longer-term issues, such as energy efficiency, accorded a much lower priority, and this despite the huge energy bills faced by UK water companies. Innovation is confined to areas that have specific regulatory requirements, implying that a broader regulatory agenda, extended to include innovation, would have a positive impact on water companies' behaviour.

8.74 The most effective way for Ofwat to stimulate an appropriate level of innovation and protect consumer interests in the long term would be to introduce competition and withdraw regulation. Ofwat have recently published reports on how they believe competition should be developed in the water industry. Where the market may not be able to provide the correct incentives for innovation (for example in the natural monopoly element of the supply chain), Ofwat's regulation should include considering how to incentivise an appropriate level of innovation that is consistent with its other objectives. Ofwat recognises this dual role in relation to promoting innovation as part of fulfilling the longer-term aspect of its duty to protect consumers.[27]

8.75 Ofwat recognises that innovation is a way to achieve sustained outperformance at the same time as delivering regulatory outputs, and argues that companies not undertaking R&D, perhaps for short-term cost cutting reasons, run the risk of failing to meet longer-term efficiency assumptions.[28]

[26] *Barriers to Innovation in the UK Water Industry*, UKWIR.
[27] Ofwat submission to the Sainsbury Review, 2007.
[28] Ibid.

Ofgem

8.76 Ofgem is the economic regulator of the gas and electricity supply industry in England and Wales. Its first priority is protecting the interests of consumers, present and future, by promoting competition and regulating the monopoly companies that run the gas and electricity networks. As with Ofwat, although promoting innovation is not a specific duty for Ofgem, innovation is an important way to protect the interests of future customers.

8.77 The customer experience since privatisation has been positive in many important respects. Ofgem, and its predecessor regulators, have taken the steps to develop a competitive market for the supply of electricity and gas.

8.78 The power sector, however, will face unprecedented challenges over the next 20 years. Some of these will be driven by the global political agenda – for example, addressing climate change through renewable generation and greater energy efficiency, and developing diverse and more secure supply sources. Other challenges will be driven by domestic issues – for example, in the UK the need for significant infrastructure investment to replace ageing assets and to reflect an evolving mix of sources of supply. The UK could also face particular difficulties as a result of the shrinking pool of skilled engineering resources, both in academia and industry. Although some action to address this issue in the power sector has been taken through, for example the development of the Power Academy (an engineering scholarship fund for students that would like to study electrical engineering at Cardiff, Imperial College London, Strathclyde, Manchester, Southampton or Queens University, Belfast), more needs to be done.

8.79 Substantial investment in R&D and innovation will be needed to address these challenges effectively. Electricity generators are investing in new generation technologies and the Government has established a wide range of policies to incentivise innovation and its deployment, including the Renewables Obligation, the Environmental Technologies Institute and the commitment to a demonstration of Carbon Capture and Storage. Research effort is required throughout the energy value chain, not just in relation to high-profile areas such as new generation technologies. For example, the UK is undergoing a period of significant network renewal and expansion in gas and electricity. Similarly, improvements in metering technologies offer substantial gains in energy efficiency and network design.

8.80 However, investment by electricity distribution companies in engineering R&D entered a progressive decline and by 2002 was approaching zero activity. In the 2004 Price Review, Ofgem introduced two financial incentives to address the situation: the Innovation Funding Incentive and Registered Power Zones. These have been operating for over two years and have been recently reviewed, showing that the investment in R&D has already returned to 1990 levels. R&D activity in the last year reported (to March 2006) totals £6.5 million. This represents some 180 projects with a total forecast net return of £50 million. Not one company is yet spending to its allowed maximum of 0.5 per cent of turnover. This amount of research still seems to us to be too low.

8.81 The "RPI-X" form of regulation, where prices are increased by RPI minus some figure, has served the industry well in the past (driving down costs by around 65 per cent). However, network industry regulators are increasingly aware that a single focus on short-term cost reduction is not always appropriate. In the medium term, Ofgem will need to incentivise focused R&D activity, especially in the price-regulated part of the energy market, and the deployment of resulting innovations where these contribute to meeting the interests of consumers, now and in the future.

8.82 R&D in any industry represents a long-term investment. From today's low levels of activity, delivering an effective industry-wide programme built on partnerships between regulated companies and universities will depend on a commitment to longer-term funding. This longer-term stability will allow the development of capabilities in research departments, with potential students seeing a clear demand for innovative engineering solutions as well as a route to potentially attractive employment opportunities.

8.83 We are concerned that Ofgem and Ofwat, in particular, do not give sufficient consideration to innovation, and that in the long term this could impact on services to future consumers.

Recommendation 8.11

Regulators should review their policies to ensure that the appropriate level of emphasis is given to innovation in their decision-making in the price-regulated sectors, to protect the interests of both current and future consumers. We would like consideration to be given to how innovation could be incorporated into their duties.

9 The science and innovation strategies of Regional Development Agencies

INTRODUCTION

9.1 At a regional level, science and innovation are increasingly important for improving economic performance. However, if we are to optimise the benefits of regional R&D support for innovation we want to make certain that such regional spending takes place within national and international frameworks.

9.2 "Tacit" knowledge, so important in the new economy, is not easily diffused over wide areas, so innovation is frequently fostered by proximity. A recent US report[2] describes innovation as a contact sport that "is best pursued through personal interactions at every stage in the game". The rise of multidisciplinary projects reinforces the importance of direct interaction between players.

9.3 Distance can reduce the success with which new innovations are transferred from the laboratory to commercial exploitation, or process innovations are adopted and diffused across developers and users. This is particularly the case for small firms that are unable to spend large amounts of company time and money searching for up-to-date knowledge and suitable contacts or potential partners.

9.4 Innovative capabilities are therefore often sustained through regional communities that share a common knowledge base and interact through common institutions. The forms of collaboration and interactions that occur in these communities draw attention to the role that regional institutions play in supporting innovation in a global economy. The US innovation report[3] points to the paradox that while innovation is a global phenomenon, "the role of regions as the critical nexus for innovation-based economic growth has increased".

THE REGIONAL DEVELOPMENT AGENCIES

9.5 To drive growth in the English regions, the Government established eight Regional Development Agencies (RDAs) in 1999. The London Development Agency (LDA) was created in 2000 under the Greater London Authority.

[1] HM Treasury, DTI and DfES, Science and Innovation Investment Framework 2004–2014, July 2004. Available at www.hm-treasury.gov.uk
[2] Regional Innovation National Prosperity, Council of Competitiveness 2006. Available at www.compete.org
[3] Ibid.

9.6 The RDAs are the strategic leaders of economic development and regeneration in their regions. Each RDA is responsible for drawing up, with local and regional partners in all sectors, a Regional Economic Strategy (RES) for the region. The role of the RES is to provide a shared vision for the development of the region's economy, to improve economic performance and to enhance the region's competitiveness. Its aim is to ensure that all those responsible for economic development work together to establish common goals and priorities for the region's economic development. Six of the nine RDAs have recently reviewed their RES, resulting in a stronger focus on distinct regional priorities, spatial analysis and on the evidence base for promoting regional growth.

9.7 The RDAs are business-led organisations. Their Chairs are appointed on the basis of their track record of working within their region and understanding the needs of regional business and society. Business representatives make up the majority of RDA Boards, which also include a range of other senior stakeholders from within the region, including local government, the voluntary sector and trade unions.

9.8 Since April 2002, RDA funding has originated from a single cross-departmental programme budget, which gives RDAs maximum flexibility to target their resources in the way they consider most effective to deliver their targets.[4] The single pot is on average £2.25 billion per annum over the 2004 Spending Review period, and the greatest share of the budget goes to the relatively poorer northern regions and to London, which has pockets of severe deprivation.

9.9 RDAs have provided detailed disaggregation of their spending as evidence for the Review of Sub-National Economic Development and Regeneration, which suggests that for the three years of the 2004 Spending Review period (i.e. 2005–06 to 2007–08) the RDAs spent on average 14 per cent of the single pot on innovation activities. However, spending on Innovation varies considerably across regions. For example, the LDA and One North East (ONE) spend 7 per cent and 19 per cent of their budgets respectively (see Table 9.2).

9.10 Differences in innovation spend in the regions are due to differences in overall available spend and the priority given to innovation by each RDA. It is worth noting that the single pot mechanism encourages RDAs to move away from easily segregated spend so that exact definitions of spend are not possible. The RDAs have emphasised that they recognise the growing importance of science- and innovation-led regeneration.

Table 9.1: Total funding allocated to a sample of the different RDA activities (£ million)

	West Midlands (AWM)	East England (EEDA)	East Midlands (EMDA)	London (LDA)	North West (NWDA)	North East (ONE)	South East (SEEDA)	South West (SWRDA)	Yorkshire (YF)
Enterprise	83	25	49	76	92	73	43	57	72
Innovation	**24**	**39**	**31**	**30**	**59**	**57**	**23**	**19**	**41**
Regeneration	105	52	75	236	211	103	99	61	155
Transport and infrastructure	9	3	4	56	14	5	2	9	1
Total expenditure	**304**	**157**	**190**	**445**	**438**	**296**	**220**	**179**	**336**

[4] BERR, CLG, DEFRA and DCMS and UKTI.

Table 9.2: The percentage of total funding allocated to a sample of different RDA activities

	West Midlands (AWM)	East England (EEDA)	East Midlands (EMDA)	London (LDA)	North West (NWDA)	North East (ONE)	South East (SEEDA)	South West (SWRDA)	Yorkshire (YF)
Enterprise	27	16	26	17	21	25	19	32	21
Innovation	**8**	**25**	**16**	**7**	**14**	**19**	**11**	**11**	**12**
Regeneration	35	33	39	53	48	35	45	34	46
Total expenditure	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

PROGRESS ON SCIENCE AND INNOVATION STRATEGIES

9.11 There are many good examples of work underway to stimulate innovation in the regions. For example, all RDAs have set up their own business-led Science and Industry Councils (SIC), bringing together business leaders and scientists to provide strategic advice on regional science and innovation priorities.

9.12 Since their creation, the responsibility for delivering a number of then-DTI business support programmes has also been delegated to the RDAs. They are now the delivery agents of the Manufacturing Advisory Service, Support for Design, Business Link services, and other business support programmes.

The Planning System and Innovation

The potential for the planning system to hinder innovation was noted by the Barker Review of Planning. For example, restrictions imposed by the planning system delayed the development of new scientific research facilities in Cambridge and, before local reforms, potentially impeded the growth of the Oxford cluster.

The Barker Review noted the importance of a well-functioning planning system to the provision of infrastructure and the attractive living and working environment vital to the retention of skilled workers. Recommendations, now taken forward by the Government's White Paper on Planning, reflected the need to deliver a speedy and efficient planning system that retains the vital elements of development control and local democracy. The importance of supporting productivity growth – including innovation – through local plans was noted.

