CHAPTER 1

SCIENCE IN THE ECONOMY

Research is essential to sustained economic progress. There was a clear link between the technological innovation of the eighteenth and nineteenth centuries and the burgeoning economic growth of the Industrial Revolution. Likewise, it is no coincidence that the economies of countries such as China, India and Brazil are choosing to develop their scientific capacity as their economies are advancing rapidly.

The link between research and economic growth is not merely anecdotal. For example, research across 16 comparable developed countries has shown that increased levels of research, in both the public and the private sectors, led to overall increases in the productivity of the economy[1].

This fact is not lost on the British public, 79% of whom believe that the country 'needs to develop science and technology in order to enhance its international competitiveness'[2].

However, the link between knowledge and money is not simple, and the average results from such international data are based on a wide spread of outcomes. As a former European Commissioner has pointed out: 'The richest country per head is Switzerland which has a very low university participation rate. Investment in research may be good; it may be bad; it may be indifferent. It may push back the boundaries of knowledge in dramatic and unexpected ways; it may lead to soaring corporate profits shared by entrepreneurial university departments; it may produce zilch'[3].

In order to achieve the optimum economic benefits from science, it is necessary to develop effective mechanisms for ensuring that scientific and engineering expertise is translated into wealth-creating activities.

In order for science to feed the economy in a healthy way, four elements need to be in place:

⇒ the science base needs to be vibrant, with a reciprocal transfer of knowledge between the science base and wealth-creating industries

⇒ industry needs to carry out its own development and research, to generate new products and processes

⇒ colleges and universities need to train scientists and engineers to the range of levels, as a skilled workforce for economically-active industry

⇒ the science base needs to maintain a wide pool of expertise, available to grasp opportunities or deal with problems as they arise.

The analysis and policies set out below are aimed at creating a policy environment in which these four areas can be successful.

> "Scientific discovery is an important part of the process leading to new technologies. However, this does not necessarily imply a 'linear process'. The steam engine appeared before the laws of thermodynamics."
>
> *Professor Geoffrey Hammond*
> *Professor of Mechnical Engineering*

1.1 The link between publicly-funded research and economic growth

Although a healthy economy requires that industry perform substantial levels of research and development, public research is also necessary. Unless a potential idea has been shown to be feasible, private industry cannot amortize the costs of research over the lifespan of a potential product or process; once something is known to be feasible, the costs of developing it can be included in the price that will eventually be charged.

It is hard to define precisely or recognise immediately, but feasibility is a key concept.

The public sector should concentrate on pure and strategic research, up to the point at which an idea has proved a feasible possibility for commercial development. The private sector can then take forward the development of an exploitable product or process.

For this and other reasons, there is abundant evidence that public support for research is a worthwhile investment on the part of taxpayers.

The Treasury accepts that a 1% increase in public funding for research has an overall effect on economic productivity of around 0.17% in the long run[4]. Since public funding for research represents only about 0.62% of the overall economy in the UK[5], this represents a lucrative investment by taxpayers. An increase of about £90 million in public support for science (1% of the existing budget) would be expected to generate an annual gain to the economy of £1,950 million (0.17% of current GDP).

1.2 The importance of pure research

One of the areas in which governments must take the lead in a healthy system of science and engineering is in the funding of pure research, sometimes known as 'blue-skies' research. Many technological breakthroughs of immense economic value have been based on pure research.

The private sector cannot be expected to invest consistently and reliably in areas where there is no obvious profit to be made from the particular individual investor on a reasonable time scale. Government can, and should, take a longer-term view, and fund research with no obvious commercial application, in the knowledge that history has shown that such a strategy produces long-term economic gain.

The economic importance of pure research is obvious from examples such as the discovery of the double helix structure of DNA, which occurred in a physics laboratory on a programme that was actively discouraged by the professor in charge. A knowledge of the structure and function of DNA is now the basis of industries in medicine and agriculture worth many billions of pounds a year.

Boxes 1.1 and 1.2 examine in more detail two examples of the ways in which pure research has fed into wealth creation, one from the physical sciences and one from the life sciences.

1.3 Knowledge transfer

One of the reasons why taxpayers support science in the public research base is because science generates ideas, products and processes that can be exploited for economic gain. The routes through which that exploitation can occur are varied, and include the creation of new companies, the selling of patented rights, and the licensing of technology to existing companies.

No one route should be promoted over any other, because the most appropriate route in any individual case will depend on the personalities of the researchers, the nature of the technology and the use to which the technology is to be put. Intelligent exploitation of university research involves making sensible choices based on high quality information.

Over the course of the past three or four Parliaments, British governments have introduced a plethora of different schemes to encourage the formation of closer links between industry and academia, with the ultimate goal of translating the results of university research into products and services that generate wealth.

Box 1.1

The economic importance of pure research in the physical sciences

Albert Einstein’s highly theoretical concept of how gravity affects time must rank as one of the purest pieces of science of all time, but it started a chain of activity that has led to a huge industry in Global Positioning Systems.

Isidor Rabi, working on theoretical physics in 1930, discovered the basis of an extremely accurate atomic clock, and in the 1950s, Rudoph Mössbauer made discoveries that allowed such clocks to be developed and used to test Einstein's theory.

