Council for Science and Technology

TECHNOLOGY MATTERS

Report on
the exploitation of science and technology by UK business

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CONTENTS PAGE

EXECUTIVE SUMMARY

The report addresses the question of *what the Government should do to increase the capacity of UK businesses to exploit science and technology.*

2. We are optimistic about the UK's prospects: the UK economy has many strengths. But future prosperity will hinge upon the growth and success of companies which invest in the creation and application of technology in new products, processes and services. These technology based businesses will become increasingly important to the nation's share of the wealth that is created and consumed in the global economy of the 21st century.

3. We are convinced that the UK, faced with mounting competition and an ageing population, must increase the capabilities of its existing companies to create, apply and exploit advanced technology. The nation's ability to create new technology based businesses and to grow them rapidly into large companies must also be strengthened significantly. These new businesses will need sufficient financial and other resources from the start.

4. The Government is already pursuing a modernisation agenda for economic competitiveness, regeneration and renewal, based on science, innovation, enterprise and fairness. The steps being taken are welcome and essential. We believe that further policy development should address the following key strategic needs:

(i) to increase the cadre of top quality, technologically sophisticated people to lead and manage the growth of technology based businesses;

(ii) to raise the standing of technology within the UK and to create a strong, underpinning platform of generic, enabling technology;

(iii) to develop a financial pipeline with sufficient capacity to meet the needs of technology based companies for equity and other risk finance. That means sufficient money and enough people with the knowledge and skills to take sensible investment decisions; and

(iv) to provide modern and effective sponsorship support from Government Departments.

5. **People:** Through its education, training and immigration policies Government should seek to increase significantly the cadre of top class, technologically sophisticated people in the labour force. In partnership with universities, Research Councils, the professional institutions and businesses, it should promote a greater two way flow of senior technologists between companies and universities; and seek to improve career pathways for students and researchers in science, engineering and technology, so that they gain the skills, knowledge and contacts needed for running technology based businesses.

6. **Technology:** Through incentive, reward, recognition and funding mechanisms, the Government, along with other key stakeholders, should seek to raise significantly the status and recognition of technology in the UK. Support for collaborative R&D programmes with companies should be expanded, permitting the participation of partners from overseas, beyond the EU, when appropriate. Government should also increase expenditure on supporting research and development in small firms and develop the services which help small firms make creative use of technology.

7. **Finance:** The Government should ensure that fiscal policies concerning technology based businesses are internationally competitive; and work closely in partnership with the business and financial communities to increase the flow of risk finance, and continue to support interaction between business and the financial community on incentives to investment in research and development.

8. **Sponsorship:** The Government should modernise arrangements for sponsoring technology based businesses within and between Departments, taking the opportunity provided by the Small Business Service and the Regional Development Agencies. In doing so, it should take a comprehensive view, including its own arrangements for procuring the best and most innovative products and services. It should ensure that support measures are appropriately focused, strike the appropriate balance between existing and emerging sectors, have sufficient scale to achieve a step change in performance; and recognise the role of large technology

based companies in the economy, and their critical importance in the establishment and growth of small ones. It should provide support for the emergence of clusters of new technology businesses, including provision for necessary infrastructure.

9. Government should systematically **monitor and report** on the outcome of policies aimed at the creation and rapid growth of technology based businesses. To do so, it will need to develop metrics for gauging the UK's performance in the production and commercial exploitation of technology.

10. This is a complex area: there is 'no one size fits all' solution. However, taken together, we believe that the additional measures we propose would enable the UK to match the world class record of its science base with performance in the complex and high risk business of creating wealth from technology.

MAIN REPORT

Introduction

As part of its programme of work for 1998/99, the Council for Science and Technology set up a sub group to consider what more the Government should do to improve the exploitation of science and technology by British business. The group focused on demand side of the process by which science and technology is exploited by companies: the pressures on business and the incentives and obstacles to technology driven innovation.

2. The work was led by Professor Sir Alec Broers. The other members of the group were Professor Kumar Bhattacharyya, Dr Chris Evans, Sir Robin Nicholson, Dr David Potter, Miss Emma Rothschild and Mr J Martin Taylor, assisted by Professor Alan Hughes, Director of the ESRC Centre for Business Research, University of Cambridge.

3. The group took into account the report to the Paymaster General by Sir Peter Williams on the Financing of High Technology Businesses[1], an analysis which David Potter presented to the Prime Minister in the Millennium Lecture on Wealth Creation in May 1999, and a more recent comparative analysis of the UK's national innovative capacity by Professor Michael Porter.[2]

4. We were supported by officials from HM Treasury and the Department of Trade and Industry who contributed data about the UK's innovation performance: a summary of the information used by the sub-group is at Annex A. A series of consultative meetings was held during 1999: a list of those who attended is at Annex B. A glossary of the main terms used is in Annex C.

The Context

5. We see tremendous opportunities for UK businesses arising from the societal, technological, economic, environmental and political changes occurring world-wide:

- patterns of capital investment, centres of manufacturing, production processing and distribution, as well as the associated supply chains including research and development are becoming increasingly global;

- national and international competition is increasing as business entrepreneurship, enterprise and innovation spread and costs, prices and barriers to entry reduce e.g. through digital technology; and

- the world-wide production of new information and knowledge including science and technology is accelerating.

6. These changes are transforming the economic and business landscape. Over the past

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[1] *The Financing of High Technology Business: A Report to the Paymaster General, HM Treasury, November 1998.*

[2] *The Determinants of National Innovative Capacity,* Stern S, and M, Furman J, MIT, Porter M Harvard Business School, October 1999.

decade, the US has enjoyed a remarkable boom in technology based fortunes while Japan and the tiger economies of the Far East have experienced recession after several decades of very high growth. In Europe, record levels of cross border merger and acquisition are occurring in sectors such as oil and gas, telecommunications, pharmaceuticals, chemicals and automotives as firms seek to strengthen their competitive position.

7. The prices and life cycles of an increasing range of products, processes and services are reducing. New technologies, new technology based industries and new competitors are emerging at an increasing rate. Barriers to entry or to establishing market position and leadership are changing. The sources of competitive advantage are changing rapidly. The line between gaining and losing market leadership through technology is narrowing. There is everything to play for in the scientific and technological revolution that is occurring worldwide.

The Challenges facing the UK

8. In the 21st century, technology is a key driver for all business: so to succeed they all need to be able to use technology for competitive advantage. In the knowledge economy, the key players invest in the creation and application of technology in new products, processes and services. They are technology based businesses.

9. To make the most of these opportunities, the UK will need highly innovative, companies generating wealth from science and technology: UK companies will need to be creative, flexible, fast, and highly productive to compete and prosper in the global markets for products, processes and services. As the proportion of the population which is of working age falls, the need for improvements in productivity to support competitiveness will become more acute. Further productivity gains through cost reductions and efficiency savings, while necessary, will not by themselves be enough to meet the UK's needs. Improved bottom line performance (costs) and top line growth (sales) by companies will be vital.