Science Cities

9.13 Most RDAs have also developed Science Cities, based on the concept that clusters of knowledge-intensive firms tend to form around large research universities. All six Science Cities have at least one major university in them and are focusing on building on this asset by joining up local policies and addressing a range of wider policy issues to create an innovation ecosystem that will make the cities attractive locations for business investment.

Science City York case study

The development of Science Cities is based on the notion that, in the global economy, the UK's future prosperity depends, first, on the capacity to expand knowledge through science (in the widest sense) and translate it into innovative products and better services and, second, on achieving this by building critical mass in clusters based around world-class universities.

Science City York (SCY) is a partnership between the City of York Council, the University of York, Yorkshire Forward – the RDA for Yorkshire and the Humber/and business. SCY is strengthening business – university links to develop and increase the competitiveness of the knowledge-based cluster in and around York. The aim is to develop the economy and employment opportunities and to ensure that new jobs are available as opportunities in York's traditional industries decline.

SCY works through three main clusters: bioscience and health, IT and digital, and the creative industries. SCY has a number of mechanisms in place to promote an environment in which technology, skills and business can thrive:

- cluster managers and business promoters help entrepreneurs to develop their business ideas and provide mentoring and business advice;
- direct access is available to two early-stage funds for technology-based businesses;
- businesses are put in contact with a wide range of schemes in the universities and other sources in the region;
- appropriate incubation and grow-on space is provided at science parks for knowledge-based businesses; and
- a programme of public understanding and support is used to promote the science-led economy.

Key employers and clusters are brought together with the universities, further education and schools to identify and address the skills needed to ensure successful growth.

Since the start of Science City York, over 60 new companies and 2,600 new jobs have been created in the technology-based cluster in York, and as many people are now employed in this sector as in tourism. Following support for the Science City concept from government, Science City York has recently been re-formed as a company limited by guarantee owned by the city and the university, and has appointed a high-level Chief Executive to lead it into a new and more entrepreneurial phase with even closer involvement of the private as well as the public sector.

SCIENCE PARKS AND INCUBATORS

9.14 The RDAs have supported high-technology incubator facilities and science parks to help create the best conditions for high-technology business to innovate and grow. These facilities house large and small high-technology businesses from the public and private sectors, providing business support and an environment for the interchange of ideas and experiences.

9.15 The £50 million that the Government gave to the RDAs to set up high-technology incubators has had a catalysing effect on the number of science parks and incubator facilities over the past decade. In 1996 there were about 25 incubators for high-technology firms in the country. By 2000 this had risen to 100, and today it is estimated that there are over 270. Incubators can be an important part of the spin-out process if they are set up and run effectively. The successful incubators tend to be located close to but separate from the university, and be surrounded by a lively business community. They house a pool of talented executives and offer a range of services, such as legal, accounting and business consultancy.

9.16 Over the same period there has also been a significant increase in the number of science parks. In 1998 there were 39. Today there are nearly 100, with almost 1,700 tenant businesses.

Daresbury and Harwell

9.17 In 2006, the Government took a strategic decision to locate its large-scale scientific and technological facilities at Daresbury, Cheshire, and to develop the Harwell site in Oxfordshire when the land became available after nuclear decommissioning. The Government has turned the sites into major Science and Innovation Campuses, with the potential to become the centres of high-technology clusters and important growth points for their regions (see following box).

9.18 The RDAs and local authorities recognised the opportunity to attract national and international high-technology companies, and have been key collaborators and funding partners in both campuses. North West Development Agency (NWDA) has been active in the development of the Daresbury Science and Innovation Centre (DSIC), investing more than £50 million. NWDA is confident that DSIC will make a significant contribution to its regional economy, including the creation of skilled jobs in the North West.

9.19 NWDA has also recognised that there are significant knowledge transfer and procurement opportunities presented by the Science and Innovation Campus, and has appointed a Knowledge Transfer Manager to work specifically with the Cockcroft Institute, a centre for accelerator science, to establish relationships with the key decision-makers on its projects. The Knowledge Transfer Manager will act as the initial conduit between the scientists and procurement specialists on the Institute's projects and UK technology companies to facilitate UK procurement opportunities.

Recommendation 9.1

The Review is aware of other opportunities which exist to create major science and innovation campuses in the medical and defence fields, and we recommend that these are actively pursued.

Daresbury and Harwell Science and Innovation Campuses

These two major Science and Innovation Campuses are emerging as centres of high-technology clusters and important growth points for their regions. The Daresbury campus is a partnership between the Science and Technology Facilities Council (STFC), the North West Development Agency (NWDA), the borough council and the universities of Manchester, Liverpool and Lancaster. Daresbury facilities include, among others:

- Daresbury Innovation Centre, a high-technology incubation centre housing approximately 44 companies which have either spun out of university or have "spun in" from elsewhere;
- the National Centre for Electron Spectroscopy and Surface Analysis (NCESS), solving problems in materials science, surface science and engineering;
- Synchotron Radiation Source (SRS), the UK's pioneering light source, providing light across the spectrum from ultraviolet to X-rays;
- HPCx, a tightly coupled supercomputing system which is used to study computational science and engineering challenges, such as transport in biological cells, helicopter rotor wake simulations and coastal ocean modelling;
- Cockcroft Institute an international centre for Accelerator Science and Technology (AST);
- Medium Energy Ion Scattering Facility (MEIS), investigating the surface structure and properties of crystalline materials;
- The Nuclear Physics Group, supporting nuclear physics research around the world; and
- Super Scanning Transmission Electron Microscope (SuperSTEM).

The Harwell Campus was originally the UK centre for civil and nuclear power and underwent a dramatic change of direction in the early 1990s to become a centre for a wide range of government facilities and business, including:

- Diamond Synchrotron, a third generation 3 GeV synchrotron radiation source, which is an indispensable tool in many research areas, such as physics, chemistry, materials science and crystallography, and which is being increasingly exploited in the fields of medicine, geological and environmental studies, and structural genomics and archaeology. Diamond is currently the best medium-energy X-ray source in the world;
- ISIS, the world's leading pulsed neutron and muon source;
- Central Microstructure Facility, providing microfabrication services and R&D facilities, based on electron-beam lithography;
- British Atmospheric Data Centre (BADC), a designated data centre for atmospheric sciences;
- Energy Research Unit, focusing on renewable energy research, including wind turbines;
- Radio Communications Research Unit (RCRU), researching radio communications, radiowave propagation and atmospheric sensing;
- Molecular Spectroscopy Facility, specialising in infrared, visible and ultraviolet spectroscopy; and
- the World Data Centre (WDC) for solar-terrestrial physics.

THE GROWTH OF HIGH-TECHNOLOGY CLUSTERS

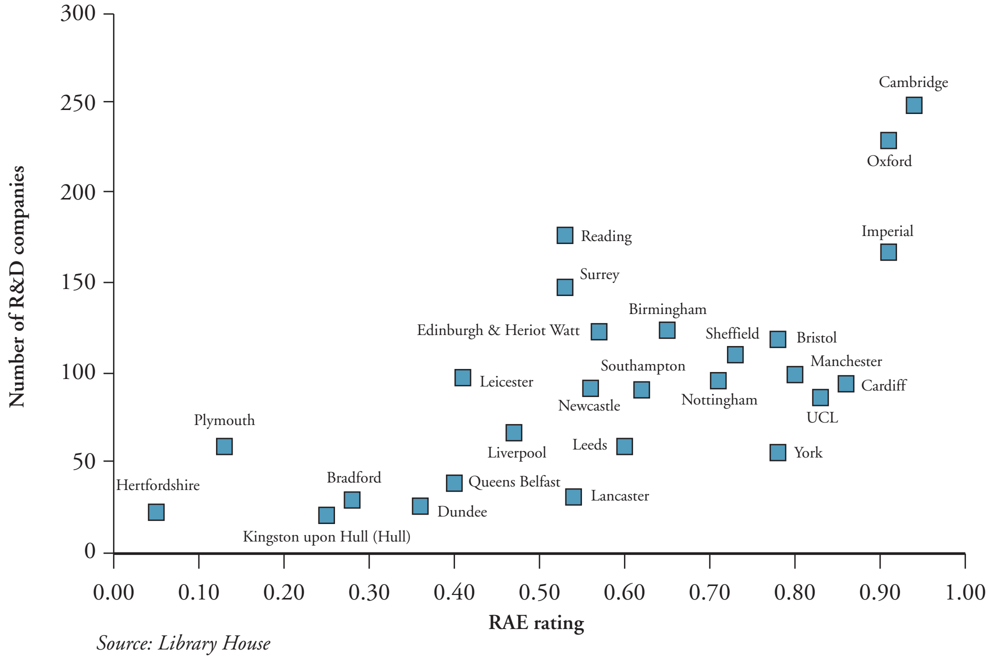
9.20 Clusters of high-technology companies can stimulate regional economic growth, and a recent report by Library House[5] showed the extent to which high-technology clusters have been forming in the UK around our world-class research universities. This supports the theory that universities are one of the driving forces behind the formation of clusters. They promote innovation and entrepreneurship, not only by spinning out companies, but also by creating an appropriate microenvironment to attract innovation-based companies and foreign R&D facilities. The formation of these clusters raises important questions about the extent to which RDAs can help them to grow faster and whether they can use them to help other high-technology companies in their regions.

9.21 According to the report, high-technology clusters are forming around large research universities, regardless of the total size of the city surrounding the university (e.g. the Cambridge cluster). In fact, there is no correlation between the number of R&D companies and the total number of other companies in the same areas. This suggests that having many companies in one city does not in itself create a high-technology cluster. A cluster grows out of the research excellence of a university.

9.22 Unsurprisingly, R&D-based and venture-backed companies locate around high-quality research universities to a far greater extent than around lower-quality research universities. So high-quality research universities have a disproportionately larger effect on cluster formation (see Charts 9.3 and 9.4).