Atomic clocks became the basis of the Global Positioning System, the idea for which sprang from the realisation that radio transmissions from a satellite could give an accurate indication of the position of a receiver on the ground.

By the 1970s, the US Armed Forces were refining positioning techniques for terrestrial defence surveys, and by 1979, a receiver the size of a backpack had been made possible. A decade later, the first commercially available hand-held GPS receiver was manufactured.

By the early years of the 21st century, Garmin Ltd, which manufactured GPS systems floated for just under £100 million. Magellan, another GPS-based company was reporting annual sales of £70 million.

Recent research at Britain’s National Physical Laboratory is generating the most accurate clock ever made, and will provide even more accurate GPS systems. They may soon be even microminiature atomic clocks.

The number and variety of such schemes has been bewildering.

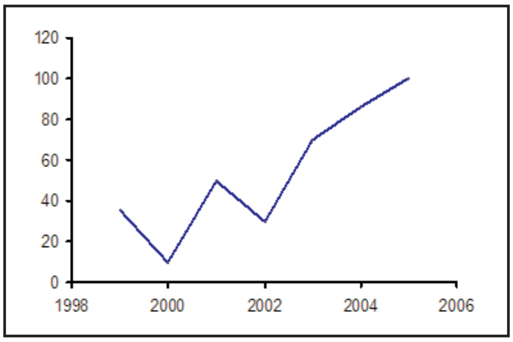


Figure 1.1. Central Government investment in knowledge transfer programmes since 1999 (£million) [Sources: *Hansard* [House of Commons] 26 Jan 2004, column 96W].

BOX 1.2

The economic importance of pure research in the biological sciences

The manufacture of predefined, specific monoclonal antibodies was made possible by the work of Georges Köhler and César Milstein. They published a definitive paper in the scientific journal Nature in 1975, for which they later won a Nobel Prize.

The work was funded by the UK's Medical Research Council, and was entirely driven by curiosity. Milstein later spoke of the "fundamental emphasis" of scientists in his field, and of "being attracted to the puzzle". Indeed, at the time, it was considered almost inconceivable that the work would prove to be of any commercial value.

However, subsequent work by Greg Winter and his colleagues further developed the potential use of monoclonal antibodies in medical treatments by discovering how to prevent them inducing an immune response in the human body.

The production and use of monoclonal antibodies had been shown to be feasible, so industry was able to invest in development. These molecules now form the basis of a huge industry - they are used to treat breast cancer, leukaemia, rheumatoid arthritis, and heart disease, as well as combating the problems associated with the rejection of organs following transplants.

The drug abciximab was developed to prevent blood clotting in patients with heart disease. In the late 1990s, just 20 years after Köhler and Milstein’s paper was published, the company that produced abciximab, Centocor Inc, reported that sales of this single drug had reached US$365 million per year, almost as much as the entire budget of the Medical Research Council.

By the turn of the millennium, the company was acquired by a multinational corporation in a deal worth US$4.9 billion, specifically because it was ‘a leader in monoclonal antibody technology’.

It is impossible to calculate the scale of the economic benefits generated from monoclonal antibodies, or to predict their future potential. However, there can by no doubt that the income generated would, by any standards, represent a healthy return on the investment in the fundamental puzzle that was pursued merely because two clever researchers thought it was interesting.

Examples include the Science Enterprise Challenge, the University Challenge Fund and the Higher Education Innovation Fund, which is split between two departments of State.

Central Government funding has been modest but growing, as Figure 1.1 shows.

The schemes that have proved most successful include the Proof of Concept scheme adopted by the Scottish Executive and the Knowledge Transfer Partnership scheme, which grew out of the Teaching Company Scheme. Box 1.3 examines the successful experience of one university in developing real economic benefits from links with industry through this initiative.

The success of diverse initiatives such as Proof of Concept and Knowledge Transfer Partnerships illustrates the importance of a sufficiently wide spectrum in the public funding of activities designed to turn research into wealth. Funding must recognise a whole range of activities, from applied industrial research involving a modest input from associates in universities, through to largely academic work of potential industrial relevance.

Making knowledge transfer activities sustainable

As with many Government funding schemes, some of the mechanisms for supporting knowledge transfer activities do not always operate over a timescale sufficient to provide sustainability.

Faraday Partnerships are consortia of organisations and institutions dedicated to improvement industrial competitiveness in particular areas through "’research, development, transfer and exploitation of new and improved science and technology’.

The partners include universities, companies, trade associations and others, and successful Partnerships include the Faraday Plastics and Polymer Partnerships. Its work on polymers has implications for areas such as energy conservation and recycling, and is of particular importance in the automotive industry and in the medical sector[6].

Faraday Partnerships are sponsored by the Research Councils and by Government departments, including those of the devolved administrations.

Funding lasts for an initial period of three years, after which to become sustainable, Faraday Partnerships are supposed to ‘access other funding mechanisms and conduct work for private sector on a consultancy basis’[7].