10. The total value added of the products and services created and produced in the UK, as well as the efficiency of their production from human, capital and other resources will determine the nation's productivity, and in turn its prosperity. This will hinge upon the investment in research and development and technological innovation; a skilled, technically competent work force; and a modern technology infrastructure.

11. To rise to this challenge by achieving a step change in total productivity, we believe that the UK must increase the capabilities of its existing companies to create, apply and exploit advanced technology. The nation's ability to create new technology based businesses and to grow them rapidly into large companies must also be strengthened significantly. These new businesses will need sufficient financial and other resources from the start. In our experience, the UK does not do as well as the United States.

12. More particularly, we are convinced that

- a pro technology culture must be created, one in which companies, the Government and the public recognise and value much more the crucial importance of technology as distinct from science;

- the cadre of people who are highly skilled both as technologists and in running a business must be greatly increased;

- the nation's platform of enabling technology must be broadened and deepened significantly in the strategically important sectors of the 'sun-rise' industries, such as computing, microelectronics, telecommunications, advanced materials and bio-technology;

- more dynamic clusters need to be developed with much stronger links to the increasingly globalised sources of leading edge S&T worldwide[3];

- the personal finance and tax incentive structures should be fully competitive internationally, especially with those in the US: business and the providers of financial resources need to become fully alive, and responsive, to the technology challenge; and that

- the Government must play a full part in driving exploitation of the new technologies in all ways it interacts with business - sponsorship in the widest sense.

13. In the past, companies and industries could be strong, and remain strong, in a single area of technology. Now, and increasingly in the future, competitive advantage depends on the capacity to bring together multiple technologies: pharmaceuticals requires not just strength in chemistry and biochemistry, but also advanced materials, electronics, information technology and bioinformatics. This presents all advanced nations even the US with some very tough decisions when determining the fields of science and technology in which to invest public funds.

14. No country, not even the US, can afford to invest a sufficient amount to be strong in every field.

The UK's Strengths and Weaknesses

15. The UK starts the 21st century with some very real strengths and advantages including:

- a substantial presence in the UK of the world's best companies;

- strong companies in such sectors as oil and gas, bio-technology, pharmaceuticals, aerospace and defence, media and communications, finance and business services and the creative industries including design, consultancy and certain types of software;

- a broad balance between the manufacturing and service sectors; and

- an excellent science base[4].

[3] The importance of these links is illustrated by the success of Silicon Valley around 14 times as many people are now engaged in R&D there than there are IBM R&D staff world-wide.
[4] *The Quality of the UK Science Base*, DTI, March 1997.

16. Nonetheless, the UK will need to increase significantly its capacity to compete through technology based innovation and otherwise achieve a step change in economic performance. Thus, as covered more fully in our assessment in Annex A:

- by international benchmarks, past and current levels of investment in innovation, research and development are low.

- in a number of important sectors, particularly among the physics and engineering based industries in the capital, industrial and consumer goods fields, the UK is no longer a leading player in exploiting and creating markets through technology based innovation and these structural weaknesses are undermining the country's balance of trade.

- Porter's analysis covering the period 1973-1995 places the UK in a middle tier of 17 countries, below Switzerland, the US, Japan and Germany in an innovation index. While the UK's index remained broadly constant in absolute terms, it eroded compared to all the other countries.

- in the recent Community Innovation Survey covering 1994-1996, the UK's share of manufacturing turnover devoted to innovation (3.2%) was lower than the EU average (3.8%), and the contribution of innovation to manufacturing turnover was substantially lower, particularly for large companies.

- business expenditure on R&D as a percentage of GDP declined from 1.5 % in 1986 to 1.2% in 1998, and the number of people working in R&D in companies has fallen by 50,000, mostly at the technician and administrative support levels[5]. Even allowing for improved productivity and such changes as "out-sourcing" of research to universities, this raises a question about the UK's national innovative capacity and potential to commercialise R&D.

- the UK has comparatively few businesses, especially in the medium to very large range, which are pioneering new products, processes or services, or deriving significant turnover from them. Just 10 companies account for 50% of the total amount of UK business expenditure on R&D and twenty firms account for some 75%.

- with some notable exceptions, there is a dearth of major British players in underpinning and enabling technology based sectors such as electronics, Information and Communication Technology (ICT) hardware or advanced materials, and in many of the markets for consumer, industrial and capital goods. Again with a few exceptions, the UK has a poor record in growing major new international businesses based on technology.

- many UK companies seem unable to make the most of the technology drivers in their businesses and markets for competitive advantage[6].

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[5] Table 8.3 of the SET Statistics 1999, OST, July 1999.

[6] "*R&D for Industry: Into the Next Millennium*" The Royal Academy of Engineering, October 1998.

- risk aversion within companies and the financial community manifests itself in a focus on securing short term gains in shareholder value[7].

The Government's Role

17. We see the Government as providing a framework of policies and instruments:

- assuring macro-economic stability, with the right fiscal system;

- providing an education system which delivers well rounded scientists and engineers, aware of the importance of finance, marketing and management skills, and with an understanding of the global marketplace;

- taking well targeted initiatives to help companies, particularly in transitional phases, while recognising that direct financial and other support for industry is less important than the overall framework.

18. The government has already taken vigorous action[8] to meet the challenges, including the 1998 Competitiveness White Paper which was published just before the Group started work:

- substantial additional funding to modernise the Science Base;

- a new round of Foresight;

- the new University Challenge Fund and the Science Enterprise Centres, together with a pioneering joint venture between the University of Cambridge and the Massachusetts Institute of Technology;

- the new venture capital fund-of-funds of £125 million for investment in UK-based, early - stage technology companies with £20m of Government funding: and a set of new fiscal incentives concerning capital gains tax, management incentives and employee share ownership, corporate venturing, and R&D

19. We welcome the steps already taken. We believe that they are contributing to a climate which is now much more positive for the development of strengths in technology, than it was even a year ago, as we started this work. The following paragraphs set out the action we believe the Government and other key players now need to take, and the reasons why.

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[7] *Boards put the company on autopilot guided by shareholder value. As a result UK plc is a very anorexic thing. It has hollowed out and lost the growth gene and the ability to innovate"* - Stephen Francis, Head of Strategy, AT Kearney.

[8] *Our Competitive Future: Building the Knowledge Driven Economy, "* Cm 4176, December 1998; M*aking Britain a more Entrepreneurial Society,* Pre-Budget Report, November 1999.

People

20. In his recent book on Wealth Creation[9], Lester Thurow makes the following observation about the UK's record in growing major technology based businesses:

> *'A country like Great Britain would seem to have all the ingredients of the American system (or maybe its the reverse), yet Britain also has a poor record when it comes to start ups and building new big corporations.*
>
> *What Britain lacks is what it lacked a hundred years ago when it lost its global position of economic leadership: the necessary mass base of technological manpower. It educates so few people technologically that the number of people necessary to run high-tech industries simply don't exist.'*

21. We agree. In our own experience, many UK technology based businesses, both large and small, are finding it increasingly hard to find top quality, highly qualified people with CVs bridging the two worlds of business and research to fill senior positions. Only rarely do UK universities find candidates from the business world with a suitably strong technology based CV for a short or longer term appointment: something which is much more common in the US.