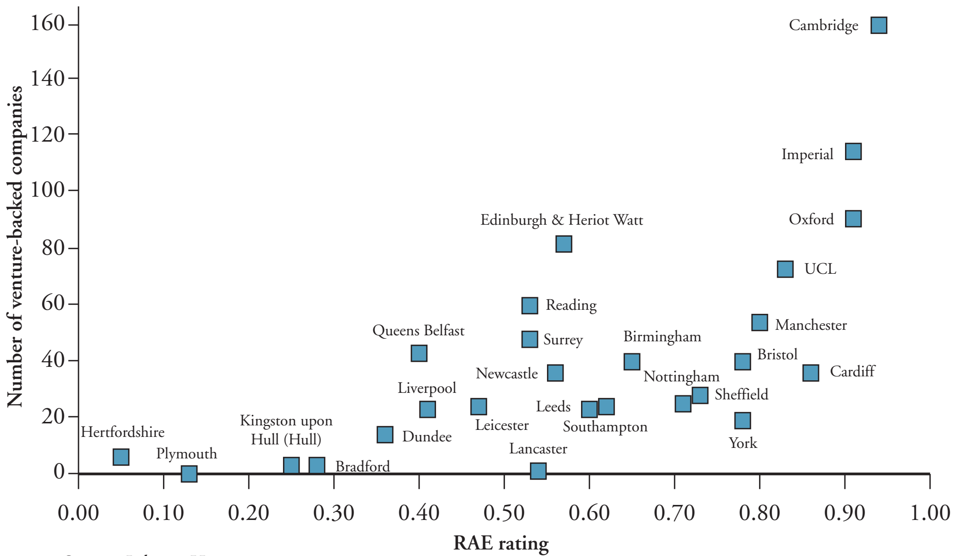
[5] An Analysis of UK University Technology and Knowledge Transfer Activities, March 2007.

Chart 9.3: Research Assessment Exercise (RAE) rating vs R&D companies



Source: Library House

Chart 9.4: RAE rating vs venture-backed companies



Source: Library House

9.23 The Library House report also found that most universities receive less than 5 per cent of their research income from industrial partners and that there is no correlation between the quality of research being conducted at a university and the extent of the industrial interaction of that institution. Universities appear to have a broadly similar level of industry interaction, regardless of the quality of research being conducted. However, the type of interaction differs. High-quality research universities interact with larger companies, while lower-quality research universities collaborate more frequently with SMEs.

9.24 High-quality research universities spin out the majority of high-quality companies, measured by the ability of these spin-outs to attract external funding. Even when lower quality research universities have efficient technology transfer operations, their lack of research raw materials means that they struggle to spin out large numbers of quality companies. The report concludes that the high-quality research universities carry out most technology transfer. As explained in Chapter 4, we believe that there is now an opportunity to strengthen the knowledge transfer between the business facing universities and SMEs.

Manchester high-technology cluster

The University of Manchester is a powerful economic driver for the city and its surrounding region. As well as its rapidly growing direct economic impact of around £1.4 billion per year through the spend of its 11,000 staff and 36,655 students, it forms the hub of a vibrant technological and cultural cluster.

At the core of the cluster is a close partnership with public bodies and business that allows a joined-up approach to economic opportunities. When Rapiscan Systems, a leading supplier of airport X-ray and scanning equipment, was looking for a location for its research subsidiary CXR Ltd, it needed proximity to a major airport and the ability to recruit the staff it needed. MIDAS, Manchester's inward investment agency, was able to co-ordinate a response with an offer that included premises in a new high-technology facility at One Central Park and assistance from the university's careers service. Collaboration has flourished, with a recent £750,000 collaboration with the university's mathematicians to develop novel mathematics and computer algorithms for a new three-dimensional baggage screening system.

Rapiscan Systems is one of over 100 science-based firms occupying the university's incubators and the Manchester Science Park (MSP). MSP is a profitable public–private partnership co-owned by Manchester's universities, the city council and private sector investors. Around one quarter of its tenants originated in the universities but more than half have active professional links with them.

The supply of new firms has been driven by the UK's most generous intellectual property offer to university staff and a funding ladder that takes firms through four stages, from an internal proof-of-concept fund, through a University Challenge fund and on through the seed funding and classic venture funding stages. A dedicated technology transfer company manages the intellectual property created. The university has set itself demanding targets of 10 per cent annual growth in third party investments attracted. The tally stands at £150 million in 2.5 years with a portfolio of 55 spin-outs and a licence income of just under £1 million in 2 years. Significant financial results have included a £63 million London Stock Exchange float of Renovo, a company specialising in wound-healing technology, and the sale of spin-out NeuTec Pharma to Novartis for £308 million.

BUILDING ON THESE INITIATIVES

9.25 This Review welcomes the action taken by the RDAs to promote regional science and innovation described above, but we believe that if the RDAs are going to have a significant impact on the economic performance of their regions they need to build on the initiatives they have taken.

Recommendation 9.2

To raise their impact on the economic performance of their regions, RDAs should shift their resources towards activities which support science and innovation, and, using business support schemes being developed through the Business Support Simplification Programme, should concentrate their efforts on four main areas:

- user-driven collaborative R&D;
- knowledge transfer;
- cluster development; and
- the start up and growth of new businesses.

9.26 We believe that the best way for the RDAs to create the jobs and industries of the future is to focus their resources on the opportunities for regional growth, with support from their SIC, rather than allocating their resources evenly across the region.

Sub-National Review

9.27 The Review of Sub-National Economic Development and Regeneration[6] has considered how to improve the efficiency and effectiveness of existing sub-national structures in England. This Review welcomes the conclusions of the Sub-National Review, which proposes a much clearer focus for the RDAs on increasing regional economic growth, with the RDAs being set a single over-arching growth objective rather than the basket of twelve PSAs and ten output targets which currently form the RDAs' objectives. The growth objective will be underpinned by five outcome-focused performance indicators. Consistent with the drivers of productivity and employment, these indicators will be:

- GVA per hour worked, as a measure of productivity;
- employment rate, showing proportion of the working-age population in work;
- basic, intermediate and higher level skills attainment, to show skills levels consistent with DIUS targets on skills;
- R&D expenditure, as a proportion of GVA, as a measure of innovation; and
- business start-up rates, as a measure of enterprise.

9.28 Other measures resulting from the Sub-National Review will help to ensure that there is greater alignment between central government agencies, the RDAs and local authorities, to work together to achieve regional priorities in a way that more effectively increases economic growth. The Sub-National Review notes that to achieve the economic objectives there must be a clearer focus on market failures in the drivers of productivity that apply at sub-national levels, particularly enterprise, science and innovation, skills, investment and employment.

9.29 This Review welcomes the proposed new performance arrangements for the RDAs, which will enable and encourage the RDAs to improve their value for money, effectiveness and efficiency in achieving the overarching growth objective, and to improve their capacity.

[6] The Review of Sub-National Economic Development and Regeneration, July 2007. Available at www.hm-treasury.gov.uk

User-driven collaborative R&D

9.30 Effective collaboration between the nine RDAs, the Science and Industry Councils and the Technology Strategy Board (TSB) is essential to achieve a closer alignment of national and regional investment in innovation and technology and to streamline business engagement in collaborative R&D programmes.

9.31 There are already a number of effective working partnerships between national government and the RDAs on individual programmes and projects in support of innovation and a growing working relationship on a broader alignment of strategy.

9.32 For example, the RDAs have found funding collaborative R&D projects an effective way of generating wealth for their regional economies, and are increasing their level of engagement and funding for the TSB's collaborative R&D programme. Collectively, the RDAs have so far contributed £27 million to the programme, which attracts private sector investment to match the public funding provided.

9.33 We believe that the RDAs should increase their support for the TSB's collaborative R&D programme and improve the process by which their funds are allocated. Support for collaborative R&D can greatly help companies in their regions to innovate and grow, and RDAs have limited resources with which to assess technological developments or specific proposals from companies and universities. Further, it is inefficient for companies to have to deal with a multitude of organisations to secure funding for a project.

Recommendation 9.3

The RDAs, TSB and SICs will collaborate to support innovation priorities that deliver the National Technology Strategy and Regional Economic Strategies. Utilising the Single Pot and European Regional Develoment Funds,[7] each RDA will earmark investment to match fund TSB programmes on a case-by-case basis or as part of a regional prospectus. This will lead to a total investment from the RDA network of £180 million over three years, starting in 2008, subject to appropriate projects being identified that benefit the regions.

9.34 This Review envisages this joint process taking the following form. The TSB consults the RDAs in formulating its plans for the collaborative R&D programmes and the RDAs stipulate up front an amount that they are prepared to match fund over the Spending Review period. Three to four months before the start of each financial year, the TSB announces the technological areas in which it is proposing to make calls in the year ahead. The SICs in each region decide which technological areas they would like to support. There should be a single application form and evaluation process for proposals, run by the TSB. If there are not enough projects of a sufficiently high quality in the region, the RDA money would not be forthcoming.

9.35 The RDAs will benefit from being able to draw on the expertise of the TSB while directing funds to support regional priorities. Business will benefit from a simpler and quicker process.

[7] Note: Subject to approval by the Commission of the ERDF Operational Programmes for the 2007–2013 period.

Knowledge transfer

9.36 The then-DTI's Knowledge Transfer Partnership (KTP) scheme has been running for over 30 years. It is one of Europe's leading programmes helping businesses to improve their competitiveness and productivity through the better use of the knowledge, technology and skills that reside within the UK knowledge base. The economic impact of the scheme is very high and the demand for the scheme is far greater than the funding available.

Recommendation 9.4

Subject to the Business Support Simplification Programme, RDAs should increase their support for the KTP scheme and invest in and support the new mini-KTP scheme, which will allow for shorter placements and hence increase the flexibility of the programme.

Support for high-technology Clusters

9.37 The Library House research cited earlier shows that strong and competitive clusters are a critical component of a good business environment and can drive regional innovation and economic growth. The RDAs have recognised the importance of excellent universities in driving regional economic growth by developing the Science Cities.

Recommendation 9.5

Drawing on the success of the CONNECT scheme in San Diego (see the following box), RDAs should support services for high-technology entrepreneurs around our world-class universities similar to the CONNECT service within the BSSP framework.

9.38 Setting up a holistic support service to assist entrepreneurs, where they can get advice from lawyers, accountants, investors and fellow entrepreneurs in one place, has the potential to significantly improve the success rate of high-technology start-up companies across the UK.

9.39 While such a service is best-placed to begin around a world-class research university, as the cluster develops it can provide a service to a much wider area.

San Diego CONNECT scheme

The CONNECT scheme was set up in 1985 by the University of California, San Diego (UCSD) in close collaboration with local business to meet the varying needs of San Diego entrepreneurs at all stages of their businesses life cycles and growth. CONNECT is now regarded as a highly successful regional programme, linking high-technology entrepreneurs with the resources they need for success: technology, money, markets, management, partners and support services. The programme, which is entirely self-supporting, has built up a network of business and university resources, creating an energetic, resource-rich environment for honing ideas, pursuing personal growth and professional development, and exploring innovation business opportunities. Since its inception, CONNECT has assisted more than 800 technology companies.

Springboard, CONNECT's flagship programme, assists technology-based companies and entrepreneurs in refining their business and financial strategies through a group mentoring process. It assists with the development of business plans and business presentations, and provides a forum in which the entrepreneurs can present their refined business model before a group of business, marketing and management experts. The scheme's success steams from its holistic approach, the range of expertise it provides and the fact that "none of us are as smart as all of us". Mentoring is provided by top-level CEOs who volunteer their services. Since its inception, Springboard has assisted over 250 technology companies in starting and funding their operations. These companies have raised over $600 million in early/seed-stage investment and 150 are still in business.