The ‘other funding mechanisms’ are unspecified, but the implication is clearly that the public sources of funds are to be used essentially to set up new projects, but that they will not be available to enhance

BOX 1.3

Knowledge Transfer Partnerships at Napier University

Napier University in Edinburgh has been particularly successful in developing links with industry through the Knowledge Transfer Partnership Scheme. The institution has formed between two and 25 new partnerships each year in recent years. They have developed real economic benefits for companies in Scotland; for example, they developed a process that has saved money for the Scotch whiskey industry and made it potentially more profitable.

The aspects of their experience that Napier's staff and partners believe have contributed to their success include :
- A significant dedication of time, equivalent to 10% of each working week, on the part of academic supervisors.
- A commitment on the part of the university, and especially the Heads of School, to the involvement of their staff in the scheme
- High calibre research associates, insisting on graduates with at least an upper second class degree and a rigorous interview process.
- Significant three-way interaction between the companies, academics and research associates involved, including a constant flow of information between the parties
- Regular assessment of what has been achieved, against clear targets.
- The selection of projects that tie in with the university's existing research strengths.

> “Patents are not just granted for ‘gadgets’ - they are also granted for industrial processes, applications and enhancements. In the new economy, knowledge has value, but if it remains within people's heads and is not recorded, ownership is difficult to establish.”
>
> *Jim Asher, Intellectual Property Director, Accentus plc.*

the long-term sustainability of knowledge transfer partnerships.

Successful knowledge transfer schemes should be eligible for continued public funding to make them more sustainable in the long-term, not just repeatedly to start new projects.

Tax regime for spin out companies

Spin-out companies form one group of conduits through which research in the science base is turned into wealth-generating activity. British universities have been particularly successful at following this route to commercialisation in recent years, with an average of approximately 200 new firms created each year; at least 6,000 people are employed by university spin-outs at any one time[8].

However, following the budget if 2003[9], the Inland Revenue has been treating spin-out companies essentially as if they are large industrial concerns. So academics who have taken equity in a spin-out based on their research have been treated as fat-cats attempting to avoid tax by being paid in shares.

Consequently, they have incurred unreasonable fiscal liabilities they cannot pay, and which amount to taxes on profits that do not exist, and which may never exist[10].

The problem has been recognised, and there is an intention to remedy it[11] but **future measures must ensure that exploitation of research is not hampered by unfair fiscal rules.**

Intelligent exploitation of research

Recent Government policies have emphasised particular methods of exploiting research, particularly those that can be measured easily.

Thus, the number of patents filed and the number of spin-out companies incorporated each year are used as specific indicators of success[12], and on at least one occasion, a 50% increase in the number of new companies was formally adopted as a measurement target[13].

Although such measures are certainly correlated with real success, they form only a small part of the overall picture. A subtler approach is needed, in which emphasis is also placed on the licensing of technology, the exchange of staff, the involvement of project students in company projects, and a variety of other methods of exploiting the knowledge and intellectual capital within the public sector for economic gain.

In measuring the success of universities in generating wealth-creating activity, the Government should use more sophisticated measures than the blunt instruments of counting spin-outs or patents.

1.4 Industrial research and development

Companies in Britain invest less in research and development, as a proportion of their profits, than companies in other parts of the world.

Figure 1.2 shows the intensity of research and development across all the large companies in the six comparable countries for which precisely comparable data are published. It suggests that investment in research and development by industry in the UK is only about half as great as it is in Germany and the USA.

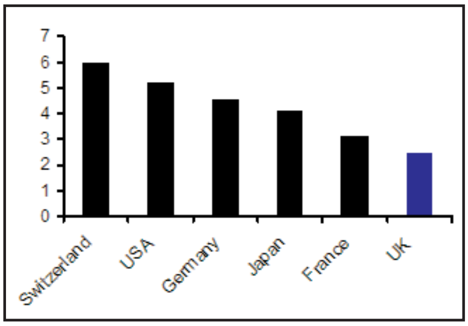


Figure 1.2. Investment in research and development as a percentage of total sales by industry in a group of industrialised countries [Source: *R&D Scoreboard 2004*, DTI, 2004].

The picture may not as bleak as the bare figures may suggest. For example, if scientific labour or equipment is cheaper in the UK than it is in other countries, then the same number of experiments may be achieved for a lower budget[14]. Nevertheless, there is no powerful evidence that research costs are sufficiently low in Britain to cancel out the difference in gross levels of investment. If they were, one might expect companies to be actively relocating research into the UK.

The failure of British business to invest in research is a long-standing problem for British science, and more importantly, for the sustained health of the nation's economy.

To devise strategies for remedying the situation, it is necessary to understand the problem, and efforts have generally been hampered by a lack of detailed insight. Figure 1.3 shows that the picture is varied among different sectors, while Box 1.4 examines the various stages of developing a new product.

The only sectors that have consistently invested in research and development at high levels in the UK are the pharmaceutical and aerospace industries, both of which continue to invest at higher levels than their international competitors[15].

One of the reasons that these industries behave so differently from others is that, to a degree, each has a monopsony customer, in the form of the National Health Service and the Ministry of Defence. In such situations, prices are set by negotiation rather than merely by competition in a market, and the costs of research and development can be spread over the life cycle of a product.

However, the industries do not have guaranteed customers; neither the Health Service nor the armed forces will buy rubbish. The pharmaceutical and aerospace industries must still produce high quality products, and getting the product right requires high quality research.