22. Technologists are people who know the science of their subject and have also gained the knowledge and skills needed to create useful technology. It is not important whether they started as scientists, mathematicians, or engineers. Many of the world's best technologists started their careers as scientists or mathematicians and many of the world's top scientists and mathematicians started as engineers.

23. They gain their skills and other capabilities through a succession of career moves after their postgraduate or post doctoral experience. This often involves periods working at the leading edge of technology in the commercial environment of a large company, within a top management consultancy and financial institution. Outstanding technologists are also bred from experience which can include how to recover from past failure: we therefore welcome the Government's present review of bankruptcy law.

24. Many of the major technology based businesses in the US, for example INTEL, were created and grown by entrepreneurs who have this essential background, and this has become a key part of the US's national innovation capacity and culture. Indeed, we believe that the two way flow and movement of such highly qualified people between the science base and businesses in the US is one of the primary reasons behind the remarkable regeneration of the US economy over the past decade.

25. By contrast, we experience far less of this sort of dynamic movement and interaction occurring in the UK, possibly due to differences in culture, personal values, ambitions or attitudes to risk. Other possible reasons are more limited range of career pathways and opportunities, or a lack of sufficient incentives or rewards. We very much welcome the new management incentive and employee share ownership incentives contained in the Chancellor's

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[9] *Creating Wealth*, Lester Thurow, Nicholas Brealey Publishing, London, 1999, ISBN 1 85788 242 -3 at page 253.

recent Pre Budget Report[10]. For small, technology based companies that cannot afford to pay competitive salaries, the offer of a share in profits through share options can be highly attractive. We believe that share options and the UK's taxation of them will become ever more important aspects of the UK's competitiveness.

26. We believe that the Government should address this issue in partnership with business, universities and the Research Councils with a view to augmenting and reinforcing such recent steps as those concerning the Science Enterprise Centres, the Council for Excellence in Management and Leadership and the Higher Education Reach Out Fund, as well as the long standing Teaching Company Scheme.

27. We consider that the Government should seek to:

> *(a) increase appreciably the two way flow between companies and universities of senior people engaged in the business of technology. This should preferably occur at early or mid career points and not only, as is all too frequently the case at present, after retirement; and*
>
> *(b) improve and enhance the career pathways and options for the wider career development of post doctoral researchers, possibly through suitable tax incentives,* thereby reinforcing the existing Research Careers Initiative[11] which is aimed at improving the career management of university contract research staff more generally.

28. Although full time or permanent appointments may not be realistic, the Royal Academy of Engineering has, over the years, developed a number of flexible innovative schemes which allow for secondments, visiting professorships and the like. These achieve "gearing" from the private sector after initial pump priming by the Government. In our view, they provide models well worth exploring in other disciplines.

29. Similarly, the Government should work further with the Research Councils, business and the universities to ensure that in the training of postgraduate students and postdoctoral researchers, university departments have the scope and incentive:

- *to maximise interaction with business;*
- *to provide a range of training experience which will best meet the needs of all users including academia itself; and*
- *to offer flexible opportunities for courses of varying length, to meet the needs of a modern economy.*

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[10] M*aking Britain a more Entrepreneurial Society*, Pre-Budget Report, November 1999.

[11] We understand that the Engineering and Physical Sciences Research Council is already planning to pilot short, experience-based courses aimed at giving post doctoral researchers greater exposure to entrepreneurship, innovation and research based spin out companies. Further, a number of institutions will be developing case studies of researchers who have moved into other areas of employment and this should make a start on providing higher profile role models.

30. More generally, we consider that Government should continue to work through partnerships with universities, Research Councils and professional institutes to develop and strengthen the trust, norms, practices and networks that are so critical for businesses and universities to work together[12]. Presently some 75% of manufacturing small to medium size firms do not employ a graduate scientist or engineer and over 90% do not in the services sectors. But given encouragement, full recognition of the transaction costs and the right coherent package of options reflecting their values and interests, we believe that many more of these companies would take on and benefit from first or higher degree graduates and undergraduates.

31. In the longer term, the Government will need to:

- *take an even more holistic, systematic approach to the education and development of future generations of S&T entrepreneurs, managers and S&T professionals;*

- *ensure that the funding arrangements for universities evolve so that universities are able to respond dynamically to the huge challenges and opportunities ahead including the ability to compete in the global market for world class scientists, teachers and researchers; and*

- *continue to develop its fiscal, monetary and immigration policies to promote the UK's competitiveness. We hope that the fundamental review of UK work permit arrangements will recognise this, and will bring the UK approach more closely into line with that of countries, such as Australia, Canada and the US, which have less restrictive work permit and visa arrangements.*

Technology

32. We are convinced that one of the deep rooted problems that has undermined the nation's economic performance for decades is that technology and technologists are undervalued and insufficiently recognised and rewarded. Received wisdom, especially among school pupils, that the UK is great at science but poor at creating wealth by exploiting technology needs to be countered. It is highly erosive and far from the truth: there are many instances of UK companies holding or gaining market leadership through their technological excellence

33. Basic and applied research produces the science and technology forming the platform of enabling technology which underpins the productivity of firms and nations. Basic science and technology both create knowledge that expands understanding; inform choices and open up fresh scientific and technological opportunities; and support the training of manpower at the leading edge. They produce a wider and deeper pool of understanding of how and why things work. This increasingly provides a crucial competitive advantage. The rationale for public expenditure is the same for both basic science and basic technologies[13], especially in terms of meeting the country's manpower requirements and the fact that companies will only invest in

[12] *Higher Education Winning with Business,* DTI, July 1998

[13] *"The relationship between publicly funded basic research and economic performance"* A report by SPRU, University of Sussex, for HM Treasury, July 1996.

research if they are to capture sufficient benefits themselves[14].

34. The engagement of business in technological research secures additional benefits such as strengthening clusters and networks including those with academia, promoting the excellence and relevance of research in the UK's science and engineering base and the mutual identification of fresh research priorities and the like. It also enables businesses to better manage their R&D requirements, plans and investment decisions. As competitive pressures mount and the period before technology loses its competitive edge shortens, it is becoming generally less common for firms of all sizes to invest in more upstream research activities.

35. We do not favour major campaigns to promote technology or technology based innovation but we do believe that the Government has an important role to play in creating a much more supportive and encouraging environment, as has occurred in the US over the past 10 years or so. *It should seek to boost the standing and importance of technology and technologists.*

36. One way of doing this is through suitably prestigious prizes for scientists and technologists respectively: the US President's annual prizes for both are a notable example of this approach. Another would be to ensure that the technological aspects of Departments' policies and measures are clearly highlighted, especially any presenting future opportunities for technology based businesses.

37. We also consider the Government should investigate what more it could do, possibly as part of the implementation of the second round of FORESIGHT, to help meet needs of companies in dealing with the technology aspects of their strategies and plans and to improve their capabilities through the promulgation of good practice. The US Industrial Research Institute provides a interesting example, in terms of helping to develop and improve the strategic management of R&D and technology by companies.