The critical success factors of CONNECT in San Diego include:

- building out of academic research excellence within a university, acting in partnership with the region;
- investing in and encouraging the infrastructure to allow companies to grow;
- enlisting early support and involvement from the private sector;
- avoiding a prescriptive focus on one or two existing sectors; new ones will emerge around research excellence and international innovation;
- scanning for and supporting the potential champions (companies and individuals) who have the potential to drive a city/region's economic change;
- understanding that companies are attracted to the hot spots where customers, competitors and research excellence are located; a cluster cannot be created in a vacuum.

Recommendation 9.6

RDAs should review the strength of their high-technology clusters and Science Cities around the world-class research universities in their regions. They should then support them with funds as necessary through the BSSP and make certain there are no barriers to their growth.

Support for the start-up and growth of new businesses

9.40 The efforts to support business start-ups, business R&D and the growth of new businesses have led to a proliferation of support schemes at the national, regional and local levels. This is both extremely inefficient and confusing for industry, a point that is now widely agreed on by many of the organisations involved. The RDAs are involved with government departments in the Business Support Simplification Programme (BSSP), announced in Budget 2006. The BSSP aims to reduce the number of support schemes from over 3,000 to under a 100. The BSSP is developing a nationally agreed and specified portfolio of innovation support schemes from which government departments and regional and local organisations providing publicly funded support for business innovation will choose the programmes most appropriate to national, regional or local needs.

9.41 This Review welcomes this initiative. Market failures do not vary in their nature between different parts of the country. However, the severity of particular market failures may be different from region to region. This Review therefore welcomes the RDAs' input to the BSSP and their commitment to products that support business in their region using nationally specified schemes.

9.42 In Chapter 6, this Review presented details for establishing a nationally agreed specification for proof-of-concept funds as part of the BSSP.

Recommendation 9.7

RDAs should establish proof-of-concept funds, subject to the BSSP, making use of a nationally agreed specification and ensure compatability with the national specification when proof-of-concept funding already exists.

Accelerating scientific innovation through design

9.43 The Cox Review (2005) looked at how the UK could harness its world-class creative skills to improve business competitiveness and its recommendations are already having a tangible impact (see case study below).

The Cox Review

The Cox Review was commissioned by the then-Chancellor in 2005 and its recommendations are now being taken forward by a number of organisations, including the Design Council, the RDAs, OGC, HMRC and HEFCE. In particular, the roll-out of Designing Demand – a national design programme for SMEs – is well underway. Five RDAs are currently delivering the programme, with a further four due to deliver during 2008. A total of 6,500 businesses are expected to have benefited from the service by the end of 2010.

The Cox Review highlighted how design input is especially important to the successful exploitation of new technology and included two recommendations specific to the science and technology sector:

- The establishment of university-based Centres of Excellence to bring together the disciplines of design, engineering, technology and business, to address the challenges of future innovation and create world-beating products and services. The first Centre of Excellence, announced in October 2006, is a partnership between the RCA, the Imperial College Faculty of Engineering and Tanaka Business School.
- The delivery of a specialist design service for technology businesses as part of the Designing Demand programme. Early evaluation demonstrates that 80 per cent of companies involved in the pilot scheme improved their financial prospects by finding it easier to raise funding, increasing investment, launching new services/products, and generating early sales and revenue.

9.44 Evidence suggests that the use of design helps scientists to develop commercial applications for their work while it is still at the research stage or at the outset of the technology transfer process. Pilot Designing Demand Innovate schemes – run in partnership between the Design Council, the EPSRC and UCL Ventures – involved designers working with a range of university researchers and technology transfer intermediaries. They reported that the design input they received raised academics' awareness of future applications of their technologies, helped to get ideas across to research collaborators and potential investors, and shaped the future direction of the IP being developed and enabled them to retain a higher proportion

Designing Demand Innovate: company testimonials

Axon Automotive

A design-led strategic shake-up has put Cranfield University spin-off Axon Automotive on the road to producing a revolutionary, affordable and energy-efficient car made from carbon fibre. This strategic repositioning is starting to pay off. In March 2006, the Axon Car was awarded a £500,000 grant equal to half the investment needed to develop a prototype vehicle. The company now has a full-time management team and has graduated from the campus at Cranfield into its own premises, close to one of its new business partners, Northamptonshire-based Scott Bader. Axon is in discussion with potential investors to take the Axon Car through to production.

"This is a real opportunity to demonstrate UK design capability from one of our leading universities. When an idea creates a market, it encourages others to do the same. I hope we can create the right arena for the UK to be a leader in CO_2 engineering reductions for the automotive sector. Participating in Innovate had a massive impact on Axon. It made us think about strategically designing the business, and gave us the confidence to seek funding and pitch for larger sums than we would have done otherwise."

Steve Cousins, Founder, Axon Automotive

Synature

Adding design to a new breed of online search technology has opened up a market forecast to be worth $1 billion by 2008. Synature has landed six-figure investment along with its first licensing deal – with MyTravel – after taking part in the Designing Demand Innovate service.

"We thought the technology spoke for itself. But we realised that potential partners, customers and investors wouldn't be able to visualise how it would work in practice. The penny dropped for me about how much design can do, and how broad the idea of design is. Understanding that design decisions could maximise the value of the company is exactly what I needed to do."

Andrew Fraser, Founder, Synature

Recommendation 9.8

Building on the success of Designing Demand Innovate, and subject to the BSSP, RDAs should consider how to support and expand the scheme to include the provision of specialist design support for Higher Education Institutes within key technology clusters. The new element of the programme could be developed and piloted by the Design Council in partnership with selected RDAs and would provide:

- design training for technology transfer staff and intermediaries, delivered by a national training institute for technology transfer such as PRAXIS;
- quality assured Design Associates to advise selected clients on issues such as idea generation, product development, user research, testing and prototyping; and
- structured design support for postgraduate researchers exploring and shaping commercial outcomes from their research.

10 Global collaboration

THE CASE FOR GLOBAL COLLABORATION

10.1 The UK has one of the most productive and efficient science systems in the world. But 90 per cent of the world's scientific output is produced overseas, therefore to stay at the cutting edge of world science and innovation we need to collaborate globally.

10.2 Science has always been a global enterprise. Research and innovation are becoming increasingly international. The scale of research, in particle physics and genomics for example, means that it makes economic as well as scientific sense to work across national borders. Many of today's challenges, such as climate change and the Millennium Development Goals, demand an international approach.

10.3 Scientists are responding to this trend. Between 1996 and 2000, 29 per cent of UK scientific publications were internationally co-authored. Between 2001 and 2005, this figure rose to 40 per cent. The impact of this collaboration is striking. UK–US collaboration, for example, represents more than 30 per cent of the UK's strongest research.[1] And researchers are also increasingly moving abroad to study and work. In 2005–06, 37 per cent of doctoral science, technology, engineering and mathematics (STEM) students in the UK came from overseas.

10.4 Like people, businesses are ready to move around the world. Small-scale foreign projects are evolving into global R&D operations, seeking out world-class science and talent. Between 1991 and 2001, R&D expenditure by affiliates of foreign companies increased by more than 50 per cent in the OECD.

The UK position

10.5 The UK is well placed to benefit from global collaboration. Almost 50 per cent of leading research investors have R&D centres in the UK, which is second to the USA (60 per cent) but significantly higher than other leading economies (China 35 per cent; France 30 per cent; India, Canada and Germany with under 20 per cent).[2] The UK's strength in R&D relies on this investment. Foreign-owned companies accounted for 45 per cent of private sector R&D in 2003, up from 29 per cent in 1995, and significantly higher than in other developed economies (Germany 27 per cent, France 23 per cent and the USA 15 per cent).

10.6 The UK attracts considerable flows of researchers from abroad, and three-quarters of universities expect their international collaboration to increase over the next decade.[3]

[1] *International Partnerships of Research Excellence: UK–USA Academic Collaboration,* Professor Sir Gareth Roberts, April 2006.
[2] UNCTAD 2005.
[3] Technopolis.

10.7 The UK is also a significant investor overseas. The amount of UK-business-funded R&D performed overseas has tripled in the past decade. This is not lost investment; research shows that knowledge flows back to the UK from operations abroad.[4]

10.8 In order to take advantage of the increasing internationalisation of science, the UK has significantly increased the resources it devotes to supporting global collaboration in science and innovation, including expansion of the Science and Innovation Network (SIN) and increased focus of UK Trade and Investment (UKTI) on research.

Expansion of the Science and Innovation Network

Before 2001, the Foreign and Commonwealth Office (FCO) had only 11 science officer posts in 10 countries, and their efforts were not co-ordinated. Today, there are 100 science and innovation (S&I) officers based in 22 countries, and their activities are co-ordinated through a new FCO department, the Science and Innovation Group. Recent examples of the work of the S&I officers include: the brokering of a collaboration that led to an £8.1 million grant from Riken in Japan to Imperial College, London, in structural genomics; the renewal of a licensing agreement by a consumer electronics conglomerate in Taiwan to a UK technology company worth £350,000; and a step change in engagement at state and city levels in the USA on the UK's climate change agenda.

10.9 The Government announced in 2005 the establishment of the Science Bridges project, which is providing £6 million over two years to enable the creation of four collaborations between world-class institutions and high-technology universities in the UK and USA. The four Science Bridges are: the University of Manchester working with the University of Washington and a wide range of businesses on the development of composite materials for use in aircraft design; Imperial College, London, working with the University of Texas, Oak Ridge National Laboratory and the Georgia Institute of Technology on the treatment of cancer and energy research; the University of Cambridge continuing its productive partnership with Massachusetts Institute of Technology; and a consortium of the Universities of Bath, Bristol, Southampton and Surrey (SETsquared) working with the University of California in the areas of wireless technology, life sciences, the environment and advanced materials (see the following box).

[4] *Study of the Relative Economic Benefits of UK Trade and Investment Support for Trade and Inward Investment: Final Synthesis Report* UKTI (DTI), March 2006, Annex 4.

SETsquared – Southern California Science Bridge

The SETsquared Partnership, the collaboration of the Universities of Bath, Bristol, Southampton and Surrey (SETsquared), is working with University of California, San Diego (UCSD) and the University of California, Irvine (UCI) to link up established regional networks of technology entrepreneurs, investors, businesses and research organisations, with a view to assisting the international development of early-stage technology companies. In its first 12 months the project assessed over 140 companies and introduced 42 into sophisticated technology networks in California and the UK; 13 have already won or are negotiating new business.