What is interesting about the example of these two industries is that they prove that where the conditions are right, industry is happy to invest in British research, to a degree that not only matches but exceeds the international competition.

More generally, companies that do not have single state-sponsored customers of this kind have deal in a

Box 1.4

The stages of researching and developing a new product or service

Most new inventions, novel products and innovative processes are ultimately based in pure research, where the discovery of new knowledge is the main aim. Such research cannot be used without innovative engineers and craftsman, but it nevertheless important. **Pure research** may be accompanied by **strategic research**, in which the funder defines a broad field, but where there is no particular application in mind.

Market research and **operational analysi**s aims to uncover knowledge that enables useful applications to be defined, and those applications may then become the targets for **applied research**. Applied research is the discovery of knowledge to demonstrate that a particular use of science or engineering, is feasible. Proving that something is feasible may include the demonstration of a complete product or service.

Once the research is at the right stage, development takes place. This involves **design** - using art and science to produce a set of instructions to manufacture a product or deliver a service to an appropriate specification and at an acceptable cost. **Product engineering** follows, establishing facilities and modifying designs to ensure a product or service can be delivered to the market. In the final stages, **market testing** supplies pre-production samples to confirm that the product or service is acceptable and fit for the purpose it was create to fulfil. This is not the end of the process, because social attitudes to technology feed into changes and developments.

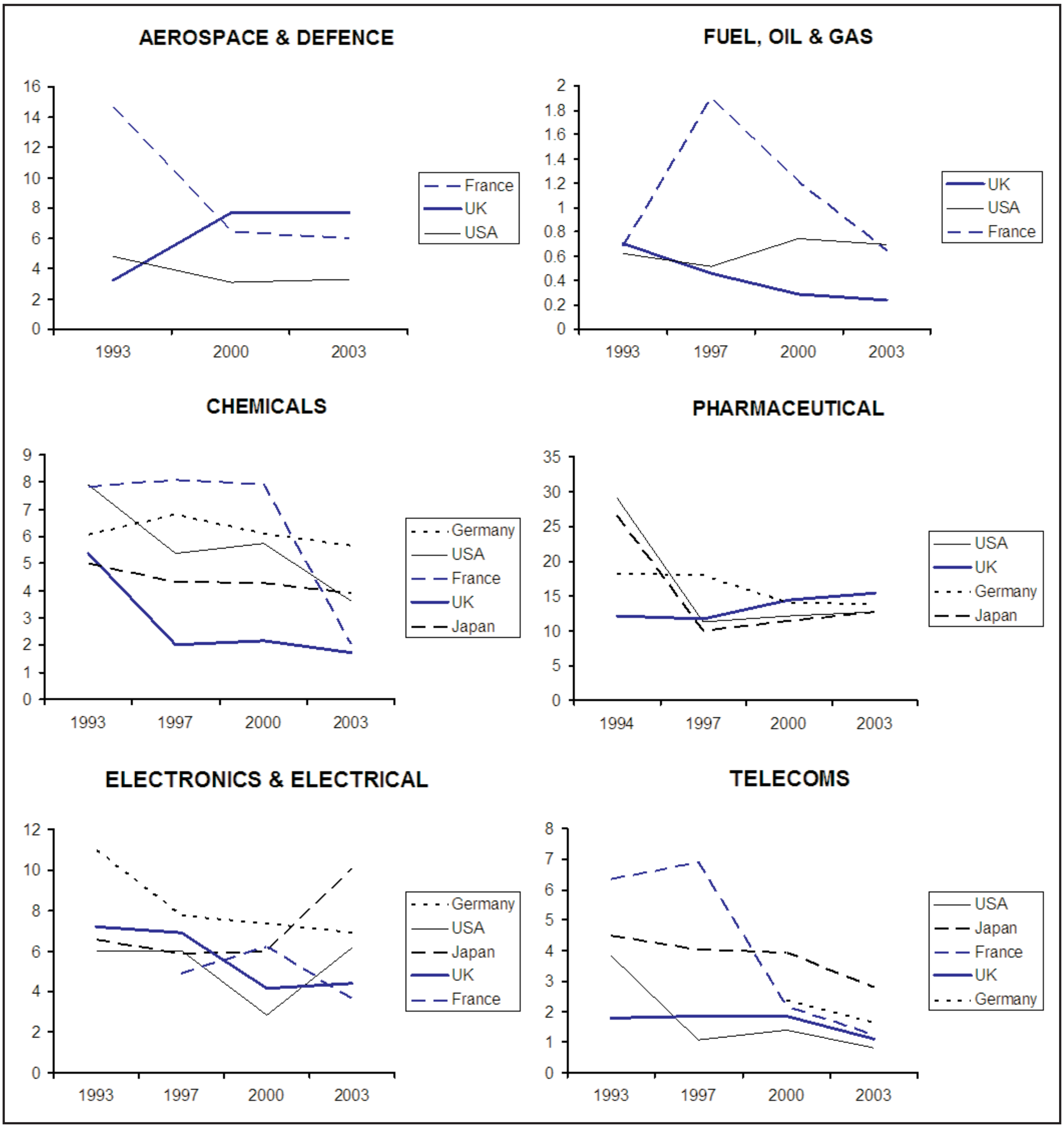
The real world is, of course, much more complex than the "linear model," in which research and development lead directly to production, which in turn leads to sales. But as a starting point it gives a fairly accurate broad picture of the elements that need to be in place for the successful exploitation of new knowledge.

different way with spreading the costs of research and development over the lifecycle of a product or process.