38. We further believe that the Government should:

> *(i) develop and increase its support for small firm R&D, including the further development of its support services to help and encourage small firms to develop from merely using technology (e.g. in the form of new machinery) into technology based businesses i.e. investing in the creation and application of new technology for their business purposes. Such support needs to take account of the distinctive needs of small companies;*
>
> *(ii) develop and increase its support for the creation of advanced technology in joint programmes with companies, permitting the participation of companies overseas, including companies outside the EU when this is warranted.*

[14] Social returns on research and development are generally estimated to be around some 60%, significantly higher than the private returns around 20%.

39. We note that the US advanced technology programme:

- focuses on enabling technology;
- does not exclude support for single companies or for projects with university partners while encouraging consortia;
- permits participation of overseas partners;
- is not limited to companies of a particular size; and
- is business led.

40. In considering the necessary action, Government should take account of:

- the impact of the significant changes in Government expenditure on research and development outside the dual support arrangements which have occurred over the past 10-15 years;
- the impact of the strategic changes which have occurred in business R&D in the UK over the same period;
- the growing importance of international science and technology collaboration which now extends far beyond EU countries and the lessons to be drawn for UK national S&T programmes and participation in international ones;
- the track record of long standing technology transfer programmes such as SMART and LINK, along with the contributions made by the Research Councils: and whether they can be improved;
- the need to improve incentives within arrangements for funding university research research so that they encourage the creation and commercial exploitation of enabling technology by universities.

Private Sector Risk Finance

41. The ability to access the appropriate level and type of finance is one of the main factors influencing the performance and growth of technology based businesses. DTI's recent report about the UK's fledgling biotechnology sector[15] contains projections about the emerging companies requiring in total some £800 million to £1.5 billion of risk investment over the next five years: venture capital invested in these companies in 1998 amounted to just over £70 million.

42. Although the UK has a highly developed venture capital industry, the investment record is heavily biased towards Management Buy Outs and Buy Ins (by amount of venture capital actually invested). In contrast, the US risk capital market devotes significantly more resources

[15] *Genome Valley: the economic potential and strategic importance of biotechnology in the UK, DTI, London, December 1999.*

to early stage firms than to acquisitions and buy-outs. In 1998, the UK invested in high technology companies, relative to GDP, a third of the amount invested by the US in such companies[16]. In the same year, only 17 per cent of disbursed venture capital in the UK went to early stage companies, compared with 28 per cent in the US. Germany, the second largest supplier of venture capital in Europe after the UK, invested similar proportions to the US in early stage companies.

43. It is essential that there is sufficient capacity and no significant blockages or dislocations in the financial pipeline for funding the many stages in the development of technology based business, from start up through early stage, expansion growth and, for some, flotation. We welcome as important steps in the right direction the Chancellor's November 1999 Pre Budget Report for improving the Capital Gains Tax regime for investors and the arrangements concerning the taxation of intellectual property, as well as the new tax credit for small firm R&D, a new incentive to encourage corporate venturing and a new, clearer definition of R&D for the purposes of the Scientific Research Allowance provisions.

44. We also note that during 1999, NASDAQ announced its intention to open a European exchange in the City, the London Stock Exchange stabilised a new TechMARK index; a number of technology based companies joined the FTSE 100, and London's Alternative Investment Market out performed all others, increasing by some 130%. It remains to be seen what impact these developments will have on the financial markets. Private and institutional investors appear to be taking a renewed interest in technology companies.

45. In many instances in which technology based companies are involved in projects perceived to be of high risk, or where lead times are long, equity finance is necessary to avoid the cash flow problems associated with debt finance. We have personally experienced decisions concerning risk investment in UK high technology ventures which have been made on evidence and analysis which was not as good as that available to institutional investors from Wall Street. Matters are undoubtedly improving, partly due to the arrival of US banks and fund managers in the City, who demand the same standards they would expect in the US, from analysts who understand the technical issues as well as financial records: British institutions can learn from this.

46. Nonetheless and despite the City's record of investment in such high tech sectors as pharmaceuticals and aerospace, many company Chief Executives and Directors still see the City as a "problem" and believe that it could and should do much more to drive innovation, boost R&D and foster a more ambitious, entrepreneurial culture in more UK firms. Related to this is a widespread perception that investment decisions in the UK are driven too much by short term profit and dividend considerations.

47. We are therefore pleased to note that the Bank of England is promoting a dialogue between business leaders and the investment community by way of follow up to its 1996 report[17], and the two reports published by DTI during 1999 concerning equity investment in

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[16] "Report on Investment Activity 1998" British Venture Capital Association (BVCA). UK pension funds and insurance companies contributed only 13% of total independent venture capital funds in the UK in 1998. Banks accounted for another 7%. This compares with 73% sourced from overseas, with the US contributing 51% of the total.

[17] *The financing of technology based small firms*, Bank of England. October 1996.

smaller quoted companies by Fund Managers and Private Investors[18].

48. We further note that in July 1999, the actuaries and benefit consultants issued a statement supporting greater investment in unquoted securities by institutional investors: "the current practice of investing predominantly in quoted equities has served pension and life company funds well over the past decade, but we believe the time has come to put more emphasis on the other opportunities, particularly unquoted securities..... As a general matter we support institutional investors making a higher allocation to unquoted securities." We welcome this approach.

49. We believe that the Government should continue to work with the financial and business communities to identify what would drive higher levels of investment of private, institutional and venture capital for technology based businesses, especially at the stages of start up, early development and at the point of initial public offering of shares.

50. In addition to taking forward these two recent DTI reports, we believe that the following issues merit attention by business and Government:

- whether the UK's accounting and reporting requirements are geared to high levels of short term profitability[19];

- the relationship between CEO performance schemes and the economic added value record of their companies; and

- the capability of company Boards and CEOs to identify, harness and explain the technology aspects of their business plans e.g. in their dealings with the City. There is a need for further work to establish and promote best practice.

51. At the start up and early development stage for high technology business:

- the use of business angels needs to be encouraged further. One way would be to re-focus the Financial Services Act to allow appropriate support for financial promotion. At this stage, we believe that there is also a need to address the following issues:

- whether minimum deal sizes are too large to meet the needs of smaller technology-based companies, thus forcing them to take on a higher investment threshold and an associated large initial equity gap. Normally, the larger the fund, the larger is minimum deal size available. This is due partly to transaction costs in dealing with a company's requirements and partly to the need of the fund manager to secure comparable returns to that of alternative investment opportunities e.g. in Management Buy-Outs (MBOs).
- the growth in available venture capital funding, but not an associated growth in the number of suitably experienced people who can pass on their knowledge to help to

[18] *Creating Quality Dialogue between Smaller Quoted Companies and Fund Managers,* DTI, March 1999: *Private Investors: Improving Share Liquidity for Smaller Quoted Companies,* DTI, October 1999.
[19] see for instance *Accounting for Europe - Success by 2000AD?* Simmonds A & Azieres O, Touche Ross Europe (1989).

make new business investments a success.