The pilot project seeks to promote international technology development and commercialisation through region-to-region collaboration. This is achieved by linking universities that already act as hubs for high-calibre entrepreneurial technology networks in their own region to universities that facilitate similar networks in other regions of the world. The link between the universities creates a "bridge" for new technologies and technology companies between the regions. The universities work with and leverage their local networks to support the development of, and provide "landing zones" for, the new technologies coming in from collaborating regions. UCSD is able to leverage CONNECT, the 20-year-old technology network it has helped to develop and facilitate in San Diego (see Chapter 9). SETsquared draws upon the networks it has built up around its successful spin-out and incubation activities as well as its formal links with organisations such as IP Group and the Regional Development Agencies (RDAs).

SETsquared identifies high-calibre early-stage UK technology companies with the potential and motivation to enter US markets. The UK team and UCSD, UCI and CONNECT work with the UK companies to introduce potential customers, strategic partners, investors and entrepreneurs in California. In cases where there is significant interest in the company, CONNECT organises a formal "springboard" panel, where the UK company receives mentoring and presents to a suitable panel of experts.

When the Bath-based software company Mirifice presented to a springboard select panel in 2006, panellists included experts from the three largest US cable companies, the venture divisions of Motorola, Nokia and Qualcomm, Intel Capital and four entrepreneurs who had enjoyed success in digital media. As a direct result, Mirifice has already won over $1million of business in the USA, entered into negotiations with four potential US distributors, set up US trials with a potential customer and remains in discussions with potential US investors.

Together with UKTI and the UK FCO, SETsquared is investigating the expansion of the programme to provide further bridges and landing zones between southern England and the Boston and Austin areas of the USA. Satellites have been discussed with the Massachusetts Technology Transfer Centre in Boston and the Austin Technology Incubator and University of Texas System in Austin. SETsquared will also pilot a springboard programme for two US companies coming into the UK later in 2007.

10.10 In response to the growing opportunities for international collaboration, the Next Steps document (2006) outlined two new initiatives to be delivered by UKTI: a five-year strategy for a step change in the Government's drive to market the strengths of the UK's economy internationally; and £9 million of funding for UKTI to implement a new international R&D strategy, to attract more business R&D to the UK and to promote innovative firms abroad.

10.11 There is also an important European dimension to the UK's scientific and technological relationships. The UK participates strongly in the European Framework R&D programmes and received 14.5 per cent of the R&D funds allocated in 2005. The UK strongly supported the creation of a European Research Council, modelled on the National Science Foundation in the USA. The European Research Council will fund the best research teams in Europe and offers a major opportunity to UK researchers.

10.12 However, there are a large number of organisations involved in our global Science & Technology relationships – UKTI, the Research Councils (RCs), the Royal Society and the British Council – and their efforts are not always co-ordinated. As a result, in many countries we are not given credit for the scope of our S&T relationships or the quality of our science and innovation.

10.13 The UK needs to be better at defining and communicating its goals in scientific international collaboration. The four goals should be:

- research excellence – through strengthened international collaborations and attracting the best researchers to the UK;
- excellence in innovation – through UK businesses accessing international science and technology and by attracting international R&D investments to the UK;
- global influence – by using international science to underpin foreign policy in meeting global Grand Challenges, such as climate change and the spread of infectious diseases; and
- international development – using research and innovation to meet international development goals, in line with the recent UK White Paper "Eliminating World Poverty".

Strengthening our international links

10.14 The Ten-year Science and Innovation Investment Framework 2004–2014 established a Global Science and Innovation Forum (GSIF), led by the Government's Chief Scientific Advisor. GSIF has brought together all the different organisations involved in international science and innovation relationships to create an overarching national strategy and to help raise the UK's reputation as a global leader in science and innovation.

10.15 GSIF published its strategy in October 2006, which the then Secretary of State for the Department of Trade and Industry and the Prime Minister welcomed. The GSIF recommendations should now be implemented.

Recommendation 10.1

Research Councils UK (RCUK) should streamline its presence overseas into single points of contact in key countries.

10.16 These contacts will raise the profile of the RCs and promote the excellence of the UK research base. They will provide local expertise to enable UK research organisations and individual researchers to find the best research teams in each country and they will strengthen collaboration with major public funders in partner countries. RCUK currently funds the UK Research Office in Brussels and plans to open offices in Beijing and Washington in the autumn of 2007.

Recommendation 10.2

The Royal Society, with support from the other National Academies and the Research Councils, should establish a new fellowship scheme to attract the best researchers to the UK from overseas and should run an alumni scheme.

10.17 GSIF has emphasised the continuing need to attract the best researchers to the UK from overseas, and recent analysis shows that fellowships are an increasingly powerful way to attract talent. Existing fellowships, such as those run by the National Academies and the Wellcome and Leverhulme Trusts, are accepting overseas applicants to an extent. But this Review supports the GSIF proposal for a new Royal Society fellowship scheme targeted at international post-doctoral researchers, modelled on the Humboldt Foundation in Germany. Royal Society branding would draw some of the brightest and best researchers to the UK. Importantly, a Royal Society alumni scheme would help sustain links with global world-class research. Given the increasing mobility of scientists, this alumni network would help the UK remain at the forefront of international science.

Recommendation 10.3

The Technology Strategy Board (TSB) should develop an international strategy that considers support for the European EUREKA programme and FP7 initiatives.

10.18 The UK has had a very small participation in EUREKA, an intergovernmental initiative to support market-driven collaborative R&D. Unlike other countries, the UK Government has made no specific funds available to support this programme, in spite of its popularity with small and medium-sized companies (SMEs). Successful UK companies in EUREKA have to apply separately for UK funding: SMEs are referred to the Grant for R&D scheme delivered via the RDAs, and large companies or consortia to the TSB's collaborative R&D competitions. But the double bureaucracy (the need to apply to EUREKA for the label for the project and also to apply to the national funding scheme for support) acts as a deterrent, and the numbers applying to either scheme are very small. Compared with other European countries, the UK maintains only a small EUREKA Unit to handle enquiries and network issues. The European Commission is currently working with EUREKA to launch (with FP7 co-funding) an Article 169 programme called Eurostars. Without a specific budget, the UK is unable to commit to the virtual pot, which will provide funding for proposals from high-technology SMEs, and consequently will not receive funding (currently assumed to be 30 per cent) from the Commission. Similar issues could constrain UK participation in the electronics Joint Technology Initiatives under FP7, ARTEMIS and ENIAC. There is also a wider need to ensure that UK businesses benefit from the expanded opportunities available in FP7.

Recommendation 10.4

The Science Bridges scheme should be extended to China and India, and to other key high-technology innovative countries.

10.19 The Science Bridges scheme, as described in paragraph 10.9, helped develop entrepreneurial skills among researchers and supported commercial development of technology and expertise in spin-outs. On the basis of the success of these pilots, this Review recommends extending the Science Bridges programme to include three projects with China and three with India. We believe that with the growing excellence of science in China and India these will be excellent long-term investments. We also recommend setting up additional Science Bridges with countries where we think we can achieve significant value by establishing such schemes.

Recommendation 10.5

The Director General of Science and Innovation in DIUS should work with the US science-funding bodies to solve the double jeopardy issue for scientists.

10.20 A recent report by the late Professor Sir Gareth Roberts highlighted the difficulty for research groups to gain bilateral support from UK and US government funding agencies. He concluded that this double jeopardy is one of the main inhibitors of UK–US research collaboration and argued that "a concerted effort in transatlantic diplomacy could yield lasting benefits for both countries".[5] Not least, the USA's spend on R&D is over one-third of the world's total spend, providing a significant opportunity for UK researchers to tap into. A number of the RCs have set up agreements with US federal funding agencies to streamline joint-funding arrangements. However, it would be much more efficient to have a single agreement between the USA and the UK. This Review recommends that the Director General of Science and Innovation seeks to reach a national agreement with US science-funding bodies, particularly the National Science Foundation.

Recommendation 10.6

A campaign of information should be launched by DIUS through embassies abroad to highlight the UK's role as a global leader in science and innovation.

10.21 This should demonstrate the UK's attractiveness and track record in international science and innovation, and underpin the role of UKTI, the RCs and others in supporting profitable partnerships with the UK.

[5] *International Partnerships of Research Excellence: UK–USA Academic Collaboration,* Professor Sir Gareth Roberts, April 2006.

11 A global leader in science and innovation

11.1 The world in which we compete today is a world of opportunities but also one of challenges. Protectionism does not provide a means of escaping from the need for change but rather, in trying to protect select groups regardless of the wider costs, leads to more drastic change.

11.2 In the UK we have made good progress in recent years in meeting the challenge of globalisation and upgrading our industry, but we should not underestimate the speed of change in the world economy. At no time since the Industrial Revolution has the restructuring of global economic activity been so great, and we need to accept that China and India are now seeking to upgrade their industries.

11.3 The UK has many of the assets essential for success in the global economy. We have an extraordinary record of scientific discovery, the difficult-to-replicate competitive advantage of world-class research universities that can act as a strong catalyst for the creation of new industries and technologies, and a large and growing supply of high-quality university graduates and talented immigrants. We have made substantial progress in recent years in improving our performance in knowledge transfer, and English is the language of science.

11.4 We have a flexible labour market and the leading venture capital industry in Europe. We have an increasing supply of the specialised infrastructure, such as science parks and incubators, that is needed to support high-tech start-ups, and a number of high-technology clusters growing up around our world-class research universities. We also have an open economy and an international outlook. If we are going to be successful in the global economy we need to protect these assets and build on them.

11.5 At the same time there are weaknesses in our national ecosystem of innovation, and this Review has set out some of the policies necessary to correct them. To maintain public support for an "open economy" and the redeployment of resources high-value-added industries, the Government needs policies that provide insurance for individuals against the risks of globalisation, while being compatible with economic openness. Not only do companies have to innovate but so does government. It has to prioritise new areas of government spending and it also has to make them more effective. If taxes are well spent and create a well-educated and healthy workforce, and if regulations lead to a cleaner and safer environment, there is no need for "a race to the bottom" as mobile companies and highly skilled workers are attracted by such policies.

11.6 There are those who claim that industrially we live on a "flat earth" where geography is no longer important and where talented individuals across the world compete on a level playing field. But while the world may be flat for industries producing simple labour-intensive products and services, for knowledge-intensive goods and services the landscape is full of hills and mountains where skills, knowledge and infrastructure are concentrated.

11.7 In the new global economy, geography has become less and more important for innovation. High-technology companies whose production was once tied to a specific place can pick it up and move it to anywhere in the world. But if they want to remain competitive, companies need to base key parts of their operations in knowledge- and information-rich regions. They need to be in high-technology hubs where there is a concentration of the research, creative individuals and infrastructure needed for innovation. Globalisation has not, therefore, eliminated geography but has increased the comparative advantage of regions that can successfully create the best conditions for its growth.