Once feasibility has been proved, the development of a product or process can be costed with a risk that is broadly understood. Businesses can plan to recover the specific costs over the probable lifespan of the product. However, it is not possible to attribute pure research, strategic research and market research to a product that has not yet been identified, it is not possible to amortise their costs into the price that is ultimately charged to a customer in a free market.

Applied research falls in the middle, and it is basically a matter of judgement where research ends and product design begins. If a company gets it wrong, it will start to make major design and production investments before feasibility has been realistically demonstrated. The Nimrod early warning aircraft is an example of this kind of failure.

One reason why the city is shy of investing heavily in research and development, is that, in the past, financiers have been being wrongly convinced to make investments on the basis of a weak assessment of whether a product is genuinely feasible.



AEROSPACE & DEFENCE

FUEL, OIL & GAS

CHEMICALS

PHARMACEUTICAL

ELECTRONICS & ELECTRICAL

TELECOMS

Figure 1.3. Changes in R&D intensity in different sectors of the economy over the ast decade compared with other industrialised countries. R&D intensity is defined as expenditure on R&D as a percentage of sales. So, for example, in aerospace, UK companies have increased their rate of investment in research and develpment, while those in France and the USA have decreased their investment [Source: *R&D Scoreboard 2004*, DTI, 2004 and previous editions].

It follows that **the public should invest heavily in the kind of applied research that robustly tests the feasibility of ideas, encouraging the private sector to use funds for the design and further development of first-rate products and processes.**

Protecting intellectual property

One of the keys to delivering economic benefits from scientific and engineering research is effective protection of intellectual property. Patenting involves costs, and inevitably industry looks to reduce those costs as far as possible.

Because the European Union does not yet offer the chance for ideas to be patented across Europe in a single step, the costs of protecting intellectual property in Europe are substantially higher than for a similar market in the UK.

It is entirely possible that if a European-wide system of patenting were introduced, the subsequent reduction in costs would encourage global industry to see European countries, including the UK, as more competitive places to carry out scientific and engineering activities.

In the words of a recently-retired European Commissioner: 'The cost of protecting intellectual property in Europe is four to five times as high as it is in the U.S. That is largely because we have failed for 15 years to agree on a European patent, as a result of self-destructive arguments about language. Can it really be necessary that every patent application should have to be translated into German even outside Germany? So long as there is no Europe-wide patent, there will be no big pick-up in business R&D'[16]. This is by no means the only problem with the ways in which intellectual property is dealt with, but it is possibly the most soluble.

The UK Government should press hard for the European Union to introduce an efficient, low cost, patenting system that would enable companies to protect their ideas across the entire trading bloc.

Short-term approach in industry

Many people believe that a culture of short-termism is one reason that companies in the UK do not perform research and development at the same level as their counterparts in some other countries. Research pays dividends over the long term, but rarely produces quick results.

Ironically, among the reasons cited for this short-term approach is the strength of the financial services sector. The argument runs that the City of London is always chasing short-term gains, and is relatively uninterested in the longer term potential of research. The culture this engenders tends to pervade British companies, which consequently treat research and development less positively than companies in other countries.

It is almost impossible to make a detailed analytical assessment of the truth of such a rationale, but there is some anecdotal evidence to support the assertion that the City has more influence in industrial decisions that might always be desirable. For example, the former Chief Executive of the drug company GlaxoWellcome said that when the company merged with SmithKline Beecham, some members of the board felt that the deal was unnecessary, but that 'it is difficult for them when all these bankers come in and produce 400 nice slides on why this should be done' and the bankers 'want it done, because they get a lot out of it'[17].

However, it is difficult to make a credible case that such city practices are the main reason that most British companies fail to invest in research. In fact, three years after its formation, the merged company, GlaxoSmithKline, was carrying out more research and development than any other British company, and in the pharmaceutical sector globally, was second only to Pfizer[18]. Moreover, the USA also has a strong financial services sector, but it does not appear to have an adverse affect on levels of research (see Figure 1.2).

The Government should commission a rigorous study of the perception that British business has shorter-term horizons than companies elsewhere, and if the perception is real, of the reasons such short-termism prevails.

Cultural change

Tax breaks and Government grants and contacts cost the taxpayer money. Ultimately, if the UK's economy is to thrive in the coming years, British industry must pay the lion's share of the costs of increasing industrial research and development.

To do this, industrialists in many industries will need reasons to change their short-termist attitudes. One of the processes by which such changes are being effected in other areas are indices of corporate social responsibility, which attempt to measure, and publicise, the extent to which companies take seriously the wider context in which they operate, including the social and environmental effects of their activities.

Such measures are of limited use, because company directors have a primary duty to return a profit to their shareholders, and the schemes may simply create unnecessary and complex bureaucratic costs, without effecting any significant or desirable change.