52. At flotation stage, there is a need for a two way flow of information between smaller companies and fund managers so that potential stock market value can be properly assessed. This is vital since so much of the value of a business is determined by perception. Further, lack of liquidity in SQC shares has arisen due to changes in the fund management sector, which is increasing its focus on larger companies: there has been a move towards consolidation of fund managers and an associated increase in the minimum deals offered to early stage businesses (with the consequent problems as detailed above). There has also been an increasing 'Europeanisation' of funds, and increasing use by fund managers of retail tracers who concentrate only on companies in the FTSE 350. Further, the Government focus on low charges has also pushed investment into tracker funds (such as ISAs and Stakeholder pensions)

53. The result of these changes is that the pipeline is not operating efficiently at the flotation end, which is a disincentive to early stage businesses. A lack of money in the SQC sector is causing analysts to pull out, which simply adds to the above problems and leads to a vicious circle of low investment, poor research, low knowledge, low value and low investment.

Government Sponsorship

54. The Council recommended in its 1999 review of S&T activities across Government[20], that a more consistent approach be taken to the industrial sponsorship aspects of Departments' roles and responsibilities. Among the points we noted were the different approaches taken by departments and the risk that some of the newer industries might fall into the cracks between departments. We also noted that there seems to be little cross-comparison and sharing of best practice between departments; the relatively low level of investment in the newer science-led industries compared with the assistance to traditional industries, and that arrangements for sharing views on priorities and approaches are patchy.

55. Our further work for this report has convinced us of the need to modernise the sponsorship role and activities of Departments in the light of the advent of Regional Development Agencies, the Small Business Service and Resource Accounting and Budgeting.

56. We are not suggesting that the Government should revert to outdated policies or involving national champions or picking winners. We also recognise that Departments' support and sponsorship work for long established sectors, especially those undergoing transition and change, are necessary, as are programmes for supporting new small businesses and improving small businesses performance and growth e.g. through subsidised information, counselling and consultancy services to help improve their productivity and ability to innovate and absorb new science and technology.

[20] OST, London, September 1999 (website www.cst.gov.uk)

57. We consider that the Government should take a fresh look at

- *its overall approach to sectoral sponsorship, including the way it identifies, and determines expenditure priorities for business support within and between Departments, taking account of the national and international situation and prospects;*

- *how it identifies the technology based industries and sectors with real potential for growth and targets support at them, in partnership with the private sector, including the role of FORESIGHT;*

- *the arrangements to support the development of clusters;*

- *the arrangements for allocating budgets to meet the priorities including the balance of expenditure between existing and emerging industries;*

- *the way that Government departments and agencies use their own buying power. We believe that there is considerable scope, at present not properly exploited, for departments to support innovative, high technology products and services, by buying the best rather than the cheapest;*

- *possibly as part of the new Competitiveness index[21], the development of metrics to assess and monitor the UK's performance in the production of a strong platform of enabling technology and its commercialisation.*

58. In relation to the relatively small group of UK technology based businesses (some 5,000-10,000 at present in the manufacturing sectors), particularly those that are pioneering breakthrough technologies to gain market leadership, we believe that there is scope for improving the existing arrangements within and between Departments for fostering and supporting:

- corporate venturing;

- strategic alliancing;

- partnerships and collaboration with large firms and multinationals e.g. in R&D or marketing;

- intermediary activities, including financing or national and international networking;

- mergers and acquisitions; and

- mentoring and god-fathering.

[21] DTI. December 1999

59. The Government also has an important role in promoting good practice in R&D management and technology based innovation, facilitating, initiating and nurturing spin out activity, and assisting large firms in corporate venturing activities with smaller firms. With very few exceptions, the creation and rapid growth of these vital small businesses depends more upon their links with larger firms than on their connections with universities.

60. Government departments also have an important role to play directly and indirectly in promoting corporate venturing, to make the most of the new tax incentive announced by the Chancellor last November; and in facilitating the development of clusters[22].

Conclusions and Recommendations

61. Overall, our view is an optimistic one. The future holds many opportunities for the UK to create wealth and prosperity. Though the historically high level sterling exchange rate at present is squeezing profits and driving fresh restructuring e.g. through further resourcing overseas, the prospects for low inflation growth over the longer term are good. We also judge the general competitive condition and shape of UK businesses as better than at any time in recent decades. And the UK has many other competitive strengths: the Government's modernisation agenda builds on them.

62. The nation's future prosperity and well being will ultimately hinge upon the ambition, vision, courage, capabilities and achievements of the people leading, managing and investing in UK technology based businesses. Fostering and supporting the establishment and growth of such companies is not simply a matter of getting the national and international dimensions of the Government's policy framework right, nurtured by public expenditure. Nor is it solely a matter of inspired genius, serendipity or business excellence within these firms.

63. Our recommendations are directed at meeting the key needs of technology based businesses. They are listed in detail in the appendix. In brief, we consider that the Government should concentrate upon the following areas in taking forward its policies for science and innovation.

People: Through education training and immigration, the Government should seek to increase significantly the cadre of top class, technologically sophisticated people in the labour force. In partnership with other key players, it should promote a greater two way flow of senior technologists engaged in the business of technology between companies and universities; and seek to improve career pathways for postgraduate and postdoctoral students in science, engineering and technology so that they gain the skills, knowledge and contacts necessary for leading and running technology based businesses.

Technology: Through incentive, reward, recognition and funding mechanisms the Government, along with other stake holders, should seek to raise significantly the status and recognition of technology in the UK. Support for collaborative R&D programmes with companies should be expanded, permitting the participation of partners from overseas, beyond the EU. Government should also increase expenditure on supporting research and development in small firms and develop the services which help small firms make creative use of technology.

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[22] *Biotechnology Clusters: Report by a team led by Lord Sainsbury*, DTI, August 1999

Finance: The Government should ensure that its fiscal policies concerning technology based businesses are internationally competitive, and work closely in partnership with the business and financial communities to increase the flow of risk finance.

Sponsorship: The Government should modernise arrangements for sponsoring technology based businesses within and between Departments. taking the opportunity provided by the advent of the Small Business Service and the Regional Development Agencies. In doing so, it should:

(i) take a comprehensive view, including its own arrangements for procuring the best and most innovative products and services;

(ii) ensure that support measures are appropriately focused, strike the appropriate balance between existing and emerging sectors, have sufficient scale to achieve a step change in performance; and recognise the role of large technology based companies in the economy, and their critical importance in the establishment and growth of small ones; and

(iii) systematically monitor and report on the outcomes of policies aimed at the creation and rapid growth of technology based businesses using still to be developed metrics for gauging the UK's performance in the production and commercial exploitation of technology.