11.8 Islands of excellence are emerging in India and China at world-class institutions such as Tsinghua University in Beijing and the Indian Institute of Science in Bangalore. But there is still some way to go for domestic businessess in these countries before they will achieve the level of performance of companies in advanced industrial countries.

11.9 The reason is that innovation and productivity growth rely on a specific national innovation ecosystem. It is difficult to transform a national innovation ecosystem rapidly, but the Chinese and Indians are starting to do so.

11.10 As well as policies to create the best possible conditions for companies to innovate and grow, we need a vision of our role in the global knowledge economy, and of how we can be one of the winners in the "race to the top". Given our assets, it is realistic for the UK to aim to be a global leader in science and innovation.

11.11 This means that the UK should be a country famed not only for its outstanding record of discovery but also for innovation, a country that invests in business R&D and education and skills, and exports high-technology goods and services to the world. We should also seek to be a country with strong science and technology links with the best research around the world, so that we can stay at the cutting edge. The UK should be the partner of choice for global businesses looking to locate their research and development and for foreign universities seeking collaboration with the science base or business.

11.12 We should be a country to which talented entrepreneurs and world-class companies come from around the world to perform research and set up high-technology companies, attracted by the quality of our research, by the strong links between our universities, research institutes and industry, by geographic clusters of high-technology companies, by their ability to raise finance, particularly venture capital, and by our quality of life.

11.13 In this Review we have set out a strategy for competing with emerging countries such as China and India, and a range of policies for the Government to pursue that build on the progress that has been made in recent years. If we pursue them vigorously there are plenty of opportunities to create wealth and new high-value-added jobs.

11.14 It is not possible to predict exactly where the new jobs will emerge, but it is possible to see many opportunities for British industries to create new products and services, and new industries in areas as diverse as aerospace, pharmaceuticals, biotechnology, regenerative medicine, telemedicine, nanotechnology, the space industry, intelligent transport systems, new sources of energy, creative industries, computer games, business and financial services, computer services and education.

11.15 These industries are likely to be growth industries and have sought-after social qualities, such as high wages, good environmental characteristics, low barriers to entry for small companies, and freedom from geographic constraints.

11.16 Twenty-five years ago it would not have been possible to imagine the UK as a global leader of science and innovation in the world economy, but today it looks an attainable goal. If we fail to be successful in the new global economy, it will not be through ignorance of the challenge or the solution, but because we do not have the energy and will to drive through the necessary changes in industry and government. We can be one of the winners in "the race to the top", but only if we run fast.

12 Summary of Recommendations

Recommendation 2.1

The Review strongly recommends that the Government continues to fund increases in basic science in line with the Ten Year Science and Innovation Framework 2004–2014; that it increases the funding of the TSB; and that civil departments and the MOD are encouraged to seize the opportunities to improve their performance by raising the level of their R&D.

Recommendation 2.2

Research into the structure and dynamics of value chains should be supported across the Research Councils. The capability to integrate stages globally may be a major opportunity for the UK to draw on its traditional strengths in innovation and its international outlook.

Recommendation 2.3

Flexible integrated mechanisms such as the Integrated Knowledge Communities (IKCs) and Innovative Manufacturing Research Centres (IMRCs) should be deepened and strengthened, as they help to match developments in products and services with developments in science and technology.

Recommendation 2.4

The Technology Strategy Board should work with the Research Councils to identify the complex, high-value-added production technologies that current and emerging industries require and which are likely to flourish in high-cost economies. Research and the development of skills in these technologies can then position the UK to be a leader in these fields.

Recommendation 3.1

The TSB should be given a new leadership role, with more formal relationships with the RDAs, government departments and Research Councils.

Recommendation 3.2

One of the Chief Scientific Advisors (CSA) should be actively involved with the TSB, attending regular meetings. This should typically be the CSA of the Ministry of Defence, given the size of the department's R&D budget, but he/she would also represent views from other CSAs.

Recommendation 3.3

Regulators should be involved from an early stage in Innovation Platforms, so that they better understand the impact of their regulations on innovation, and can bring valuable knowledge to the members of the Innovation Platforms. Early indications suggest that regulators would be keen to do so.

Recommendation 3.4

TSB should encourage the production of technology road maps by all fast-growth, high-tech industries as a way to raise their level of innovation and to align technology capability with consumer demand.

Recommendation 3.5

A flexible, short-term Knowledge Transfer Partnership (KTP) scheme should be developed and KTPs extended more widely into the further education sector, as described in Chapter 4.

Recommendation 3.6

The TSB's activities should be extended into those service sectors where technological innovation is important. The TSB has already started work with the creative industries and there is considerable scope for it to extend its work to other areas.

Recommendation 3.7

The TSB should be made the repository for information about technology's role in the competitive strategies of different industries and should be responsible for providing this when it is needed by other organisations.

Recommendation 3.8

The process of evaluation for support from the TSB should cover both the technical and business merit. The backgrounds of evaluators within the TSB should be expanded to include technical specialists with strong commercial backgrounds. As in the Defence Advanced Research Projects Agency (DARPA), a proportion of staff in the TSB should be secondees from industry or academia, with an emphasis on selecting high-calibre candidates whose careers will be enhanced by spending two to four years in the TSB.

Recommendation 3.9

The TSB should take over support for the Eureka programme from DIUS, and offer advice and guidance on Framework Programme 7 to encourage more UK businesses to take advantage of the significant European research funds available. (See Chapter 10 on Global Collaboration.)

Recommendation 4.1

The Review believes that there are four ways to strengthen our performance in knowledge transfer:

1. More support through HEIF to business-facing universities, incentivising them to perform more knowledge transfer with small and medium-sized enterprises;
2. Drive up the knowledge transfer activities of Research Councils;
3. Increase the number of Knowledge Transfer Partnerships; and
4. Encouarage further education colleges to undertake more knowledge transfer.

Recommendation 4.2

Universities should initiate pilots with HEIF money for senior industry professionals to be embedded into departments to act in a similar manner to the Principal Scientists in MIT, acting in parallel to the scientific leader of major projects.

Recommendation 4.3

HEIF4 funding should be allocated entirely on the basis of a formula, and the formula should be constructed so that the money that was allocated on the basis of a competition now goes largely to business-facing universities.

Recommendation 4.4

Specific targets in each of the five areas of knowledge transfer should be agreed between each Research Council and the Director General of Science and Innovation as part of the Research Council Delivery Plans. RCUK should take responsibility for common branding and alignment across the schemes, ensuring that this branding fits with the Business Support Simplification Programme (BSSP).

Recommendation 4.5

Subject to the BSSP, the Government should build on the success of the KTPs by doubling their number. Responsibility for the KTP scheme was transferred to the TSB from July 2007, but the roll-out and funding of KTPs should be led by the RDAs (see Chapter 9).

Recommendation 4.6

Subject to the BSSP, a standard nationwide mini KTP scheme should be introduced in all regions to facilitate shorter, light-touch collaboration (3–12 months). For some time there has been a demand for shorter, less expensive mini-KTPs, and we believe that they could perform a useful function. They may also be of particular interest to the creative industries, service sectors and SMEs.

Recommendation 4.7

The Department for Innovation, Universities and Skills (DIUS) should develop a strategy to promote and support knowledge transfer within the wider FE reform agenda. Aligned with the BSSP, it should include:

- encouraging and supporting staff secondments to and exchanges with businesses as part of the FE workforce reform programme;
- funding further FE knowledge transfer projects and initiatives through the Regional Development Agencies;
- incorporating knowledge transfer capacity building in the criteria for the new employer responsiveness standard for Centres of Vocational Excellence;
- encouraging increased FE participation in Knowledge Transfer Partnerships;
- raising business awareness of FE knowledge transfer potential through Business Links and other business support routes;
- promoting FE's knowledge transfer role in advice from Regional Development Agencies and Regional Skills Partnerships to local employment and skills boards;
- using existing FE networks to share best practice in knowledge transfer and business support.

Recommendation 4.8

The Government should continue to support PSRE commercialisation. To increase the impact of the PSRE Fund, the Government should require PSREs with strong track records of commercialisation to lever in additional funding from other sources. The then-Office of Science and Innovation (OSI) consulted the community on this proposal and it has their support.

Recommendation 5.1

Government and business should be encouraged to make greater use of the enormous amount of technical information contained in patent databases to further innovation, avoid duplication of research and support informed decision-making. It is also recommended that UKIPO should continue to develop its expertise in patent informatics to provide information that can aid government and commercial bodies in strategic planning.

Recommendation 5.2

DIUS should fully endorse the setting up of a new, world-class incubator facility on NPL's Teddington site (AIMtech) to help measurement and instrumentation start-ups.

Recommendation 5.3

In developing its strategy for supporting the development and dissemination of key technologies, the TSB should systematically consider the role of metrology and standards as part of its portfolio of targeted interventions and ensure that this strategy is widely communicated through the relevant KTNs. In allocating resources to these activities, the TSB will clearly wish to develop management metrics of successful outcomes and maximum impact.

Recommendation 5.4

Working with the TSB, DIUS should take a more proactive approach towards the development of European and international standards in areas of UK strength.

Recommendation 5.5

An Emerging Industries Co-ordinating Committee should be established by DIUS to bring together representatives from the TSB, the Research Councils, The National Measurement System, the UK Intellectual Property Office and the British Standards Institute to co-ordinate support for emerging industries, such as regenerative medicine, as has been done in recent years for microsystems technology and nanotechnology.

Recommendation 6.1

The conditions of the EIS scheme concerning the time constraints for the start of trading and the expenditure of money raised should be reviewed.

Recommendation 6.2

Consideration should be given by government to utilising the Young Innovative Enterprises (YIE) definition to provide targeted support for investment in new high-technology businesses.

Recommendation 6.3

A nationally agreed specification for proof-of-concept funds should be developed subject to the Business Support Simplification Programme (BSSP), drawing on current best practice. It should cover:

- rigorous project management and budget control over funded projects;
- well-defined outcomes and objectives for the fund;
- carefully specified application criteria and independent assessment of commercial potential;
- a strong focus on strengthening “investor readiness”; for example, access for entrepreneurs to managerial and investment expertise through a dedicated mentor; and
- awards to bring access to facilities (e.g. linked to Enterprise Hubs and Centres of Excellence) to support concept development.

Recommendation 7.1

Progress in achieving this plan will be monitored by the Department for Children, Schools and Families (DCSF) on an annual basis and corrective action will be taken if it looks as if the targets will not be met. This Review recommends that this could include financial incentives being offered to teachers during their first five years to address critical retention issues.

If experience shows that, with the expenditure of further funds, the target dates can be brought forward, we recommend that the necessary resources are made available. Clearly the shortage of qualified teachers must be rectified as soon as possible.

Recommendation 7.2

A mentoring scheme should be rolled-out nationally along the lines of the IoP scheme to increase support for newly qualified science teachers. We believe that the relevant professional bodies would be keen to support such a programme.