Nevertheless, some methods of attempting to measure the consciences of companies undoubtedly have some effect on the reputations of some companies and the individuals who run them. For example, the FTSE4Good Index appears to have stimulated 266 companies to change their environmental practices in 2003[19].

In this context, company bosses need to understand that in undertaking more research, they will not only add to the sum of knowledge, but will embed this knowledge in their employees. This tacit knowledge has benefits over and above the immediate return to the company, and can benefit both the individual company and the wider economy in the long run.

1.5 Government support for research in industry

Studies that compare the economics of science in different countries find that government support for industrial research is an important element of a successful knowledge economy. In areas where the primary purpose is a civilian one, public funding of business research and development has a strong effect on the economy[20]. The trend does not apply in defence research and the reasons for the difference are uncertain.

In the UK public investment for research within businesses comes from at least three sources: grants and contracts from the Department of Trade and Industry (DTI); tax credits for companies carrying out research; and competitive grants awarded through the Research Councils.

Direct grants for research and development

The most obvious source of government funding for research in the private sector is finance paid directly from the Department of Trade and Industry private companies. This form of support currently runs at about £232 million per year, but has fallen substantially over the last ten years (see Figure 1.4)

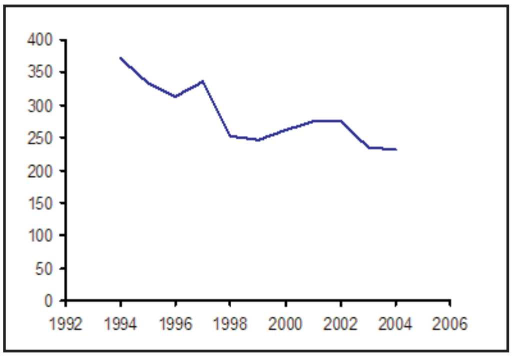


Figure 1.4. Investment in research and development via the Department of Trade & Industry, in real terms (£million at 2001 prices) [Source: Forward Look 2003: Government funded science, engineering and technology, DTI, 2003].

In fact, because some of the DTI's schemes (particularly 'LaunchAid') require beneficiaries to make a return on the investment where possible, the department actually makes a profit of around £44 million per year from its research and development activities[21]. Ministers have been keen to highlight the success of companies like 'Airbus in Broughton, backed by UK Government with Launch Aid ...Employing over 3,000 people in the most high value added part of the aerospace sector'[22].

BOX 1.5

Regional Development Agencies

The Regional Development Agencies (RDAs) are relatively new bodies set up with powers defined by Parliament in 1998. Each is required to 'further the economic development and the regeneration of its area,' and each has a scientific capacity.

Scientific, engineering and technological activities representing between 5% of the overall budget in London and 29% in the Northeast. Collectively, the English RDAs will be using £239 million each year on science, additionally, will be taking over responsibility for some of the DTI's funding for research, including the Grants for Research and Development scheme.

Although each RDA has a Regional Science Council, there is substantial variability in the degree to which the scientific community has confidence in them to deliver benefits for the scientific health of the regions. The North West Development Agency, spurred originally by the central decision to site a major scientific facility elsewhere, has worked hard to ensure that scientific industry in the region thrives. Under the Chairmanship of Sir Tom McKillop, the Chief Executive of AstraZeneca, the Regional Science Council has significant raised the profile of science and engineering in the local economy; for example, the Chemicals Northwest initiative is attempting to address the shortage of trained chemists for an industry that provides 43,000 jobs locally.

However, such stories are rare, and the scientific community as a whole can be hostile towards the RDAs. In order to use their funds widely, the RDAs will need to plug into the existing science policy network in the universities, learned societies and professional associations. Anecdotal evidence suggests that this is not yet happening.

As a matter of urgency, the staff responsible for science in all the Regional Development Agencies should begin to build relationships with those engaged in science policy in a wide range of organisations.

One of the most successful schemes in recent years has been the Grants for Research and Development initiative, under which hundreds of small businesses have been supported in their research objectives[23].

However, the DTI announced in the summer of 2004 that it was cutting back on the scheme. The reason was the 'very success of the scheme,' which appeared to mean that a flood of applications, rather than being viewed as a endorsement of a scheme designed to fill a real need, was perceived as a problem. Instead of investing £45 million a year, investment now runs at £36 million annually, to the dismay of both the university sector and the industrial representatives[24]. This particular scheme is now being transferred to the Regional Development Agencies (see Box 1.5).

It is obvious that there is a significant body of private enterprise that would be willing to conduct more high-quality research if some measure of appropriate support were to be available. Whilst it is not the job of public funds to pay for activities that firms ought to pay for themselves, there is clearly a case for allowing large and small companies to bid for more Government contracts. Such contracts could perhaps focus on technological goals that would enhance the public good, such as cost-effective solar energy, or economically-attractive alternatives to fossil fuels.

Tax credits for research and development

The second way in which government can support research and development in the private sector is through the fiscal regime. Companies that undertake research and development in the UK now qualify for a reduction in their tax liabilities. The scheme was introduced in the budget in 2000 as a measure to assist small firms[25]. The aim is to stimulate more research and development by making it cheaper to perform, and the Government has refined the scheme several times, to widen the scope of companies that are eligible, to ensure that new companies that do not yet show a profit can benefit, and to encompass the widest range of research activities[26].