CST
February 2000

APPENDIX

LIST OF RECOMMENDATIONS

General - Paragraphs 8 to 12

1. In developing its policies for science and innovation, the Government should concentrate upon:

- *increasing the capabilities of all its companies to create, apply and exploit advanced technology;*

- *broadening and deepening the UK's technology base, particularly in the strategically important sectors of the 'sun-rise' industries, such as computing, microelectronics, telecommunications, advanced materials and bio-technology;*

- *developing more dynamic clusters and strengthen links to the increasingly globalised sources of leading edge S&T worldwide and*

- *strengthening the nation's ability to create new technology based businesses and to grow them rapidly into large companies. This means they will need sufficient financial and other resources from the start. In our experience, the UK does not do as well as the United States.*

2. These further policy developments should be directed at meeting the need for:

- *government, and society more widely, to place technology on par with science in terms of the standing, recognition and value attached to each of them;*

- *a larger cadre of people who are highly skilled both as active technologists and in running a business;*

- *personal finance and tax incentive structures to be fully competitive internationally, especially with those in the US: business and the providers of financial resources need to become fully alive, and responsive, to the technology challenge; and*

- *the Government to play its full part in driving exploitation of the new technologies in all ways it interacts with business - sponsorship in the widest sense.*

People - Paragraphs 20 to 31

3. In partnership with business, universities and the Research Councils, the Government should seek to:

(a) increase appreciably the two way flow between companies and universities of senior people engaged in the business of technology. This should preferably occur at early or mid career points and not only, as is all too frequently the case at present, after retirement; and

(b) improve and enhance the career pathways and options for the wider career development of post doctoral researchers, possibly through suitable tax incentives, thereby reinforcing the existing Research Careers Initiative.

(c) ensure that in the training of postgraduate students and postdoctoral researchers, university departments have the scope and incentive:

- *to maximise interaction with business;*
- *to provide a range of training experience which will best meet the needs of all users including academia itself; and*
- *to offer flexible opportunities for courses of varying length, to meet the needs of a modern economy.*

4. The Government should also continue to work through partnerships with universities, Research Councils and professional institutes to develop and strengthen the trust, norms, practices and networks that are so critical for businesses and universities to work together.

5. In the longer term, the Government will need to:

(a) take an even more holistic, systematic approach to the education and development of future generations of S&T entrepreneurs, managers and S&T professionals;

(b) ensure that the funding arrangements for universities evolve so that universities are able to respond dynamically to the huge challenges and opportunities ahead including the ability to compete in the global market for world class scientists, teachers and researchers; and

(c) continue to develop its fiscal, monetary and immigration policies to promote the UK's competitiveness.

Technology - Paragraphs 32 to 40

6. The Government should:

(a) seek to boost the standing and importance of technology and technologists.

(b) investigate what more it could do, possibly as part of the implementation of the second round of FORESIGHT, to help meet needs of companies in dealing with the technology aspects of their strategies and plans and to improve their capabilities through the promulgation of good practice.

(c) develop and increase its support for small firm R&D, including the further development of its support services to help and encourage small firms to develop from merely using technology (e.g. in the form of new machinery) into technology based businesses i.e. investing in the creation and application of new technology for their business purposes. Such support needs to take account of the distinctive needs of small companies;

(d) develop and increase its support for the creation of advanced technology in joint programmes with companies, permitting the participation of companies overseas, including companies outside the EU when this is warranted.

Private Sector Risk Finance - Paragraphs 41 to 53

7. The Government should continue to work with the financial and business communities to identify what would drive higher levels of investment of private, institutional and venture capital for technology based businesses, especially at the stages of start up, early development and point of initial public offering of shares, taking account of the issues which we highlight.

Government Sponsorship - Paragraphs 54 to 60

8. The Government should modernise the sponsorship role and activities of Departments in the light of the advent of Regional Development Agencies, the Small Business Service and Resource Accounting and Budgeting. It should take a fresh look at

(a) its overall approach to sectoral sponsorship, including the way it identifies, and determines expenditure priorities for business support within and between Departments, taking account of the national and international situation and prospects;

(b) how it identifies the technology based industries and sectors with real potential for growth and targets support at them, in partnership with the private sector, including the role of FORESIGHT;

(c) the arrangements to support the development of clusters;

(d) the arrangements for allocating budgets to meet the priorities including the balance of expenditure between existing and emerging industries;

(e) the way that Government departments and agencies use their own buying power; and

(f) possibly as part of the new Competitiveness index, develop a set of metrics to assess and monitor the UK's performance in the production of a strong platform of enabling technology and its commercialisation.

9. In relation to the group of UK technology based businesses, the Government should seek to improve the existing arrangements within and between Departments for fostering and supporting:

- *corporate venturing;*
- *strategic alliancing;*
- *partnerships and collaboration with large firms and multinationals e.g. in R&D or marketing;*

- *intermediary activities, including financing or national and international networking;*
- *mergers and acquisitions; and*
- *mentoring and god-fathering.*

10. The Government should also:

(a) promote good practice in R&D management and technology based innovation, facilitating, initiating and nurturing spin out activity, and assisting large firms in corporate venturing activities with smaller firms.

(b) directly and indirectly promote corporate venturing and facilitate the development of clusters.

11. More generally, it should:

(a) ensure that support measures are appropriately focused, strike the appropriate balance between existing and emerging sectors, have sufficient scale to achieve a step change in performance; and recognise the role of large technology based companies in the economy, and their critical importance in the establishment and growth of small ones; and

(b) systematically monitor and report on the outcomes of policies aimed at the creation and rapid growth of technology based businesses using still to be developed metrics for gauging the UK's performance in the production and commercial exploitation of technology.

ANNEX A

ANALYSIS AND SUMMARY OF KEY DATA ABOUT THE INNOVATIVE PERFORMANCE OF UK BUSINESSES;

(a) Context

A.1 The UK's under performance in creating wealth from its world class science base has been the subject of concern, inquiry and study ever since the country lost its industrial and technological leadership towards the end of the 19th century. An extensive range of different priorities and approaches have been pursued by successive Governments over the years. Yet the nature of the problem, possible solutions and the role of the Government remain among the most vexed policy issues of the age.

A.2 Among the commonly cited reasons are an anti-technology culture in the UK; a failure or inability within companies to exploit the opportunities of technology; more interest in science or financial performance than technology based innovation; a lack of enterprise, ambition, vision, drive and entrepreneurship; management and managerial weaknesses; risk aversion and too great a focus on the short term.

A.3 Others include a relatively small, undemanding domestic market; frequent boom and bust cycles with widely fluctuating interest and exchange rates; the haemorrhaging of the manufacturing base during the 1980s with two recessions and extensive corporate raiding by so called asset strippers; failings in Government policies, and a widely perceived flight of the nation's most able young people from careers in science, engineering and technology in favour of such professions as medicine, finance, law, accountancy and the media.

(b) The new industrial revolution and technology based innovation by business

A.4 The profound changes that are occurring world wide are increasingly being seen in terms of a third industrial revolution. By this is meant one in which wealth creation and competitive advantage is becoming increasingly underpinned by creativity and knowledge rather than by just the ability to organise capital, labour and resources to make and run things efficiently and cost effectively.

A.5 The innovation process by which new scientific and technical knowledge is exploited by businesses is highly non linear, and varies considerably between sectors. In health care for example links with basic leading edge research are crucial for pharmaceutical companies. In computer, electronics and telecommunications hardware, enabling technologies and applied research are normally more critical for the companies than basic research, although basic technological leadership can be hugely advantageous.