Recommendation 7.3

In line with the STRB’s recommendation, financial incentives should be introduced to encourage the take-up of conversion continuing professional development courses to help meet stretch targets for teacher recruitment.

Recommendation 7.4

The self-evaluation form that schools complete prior to inspection should prompt schools to set out any difficulties in recruiting and retaining staff, with specific reference to mathematics and science teachers. This will allow Ofsted inspectors to have a more informed discussion with head teachers to agree how to tackle any shortages.

Recommendation 7.5

DCSF should commit to the long-term funding of the Science Learning Centre network. The National Science Learning Centre should be given a leadership and co-ordinating role for the network, and resources should be made available to pay for supply cover costs for schools that have a shortage of well-qualified science teachers. Industry, the professional scientific institutes, and the Wellcome Trust are keen to provide support for the network of Science Learning Centres. A high level advisory group should be set up for the network with each of these organisations represented, as well as teachers and government.

Recommendation 7.6

Government should continue its drive to increase the number of young people studying the three sciences as separate GCSEs.

Recommendation 7.7

The school profile, which provides valuable information for parents, and the accompanying guidance should be amended to encourage schools to provide information about whether they offer triple science.

Recommendation 7.8

STEM careers advice should be built into the school curriculum. To support this, teachers need to be given greater support in delivering careers advice and therefore we further recommend that careers advice is built into CPD for teachers.

Recommendation 7.9

When the National STEM Careers Co-ordinator takes up the new post in April 2008, he or she should be attached to the Science Learning Centre network and be responsible for driving forward the careers advice agenda and co-ordinating activities to ensure that a uniform approach, which is accessible to all, is adopted.

Recommendation 7.10

The policy advice from the DCSF to schools should indicate the sort of careers advice and timing that students should expect to receive.

Recommendation 7.11

DCSF and DIUS, in partnership with stakeholders in other sectors, should adopt and develop the framework of ten schemes and the associated infrastructure, including:

- the network of national and regional Science Learning Centres;
- STEMNET, with its team of Science and Engineering Ambassadors;
- the National Centre for Excellence in Teaching Mathematics (NCETM);
- the science and mathematics strands of the National Strategies;
- the network of Specialist Schools with STEM specialisms;
- the STEM Community Portals.

Recommendation 7.12

Subject to a detailed evaluation of the pilot science and engineering clubs, we would like to see a science and engineering club in all secondary schools within the next five years.

Recommendation 7.13

A National Science Competition, which could include a number of different prizes, should be established as part of Science Week, bringing together existing contests to maximise their impact, with a well-publicised (ideally televised) final taking place during Science Week. All school science and engineering clubs should be eligible for entry.

Recommendation 7.14

All pupils who would benefit should have the option to study the second mathematics GCSE and schools should find ways to make it available to them.

Recommendation 7.15

To address the lack of information on the supply and demand of STEM skills, HEFCE should transform the Strategically Important and Vulnerable Subject Advisory Group into an Advisory Group on Graduate Supply and Demand and extend its remit to include responsibility for publishing an annual report describing: undergraduate subject trends; recent graduate jobs and salaries; and the subjects where employers and government departments believe that there are, or are likely shortly to be, shortages of graduates with key skills. The Review welcomes the extension of the group's membership to include an industry and a STEM business representative.

Recommendation 7.16

SEMTA, the Science, Engineering and Manufacturing Sector Skills Council, should liaise with subject associations to ensure that messages about science employment needs and prospects are communicated to students.

Recommendation 7.17

A leading member of the engineering profession should be asked to set up a working group of experts from academia and industry to review current approaches to engineering education. The group should develop, with a number of leading engineering universities, an experience-led engineering degree which integrates technical, operational and business skills.

Recommendation 8.1

Business people should play a major role in the new business support management body. This body will evaluate, endorse and manage the business support products, according to government criteria on the proper expenditure of public money.

Recommendation 8.2

The Director of Innovation in DIUS should be tasked each autumn to produce an Innovation Report on the innovation activities of DIUS, including the Technology Strategy Board, other government departments and the Regional Development Agencies.

Recommendation 8.3

Innovation should be made a core part of the mission statement of each government department and embedded in Departmental Strategic Objectives. Progress in stimulating innovation should be measured in the annual Innovation Report produced by the DIUS.

Recommendation 8.4

A more robust mechanism should be put in place to identify and protect departmental R&D budgets. Chief Scientific Advisors should work closely with their departments and HM Treasury spending teams early on in the Spending Review process to agree amounts and priorities for R&D spend. Once this has been agreed, a department should consult with the Government CSA and HM Treasury and must show a sound justification if it wishes to reduce its level of spend.

Recommendation 8.5

The Chief Scientific Advisors' Committee (CSAC) should identify cross-cutting areas of research on an annual basis and appoint a Chief Scientific Advisor to each of the priorities to co-ordinate resources and funding across relevant departments.

Recommendation 8.6

Other government departments should follow the MOD's example in focusing some of their R&D spend on encouraging innovation in the companies with which they interact.

Recommendation 8.7

Government should urgently press ahead with the Transforming Government Procurement agenda to improve procurement capability. This requires the OGC to develop outcome-based specifications in procurement, and to ensure that innovative procurement is placed at the heart of the government procurement function. It also places a responsibility on the OGC to raise the level of capability of government purchasing.

Recommendation 8.8

Government departments should consider using outcome-based specifications as part of forward procurement programmes like the Grand Challenge and the Competition of Ideas to stimulate innovation. Early discussions with some government departments have indicated that there is appetite to do so.

Recommendation 8.8

The SBRI should be reformed, adopting the following principles of the successful US SBIR scheme:

- departments should focus on active engagement with innovative businesses and act as intelligent customers to fulfil their departmental objectives;
- departments should specify up front, in a simple and standard format, and update on a fixed and regular basis, the technological areas in which they would like to see projects, in a simple, standard format;
- SBRI contracts should adopt a two-phase structure, tendering a second, larger award after successful completion of a smaller, early-stage development, so as to minimise risks associated with innovation;
- SBRI awards must take the form of contracts, not equity loans or grants; this will ensure that departmental objectives are clearly identified and met, and will enable the award of an SBIR contract to act as a "seal of approval", reassuring future investors and customers of the firm's value;
- SMEs should retain the intellectual property associated with any new technology, boosting incentives for high-quality small businesses to bid for SBIR awards; and

- to maximise the SBIR's effect, award availability should be restricted to products and services meeting the HM Treasury's R&D tax credit criteria; this would exclude humanities and social science research and consultancy, for which the scheme was never intended.

Recommendation 8.9

In order to ensure this time that the new SBRI scheme achieves its objectives, this Review recommends that a central administrative role be given to the TSB. Government departments should be required twice a year to notify to the TSB in a standard form those technological areas where they would like to support projects. The TSB would then be responsible for publishing twice a year, at fixed dates, a list of the projects notified to it by government departments so that SMEs are readily able to find them. The awarding of contracts should also be administered by the TSB, with assessment of proposals being made jointly with the relevant government departments.

Recommendation 8.10

SBRI targets for extramural departmental R&D should build up over three years, from 1.5 per cent in the first year to 2 per cent in the second year and 2.5 per cent in the third year.

Recommendation 8.11

Regulators should review their policies to ensure that the appropriate level of emphasis is given to innovation in their decision-making in the price-regulated sectors, to protect the interests of both current and future consumers. We would like consideration to be given to how innovation could be incorporated into their duties.

Recommendation 9.1

The Review is aware of other opportunities which exist to create major science and innovation campuses in the medical and defence fields, and we recommend that these are actively pursued.

Recommendation 9.2

To raise their impact on the economic performance of their regions, RDAs should shift their resources towards activities which support science and innovation, and, using business support schemes being developed through the Business Support Simplification Programme, should concentrate their efforts on four main areas:

- user-driven collaborative R&D;
- knowledge transfer;
- cluster development; and
- the start up and growth of new businesses.

Recommendation 9.3

The RDAs, TSB and SICs will collaborate to support innovation priorities that deliver the National Technology Strategy and Regional Economic Strategies. Utilising the Single Pot and European Regional Develoment Funds,7 each RDA will earmark investment to match fund TSB programmes on a case-by-case basis or as part of a regional prospectus. This will lead to a total investment from the RDA network of £180 million over three years, starting in 2008, subject to appropriate projects being identified that benefit the regions.

Recommendation 9.4

Subject to the Business Support Simplification Programme, RDAs should increase their support for the KTP scheme and invest in and support the new mini-KTP scheme, which will allow for shorter placements and hence increase the flexibility of the programme.

Recommendation 9.5

Drawing on the success of the CONNECT scheme in San Diego (see the following box), RDAs should support services for high-technology entrepreneurs around our world-class universities similar to the CONNECT service within the BSSP framework.

Recommendation 9.6

RDAs should review the strength of their high-technology clusters and Science Cities around the world-class research universities in their regions. They should then support them with funds as necessary through the BSSP and make certain there are no barriers to their growth.

Recommendation 9.7

RDAs should establish proof-of-concept funds, subject to the BSSP, making use of a nationally agreed specification and ensure compatability with the national specification when proof-of-concept funding already exists.

Recommendation 9.8

Building on the success of Designing Demand Innovate, and subject to the BSSP, RDAs should consider how to support and expand the scheme to include the provision of specialist design support for Higher Education Institutes within key technology clusters. The new element of the programme could be developed and piloted by the Design Council in partnership with selected RDAs and would provide:

- design training for technology transfer staff and intermediaries, delivered by a national training institute for technology transfer such as PRAXIS;
- quality assured Design Associates to advise selected clients on issues such as idea generation, product development, user research, testing and prototyping; and
- structured design support for postgraduate researchers exploring and shaping commercial outcomes from their research.

Recommendation 10.1

Research Councils UK (RCUK) should streamline its presence overseas into single points of contact in key countries.

Recommendation 10.2

The Royal Society, with support from the other National Academies and the Research Councils, should establish a new fellowship scheme to attract the best researchers to the UK from overseas and should run an alumni scheme.

Recommendation 10.3

The Technology Strategy Board (TSB) should develop an international strategy that considers support for the European EUREKA programme and FP7 initiatives.

Recommendation 10.4

The Science Bridges scheme should be extended to China and India, and to other key high-technology innovative countries.

Recommendation 10.5

The Director General of Science and Innovation in DIUS should work with the US science-funding bodies to solve the double jeopardy issue for scientists.

Recommendation 10.6

A campaign of information should be launched by DIUS through embassies abroad to highlight the UK's role as a global leader in science and innovation.