In general, companies base their decisions about research and development on factors other than the cost of performing it. The fiscal regime is probably a relatively small part of the overall picture. Most of British industry has continually failed to invest, despite changing tax rules, and a few sectors (like the pharmaceuticals sector) were investing heavily long before tax credits were introduced.

The Treasury believes that 'every pound spent in tax support is invested by companies in additional R&D'[27]. The costs of the scheme, in lost tax revenue, are expected to exceed £750 million each year[28]. If the Treasury is correct in believing that there will be an equivalent increase in business R&D, this would represent an increase of about 11% on the current annual figure for industry-financed expenditure on business research and development in the UK, which is approximately £7,000 million[29].

Yet the stated intention of the tax relief was that it would reduce the costs of research by up to 30%[30] and the Government has cited the existing body of evidence to suggest that for every 1% reduction in the cost of carrying out research, companies will, on average, increase the volume of research they perform by about 1%[31]. These figures give a much rosier picture of the likely benefits of the current scheme.

On current evidence, it seems possible that the scheme will have the ultimate effect of increasing overall research and development, although it is difficult to judge the probable extent of the benefits.

Although some 95% of eligible companies have claimed the relevant tax relief[32], it is not yet clear whether the introduction of tax credits for research and development has caused or will cause a marked increase in the amount of research and development that British companies were carrying out (see Figure 1.5). There had already been an increase in the late 1990s[33], following the recession of the earlier part of the decade, and companies have subsequently continued to increase the intensity of their research and development. Some of the increase was probably in response to tax credits, but it is not obvious that there has been a substantial and rapid increase in the years following the introduction of tax credits.

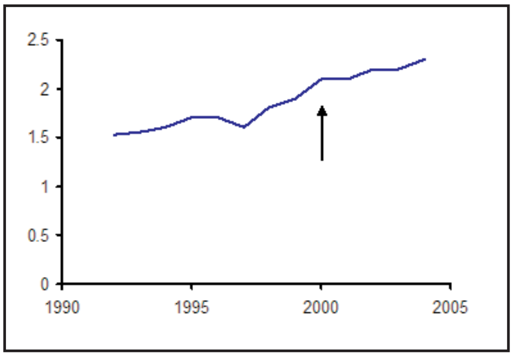


Figure 1.5. Intensity of research and development in UK companies since 1998. R&D intensity is defined as spending on R&D as a percentage of total sales. The arrow indicates the point at which the Government introduced the current system of tax credits for research [Source: *R&D Scoreboard 2004*, DTI, 2004 and previous editions].

However, it would be a serious mistake to judge the scheme too soon. Large companies were not eligible until very recently, and international evidence suggests that tax relief of this kind takes a number of years to pay substantial dividends[34].

Research Council support for research and development

As well as giving direct grants to particular companies and providing general support through the tax system, governments can encourage private sector research by allowing firms to compete for grants from the Research Councils.

At the moment, only a tiny fraction of Research

Council budgets are allotted in this way, as Table 1.1 shows.

Research Council	Proportion of budget allocated to ‘private industry’ or ‘public corporations’
Biotechnology & Biological Sciences	0.0%
Engineering & Physical Sciences	0.2%
Economic & Social	0.4%
Natural Environment	3.2%
Particle Physics & Astronomy	0.0%
Medical	3.2%

Table 1.1. Investment in industrial research by the Research Councils. [Source: *Forward Look 2003: Government Funded Science, Engineering and Technology,* DTI, 2003].

Advantages and disadvantages of the three methods of support

Figure 1.6 gives an indication of the relative amount of public money being used to support private sector research and development each year in the UK, and shows how tax credits are by far the largest sources of funds, and Research Councils by far the smallest. Together, the three sources shown in Figure 1.6 represent most of the Government's support for private sector research where the purpose is to support industrial science and engineering. The Government also spends money on industrial research via individual government departments (especially the Ministry of Defence) but this money is used in pursuit of Government policy, and is not primarily aimed at supporting industry.

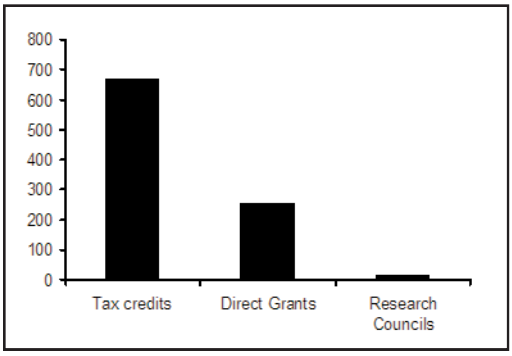


Figure 1.6. Public support for industrial research and development through different routes in 2004 (£million). [Source: *Forward Look 2003: Government Funded Science, Engineering and Technology*, DTI, 2003 and *Hansard* [House of Commons] 2 March 2004, Column 816W].

The principal differences among the three methods by which government gives financial support for industrial research are concerned with guarantees of quality and the capacity to focus on areas of national importance.