A.6 In these and other engineering and physics based sectors, successful innovation lies in marrying leadership in core technology with the necessary complementary technologies and with rapid product deployment. While in others such as general manufacturing and distribution, companies add value by taking up and integrating the existing technologies of others in complex systems. The development of IT applications, for example, for conventional personal computers or for e-commerce, primarily involve the writing of software and traditional doctorate level research is unnecessary.

A.7 Traditionally, the innovation activities of large, research intensive companies with their corporate R&D facilities and their links with sources of external S&T have been the prime movers in many sectors:

- creating new markets and other opportunities for other firms to follow.
- playing a symbiotic role in the start up and growth of other new, technology based businesses.
- providing the education and training ground for scientists, engineers and technologists at all levels;
- forming technological capability; and
- acting as the principal partners for universities for their teaching, research and such other activities as IPR licensing.

A.8 Over the last 10-15 years however, many of these companies have downsized, outsourced and re-engineered their R&D function in response to the globalisation of markets, manufacturing and S&T; the increasing pace of scientific and technological change, the rise of new technology sectors such as IT, advanced materials, and shorter product life cycles and the internationalisation of leading edge S&T activities.

A.9 These and other, smaller technology based firms are increasingly innovating through new trans-national networks to meet their S&T requirements and to improve their R&D efficiency. Through these networks, they tap into relevant world class centres of S&T in university and other laboratories, forge new alliances and relationships with their suppliers, customers and users, and otherwise sharpen their competitive edge.

A.10 With shortening product development and life cycles and rising competitive pressures, some have shifted their in-house R&D focus to near market development.

A.11 Others have increased their reliance on universities for pioneering and applied activities, reduced or stopped their investment in long term, high risk, or speculative technological research, relying instead on shorter term, lower risk investment, S&T outsourcing, mergers, and the acquisition of smaller, high growth businesses.

A.12. Generally, as with other costs to businesses, there has been a downward pressure on R&D expenditure to secure efficiency savings.

(c) Innovation, Science and Technology Policies

A.13 Studies[23] show a wide variation in the innovative performance of UK firms, both using measures such as R&D expenditure, but also in the numbers of firms reporting that they have marketed new or improved products. Furthermore, studies[24] show that innovation styles tend to vary by firm, being a function of both technological, market and industry characteristics.

A.14 Science and Technology (S&T) policy aims to ensure that an effective technology infrastructure exists to bridge the gap between the science base and business. Innovation policy on the other hand seeks to help businesses exploit knowledge effectively and improve the economic and social well-being of the UK[25]. Together, the policies should combine to:

- ensure that firms can access a wide range of technological knowledge sources, e.g. Universities, Research and Technology Organisations;

- help firms develop the absorptive capacity and complementary assets (in marketing, management and skills) which are essential to exploit scientific and technological knowledge into new, and successful, products, services or processes;

- help markets work more effectively thus removing barriers to the take up of new products or processes.

A.15 One goal of innovation policy is to ensure that the wide range of benefits of the science base are exploited by those firms that can use them effectively. The main benefits include: science and technology per se, e.g. in the form of a patentable invention, access to specialised sources of knowledge, access to networks and access to qualified people[26].

A.16 The contribution of the science base is also indirect in that its outputs feed other sources of technology - for example, postgraduates working in consultancy and other research based organisations.

A.17 Further, innovation policy also serves to increase the pool of firms that can benefit from the science base - for example, by ensuring that they have access to sources of complementary skills or knowledge which they need.

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[23] See for example: 'Technology sources for SMEs' by Lambert R and J Barber in New technology Based Firms in the 1990s V5 edited by R Oakey and Wim During, Paul Chapman Publishing Ltd 1998.
[24] K Pavitt, 'Sectoral Patterns of Technological Change: Towards a Taxonomy and a Theory' Science Policy Research Unit, 1983.
[25] JS Metcalfe 'Innovation as a policy problem: new perspectives and old on the division of labour in the innovation process' Paper presented at Robinson College, Cambridge. November 1998.
[26] 'The Relationship between Publicly Funded Basic Research and Economic Performance', A SPRU Review, Report prepared by the Science Policy Research Unit for HM Treasury (1996).

(d) The UK's Stock of Technologically Innovative Businesses

A.18 Data from the most recent EU Community Innovation Survey[27] suggests

- Around **50**% of UK businesses are innovators in the sense that they recently introduced technologically new products, processes or services. Around **10%** are novel innovators, (pioneers in introducing new to market products etc) and 40% are follower (catch up) innovators.

- 43 % of manufacturers are product innovators (32 % follower, 11 % novel) and 24% are process innovators (16% follower and 8% novel), while in service sectors, some 50 % are new service innovators (43% follower, 7% novel)

- Novel Innovators are much more likely to consistently engage in R&D; invest more of their turnover in R&D and qualified personnel (R&D and Scientists and Engineers) form a greater share of their workforce.

- Follower innovators are much less likely to do R&D. They rely on other means of technology innovation - software development, process engineering, systems integration etc. - or by buying in and adapting existing technologies rather than developing their own.

- The remaining 50% of UK businesses do not engage in any form of technological development, R&D based or otherwise to any significant extent.

- Innovative firms (particularly novel innovators) account for a disproportionate share of economic activity:

	Number	**Distribution by sizeband (%) - employees**			**Share of turnover**
		< 250	>250<1000	> 1000	%
Novel innovators	13700	88	10	3	31
Follower Innovators	63317	96	3	1	36
Non/Low Innovators	78216	98	2	1	33
Total	155233	96	3	1	100

- Around 20% of employment is in low/non-innovative SMEs, while 21% is accounted for by very large novel innovators:

[27] The sampling frame included enterprises (not companies) in most production and service sectors with 10 or more employees (i.e. micro firms were excluded). These enterprises accounted for 57% of all non-agricultural business employment. Some 2400 responses were received, from a relevant population of over 155000. The figures presented are based on the survey results grossed up to the population level. They are threforeare indicative of orders of magnitude. The survey was limited to firms with more than 10 employees in most production and service sectors. These firms accounted for 57% of all non-agricultural business employment in the UK.