12 Summary of Recommendation

Annex A:

Terms of Reference

The terms of reference for the Review are:

To take stock of the response of the U.K.'s Science and Innovation System to the challenges and opportunities of globalisation, and to take a forward look at what needs to be done to ensure the U.K.'s continued success in wealth creation and scientific policy-making.

The Review will build on the Government's existing policy agenda in this area, especially the Science and Innovation Investment Framework 2004-2014, as well as the Next Steps on that Framework published alongside the 2006 Budget.

The Review will take stock, in the context of globalisation, of the overall impact and balance of Government interventions, at national and regional levels. In order to reach its conclusions it will include examination of:

- Industry R&D and investment in innovation;
- Publicly funded R&D (including government departments) and investment in innovation;
- Knowledge exchange between universities and business, including examining progress made since the Lambert Review
- The supply of skilled people;
- The supply of Venture Capital;
- Patents, Measurement System and Standards; and
- International science and technology collaboration

The Review will report to the Chancellor of the Exchequer and the Secretaries of State for Trade and Industry and Education and Skills. It will report in time for the 2007 Comprehensive Spending Review.

Acknowledgements

Lord Sainsbury and the Review team carried out various consultations with key stakeholders through a series of meetings and workshops, as well as an international visit.

Lord Sainsbury and the Review team would like to thank all those who have attended meetings and sent submissions to the Review.

We hope we have not left anyone out who should have been included in this list. If we have, please accept our apologies. Particular thanks go to:

- Department for Business, Enterprise and Regulatory Reform;
- Department for Children, Schools and Families,
- Department for Innovation, Universities and Skills
- HM Treasury
- Lord Sainsbury's Private Office

SUBMISSIONS

The Review received a number of submissions from interested organisations and individuals.

These included:

1994 Group

Association of Independent Research and Technology Organisations

ARM plc

Association of British Healthcare Industries

Biella Research

Bioindustry Association

Building Research Establishment

Building Services Research and Information Association

Cambashi Ltd.

Anne Campbell

The Carbon Trust

The Concrete Society

Confederation of British Industry

David Connell

Construction Industry Research and Information Association

Council for Industry and Higher Education

Design Council
Engineering Professors Council
Fuel Cells UK
Global CONNECT, University of California San Diego
GSK
Heptagon
Higher Education Funding Council England
Institute for Manufacturing
Institute of Biology
Institute of Physics
Institution of Engineering and Technology
Library House
Ministry of Defence
Merck, Sharp and Dohme
National Endowment for Science, Technology and the Arts
Nottingham University Business School
Ofgem
Pfizer
PRTM
Queen Mary College, University of London
Rolls-Royce plc
Royal Academy of Engineering
The Royal Society
Royal Society of Chemistry
Scottish Enterprises
Sector Skills Development Agency
SETsquared
Southampton University
Timber Research and Innovation Association
Training and Development Agency
UNICO
University of Birmingham
University of Hertfordshire
University of Salford
Universities UK
UK Intellectual Property Office
UK Research Councils

UK Resource Centre for Women in Science, Engineering and Technology

Wellcome Trust

Bill Wicksteed

MEETINGS WITH STAKEHOLDERS

In addition to submissions and workshops, Lord Sainsbury or a representative from the Review team held a number of meetings with stakeholders to outline the purposes of the Review and take soundings on its analysis, evidence base, and policy recommendations.

Individuals and organisations met included:

Airto

Arts and Humanities Research Council

Astrazeneca

Auril

Biotechnology and Biological Sciences Research Council

British Business Angels Association

British High Commission, Singapore

British Venture Capital Association

Cambridge Antibody Technology

Campaign for Science and Engineering

Lucius Carey

Anne Campbell

Chief Scientific Advisors Group

CLIK Knowledge Transfer

Coalition of Modern Universities

Confederation of British Industry

CONNECT

Council for Science and Technology

David Connell

Design Council

Department for Health

Department for Transport

Economic and Social Research Council

Engineering and Physical Sciences Research Council

E-Skills UK

Foundation of Science and Technology

Gatsby Technical Education Projects

Goldsmiths College, University of London
Manchester Business School
Hermann Hauser
Professor Celia Hoyles CBE
Higher Education Funding Council England
Highlands and Islands Enterprise
Professor Richard Lambert
LogicaCMG
Lord Hollick of Notting Hill
Imperial College London
Institute for Manufacturing
London Stock Exchange
Medical Research Council
National Endowment for Science, Technology and the Arts
National Physical Laboratory
National Science Learning Centre
Natural Environment Research Council
Nuffield
Ofcom
Ofgem
Office of Government Commerce
Office of Science and Innovation
Ofwat
OSCHR
Oxford Innovation
Partnerships UK
Portland Capital
Prime Minister's Strategy Unit
The Royal Society
QinetiQ
Queen Mary College, University of London
Research Councils UK
Rolls-Royce plc
The Royal Academy of Engineering
The Royal Society
The Royal Society of Chemistry
Russell Group

Science Learning Centre

Science and Technology Facilities Council

SETNET

techMARK Advisory Group

Trade Union Congress

UK Intellectual Property Office

UK Skills Forum

UK Trade and Investment

Unico

Universities UK

University College London

University of Exeter

University of Greenwich

University of Hertfordshire

University of Lancaster

University of Liverpool

University of Manchester

University of Manchester Metropolitan

University of Southampton

University of York

Wellcome Trust

INTERNATIONAL VISIT

Lord Sainsbury and the Review team visited the USA.

Organisations and individuals met included:

British Consulate-General	Los Angeles
British Embassy	Washington DC
California Institute of Technology	Pasadena, CA
Council on Competitiveness	Washington DC
Department of Defense	Washington DC
Larta	California
National Academy of Sciences	Washington DC
National Institute of Standards and Technology	Washington DC
San Diego Regional Economic Development Corporation	California
Scripps Institution of Oceanography	California
Stanford University	California
The National Academies	Washington DC

University of California	California
US Department of Commerce	Washington DC
US Department of Energy	Washington DC
US Department of State	Washington DC

WORKSHOPS

The Review held a series of workshops focusing on different aspects of its terms of reference.

STEM Schemes

Catherine Aldridge	Science Learning Centres
Aileen Allsop	AstraZeneca
Louise Morgan	CBI
Jenny Baker	DCSF
Yvonne Baker	SETNET
Nick von Behr	Royal Society
Derek Bell	Association of Science Educators
Julie Bramman	DfES
Ben Brierley	IET
Mike Evans	Npower
Richard Hamer	BAE Systems
Matthew Harrison	Royal Academy of Engineering
John Holman	National STEM Director
Robert Kirby-Harris	Institute of Physics
Claire Matterson	Wellcome
Dr Sean McWhinnie	Royal Society of Chemistry
Dawn Ohlson	Thales
Michael Reiss	Royal Society
Ian Richardson	Ofsted
Kay Roberts	GSK
Martin Thomas	Qinetiq
Anthony Tomei	Nuffield
Baroness Wall	Sector Skills Council
Tony Whitehead	OSI
John Williams	Gatsby
Noor Yafai	Shell
Annette Smith	British Association
Stephen Darvill	Logica
Gerard Leahy	Rolls Royce

Schools

Gillian Betts	Tunbridge Wells School
Debra Dance	DCSF
Diane Cochrane	ACME member
Marianne Cutler	Association of Science Educators
Des Herlihy	Royton and Crompton School
John Holman	National STEM Director
Valerie Houldey	Downs School
Chris Hoyle	Ridgewood School
Jane Kirby	OSI
Pat Langford	SETNET
Alan Malcolm	Institute of Biology
D Meredith	SS Peter & Paul Catholic School
John Prosser	Hungerhill School
Ian Richardson	Ofsted
Alan Smithers	Gatsby
Karen Spencer	ACME member
Juliet Strang	Villiers School
Jacqueline Verrall	Francis Bacon Maths and Computing College
Mrs Brodie	Bilton School

RDAs

Sue Baxter	National Secretariat
Rob Douglas	SEEDA
Richard Ellis	EEDA
David Evans	DTI
Margaret Fay	ONE
Mark Gibson	DTI
Bryan Gray	NWDA
Terry Hodgkinson	Yorkshire Forward
Brian Jackson	EMDA
Nick Paul	Advantage West Midlands
Mary Reilly	LDA
Stephen Speed	DTI
Juliet Williams	SWERDA

Technology Strategy Board

Graham Spittle	IBM
Catherine Beech	Babraham BioConcepts Ltd.
Alan Begg	Automotive Academy
Janet Brown	Scottish Enterprise
John Brown	Scottish Biomedical
Nick Buckland	SWDA
David Evans	DTI
Joseph M. Feczko	Pfizer
Mike Howse	Rolls-Royce plc
Sir Keith O'Nions	DTI
Vicky Pryce	DTI
Randal Richards	EPSRC
Michael Walker	Vodafone

Venture capital

Timothy Barnes	Lodestone IP
Jamie Brooke	Quester
Phil Cammerman	YFM Group
Stephen Edwards	Core Capital Growth
Anne Glover	Amadeus Capital Partners
Dr Melanie Goward	NESTA Investments
Wendy Hart	Grant Thornton UK
David Holbrook	MTI Partners Ltd
John Hughes	KPMG LLP
Duncan Lowery	NEL Fund Managers Ltd
Nicole Osborne	BVCA
Calum Paterson	Scottish Equity Partners
Peter Shortt	The Carbon Trust

Jo Taylor	3i
Malcolm White	HMRC
Simon Walker	Taylor Wessing

Science forum

Mike Carr	BT Group plc
Dr Annette Doherty	Pfizer
Professor Stephen Emmott	Microsoft
Tom Glocer	Reuters
Joe Greenwell	Ford
Sir Tom McKillop	Royal Bank of Scotland
Tony Meggs	BP plc
David Morgan	Johnson Matthey plc
Dr John Patterson	AstraZeneca plc
Michael J. Turner	BAE Systems plc
Dr Mark Walport	Wellcome Trust
Andrew Witty	GSK

In addition, the Review held a workshop, organised by the CBI, at which a large number of relevant trade associations were represented.

The Review would also like to thank:

- Birkbeck, University College London
- Cambridge Antibody Technology
- Cogent SSC Limited
- Connects in UK
- Heller Ehrman Venture Law Group
- Insight SRI
- Lancaster University Management School
- MDY Healthcare plc
- Medical Science
- Medisys plc
- National Grid
- NOKIA

- Park Road Associates Ltd
- Pfizer Global Pharmaceuticals
- Price Waterhouse Cooper
- Science, Engineering, Manufacturing Technologies Alliance
- Science, Technology, Engineering and Mathematics Network
- Science and Technology Facilities Council
- Shell
- Society of British Aerospace Companies
- Stem Cell Sciences
- UK Business Incubation
- University of Birmingham
- University of Cambridge
- University of Glasgow
- University of Manchester
- University of Salford
- University of Sunderland
- University of Surrey

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