Tax breaks support all research, regardless of the subject and irrespective of the quality. Any activity that meets the accepted definition of research qualifies for what amounts to a subsidy by taxpayers. But the scheme presumably has a low bureaucratic price-tag, because there is no need for complex rules and accounting procedures over and above those that companies are required to administer anyway, and there is evidence from other countries of long-term benefits.

Direct grants from the DTI support areas that are judged to be important, and can be focused on particular sectors of the economy, such as start-up companies. But it is necessary to advertise the scheme continually to a new generation of businesses, and bureaucracy is required to administer it; to set up and run the website of the Small Business Service for a single year cost £14 million[35], more than the combined annual support for industrial research from all the Research Councils combined. As with tax relief, direct grants tend to support development work, after the stage at which a concept has been shown to be feasible.

Industrial support from the Research Councils piggybacks on an administrative system that already exists to support university research, and can also be targeted in the same way as direct grants from the DTI. It also has an in-built mechanism of quality-control, ensuring that money is focused on the best research. The main disadvantage is that, by considering the quality of research as its overriding criterion, the system is insensitive to other factors, including the need to support early-stage companies. This problem could be overcome, but only by creating new rules, and a concomitant bureaucracy.

With these considerations in mind, the balance of funding shown in Figure 1.6 is difficult to justify. Although tax credits are extremely welcome and should certainly be maintained, other mechanisms deserve expansion. Most particularly, **in the Government's portfolio of finance for business research and development, the role of the Research Councils should be expanded to include support for high quality research and development in the private sector.**

To achieve this, it will be necessary to ensure that the Research Councils put in place mechanisms to assess a wide spectrum of industry-based proposals, rather than merely considering research in academic institutions and academic analogues.

There should be appropriate safeguards to ensure that work supported in this way is strategic or applied research, in the phase before feasibility of a product has been demonstrated. The job of development could then be properly supported by private industry, with the possibility of including the costs in the price of the final product or process.

Moreover, support for business research must not come at the expense of the academic research on which the Research Councils currently invest the bulk of their budgets, because that role is already overstretched (see Chapter 5).

1.6 Training

A successful nation needs a well-trained workforce. The type of training that is required depends on the particular circumstances of the country, and on the historical framework in which it finds itself. In the past, the UK performed well by having good navigators and skilled shipwrights. In the future, it will need very different skills, but it is difficult to predict what they will be.

Box 1.6

The automotive industry

Research and development is critical to success in the automotive industry, where those companies that continued to invest in research during the recession of the early 1990s were the ones that were performing best by the end of the decade. Around the world, the two heaviest investors during the recession were both Japanese companies - in 1992, Toyota invested £21,860 per employee in research and development, while Honda invested £11,250 per employee. By 1999, the worldwide sales of cars by these two companies had grown by 21% and 37%, respectively. The Italian company Fiat, which in 1992 invested only £3,890 per employee in research and development, had not grown at all by 1999. Pirelli, another Italian firm, whose research investment was just £2,070 per employee, had performed disastrously, and had seen its sales shrink by 28%. Between 1992 and 1999, the combined workforces of Honda and Toyota grew by 97,000, while Pirelli and Fiat had shed a total of 90,000 jobs .

Across the industry, the trend for good performance to follow investment in research was extremely strong. The companies that invested most heavily in research were those that went on to achieve the best financial returns, and to create the most jobs.

So when the Rover car factory at Longbridge in Birmingham was experiencing deep financial problems, it may have been understandable, but was potentially unwise that about 600 workers were made redundant at the company's research and development facility; the decision was heavily criticised locally .

The key to future success was whether the company could recover its ability to create new and innovative products, by tapping into a base of research and design. In the end, it could only do so because of an injection of cash and low-cost manufacturing by a Chinese company, the SAC (Shanghai Automotive Corporation), but that link was only possible because the SAC saw opportunities to tap into the potential for enhanced research and development of the British market.

The growth of computer technology has been so rapid that even if it had been possible to train thousands of software engineers in the 1970s, nobody would have predicted that it was going to be necessary. The only certainty for future requirements for skilled labour is that in the competitive global economy, the countries and companies most likely to succeed will be those train a wide cross section of their populous to a high degree in the broadest range of skills and technologies.

Training scientists provides a mechanism for disseminating innovative capacity. For example, well-trained mathematicians work in finance companies, refining the ability to predict the financial markets. Disseminating capacity in this way can be a powerful tool in enhancing economic activity.

The curriculum, including the vocational elements, in schools, universities and colleges should be sufficiently flexible to suit the changing needs of the economy.

More detailed ideas about education and training are set out in Chapter 6.

Maintaining a pool of expertise

Businesses cannot afford to maintain all aspects of the extensive pool of knowledge that is of no current use to them, but which might turn out to be important in the future. In a competitive environment, each firm would have to maintain a complete portfolio of potentially-useful research, which for a single company would be impossible.

However, for an industrialised nation, the risk can be spread, and the task is much more achievable. It is one of the roles of government to sustain a very broad public research base from which companies can seek expertise when they discover unexpected requirements.

Box 1.6 explains why this is important for the automotive industry.

Another way of looking at the issue of maintaining a pool of expertise is the concept of tacit knowledge. In essence, this can be summed up in a single sentence: by performing 5% of the world's research, the UK maintains the expertise to access the other 95%.