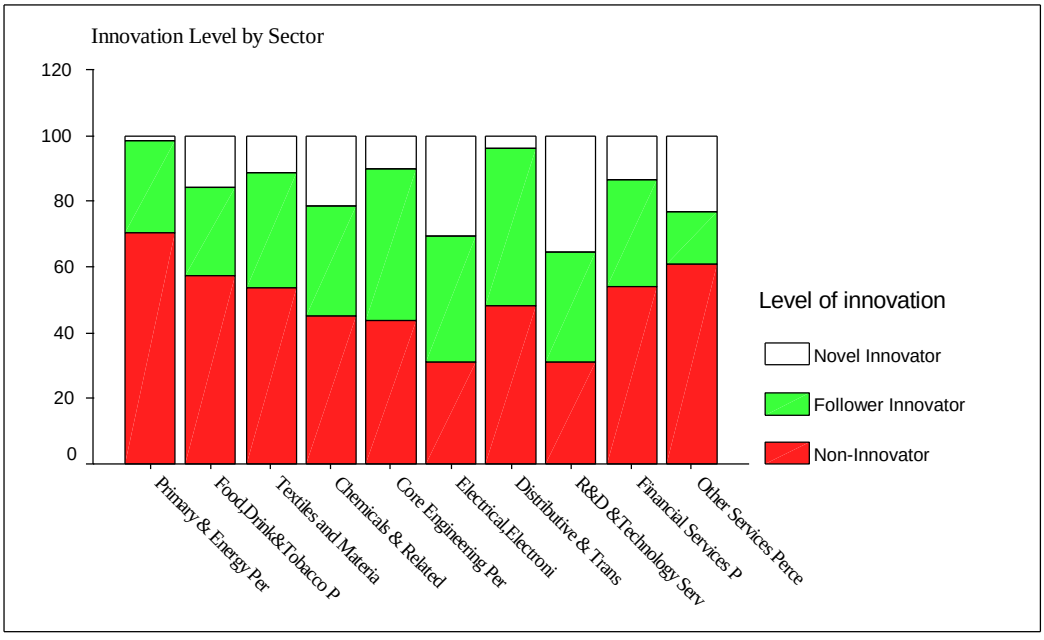
	SME	medium large	large	All
Non / Low Innovator	20%	6%	11%	37%
Follower	14%	8%	9%	31%
Novel Innovator	5%	5%	21%	32%
Employment in 000s[28]	4479	2167	4626	11272
	40%	19%	41%	100%

- Around 6 % of UK business output is in novel products or services, and 16% in catch up products or services, with 78% in unchanged products or services.

- The average degree of innovation and the economic contribution of innovations varies significantly across industrial and commercial sectors. Primary and energy industries and services including distributive trades, show the lowest overall innovation rates.

- Novel Innovators are more driven by market considerations – new markets or market share and adding to the product range. Followers are relatively more focused on cost reducing innovation, including reducing environmental impact. This difference in outlook may well explain the differences in the two groups propensity to engage in R&D and access the science base.

UK Sectors



[28] Grossed up survey figures not adjusted to the business population.

- The following features distinguish the innovative performance of these three categories of businesses:

Distinguishing Features	**Novel Innovators**	**Follower innovators**	**Non Innovators**
Share of turnover in 1996 from new or improved products	40%	29%	3%
Proportion of enterprises engaged continuously or occasionally in R&D between 1994-1996	76%	18%	13%
R&D as % sales	1.3%	0.5%	0.1%
R&D staff as % of total employment	3.7%	1.8%	0.4%
Qualified Scientists and Engineers as a proportion of total employment	6%	5%	2%

(e) The UK's stock of hi-growth businesses

A.19 A relatively small number of fast growing enterprises tend to be the main source of innovations, wealth and jobs - mostly firms which are good at exploiting emerging or niche markets and technologies. Of the 168,000 enterprises registering for VAT in 1994, an estimated 8,400 had achieved annual turnover of £1 million or more by their fourth year of trading. A further 6,900 enterprises had not yet done so, but had grown to employ 10 or more employees. Recent research suggests that this proportion of roughly 9 per cent of firms being fast growth firms is remarkably consistent across size bands.

A.20 As for the relative innovation efforts of our small and large firms[29]:

- the UK's high technology sectors are dominated by large not small firms with the top 6 firms accounting for between 33% and 88% of value added;
- firms with over 99 employees average around 90% of business R&D;
- new and small firms tend to introduce lower value innovations than larger firms. The sales value of over 100 award winning innovations introduced by these UK firms was found to be less that the value of just seven introduced by large established companies[30];
- some of these new, smaller firms are highly innovative and play an important role in innovation and product networks involving both large and small firms

[29] *Small Firms and Employment Creation in Britain and Europe,* CRIC Briefing Paper No 2, March 1999."
[30] B Tether (1998) *Small and Large Firms, Sources of Unequal Innovation,* Research Policy, 27, pp 725-745.

- innovative and technology based firms (both in the UK and in Europe) are no more likely to fail than other small firms. Like the general population of small firms, their death rate tends to be particularly high in the period immediately after start up[31];

- on average their rate of employment creation tends to be modest, at less than ten new jobs a year;

- growth tends to be concentrated in a few firms. One recent study found 10% of the 149 firms sampled generated half of all the new jobs they created over a decade[32].

A.21 Even among the fastest growing, the absolute number of jobs created over a decade tends to be counted in hundreds rather than thousands[33]. More generally, anecdotal and some quantitative data suggests that firms are tending to concentrate on their bottom line performance - efficiency and productivity gains - at the expense of top line growth of sales.

A.22 For example, over a 15 year period from 1984, the FTSE 100 companies doubled their profits before tax and interest from 6.4% to 11.6% in 1997 while their revenue increased by 0.1% after allowing for inflation[34]. A notable common factor of all the top share price performers has been their success at growing income - often but not exclusively through mergers and acquisitions (M&As).

A.23 A recent study[35] suggests that within the UK and Europe, what distinguishes high performing, high growth businesses is that they are initiating/implementing change across most of the following elements of their business, not just a few of these:

Structures - decentralising, delayering and project related forms of activity organisation.

Processes - investment in IT, horizontal and vertical communications and new human resource practices

Boundaries - downscoping, outsourcing and strategic alliances.

[31] P Westhead and D Storey (1994), *An Assessment of Firms located on and off Science Parks in the UK"* HMSO, London. Indeed the evidence suggests that innovative and technology based ventures are more likely to survive than new firms generally.

[32] B Tether and S Massini (1998), *Employment Creation in small technological and design innovators in the UK during the 1980s*, BS, Small Business Economics, 11, 353-370.

[33] Tether and Massini (1998) op cit.

[34] *What's driving your share price today ?* AT Kearney, London, 1999.

[35] *Organising to improve company performance*, Warwick Business School, March 1999.

(f) UK Business Expenditure on R&D

A.24 The 1999 R&D Scoreboard[36] shows that a significant portion of the overall UK R&D investment (£10.9 billion) is in low intensity sectors.

A.25 Of the top 16 UK companies, which also feature in the international top 300 list, three quarters of their turnover is in sectors with international average intensities of less than 2.5%.

A.26 In contrast, only a quarter (by turnover) of the top US and Japanese companies shown are in such sectors. In the chemicals and IT hardware sectors, the aggregated R&D intensity of UK companies is around a quarter of the international level. Only in the aerospace/defence and pharmaceutical sectors is UK R&D intensity higher then the international average.

A.27 Though they are not all in high-technology sectors, the top 16 UK companies (by R&D spend) which appear in the international list appear to be investing at about the expected level for a group with their mix of sectors (that is, their combined R&D intensity is only just below what it would be if they all invested at the international intensity rate for their sector)

A.28 The strongest featuring sector is pharmaceuticals with an R&D intensity of 15% - above the international average (13.5%). Others include aerospace & defence, and healthcare.

A.29 In other prime 'high-tech' area of information and communication technology (ICT) hardware, there are no UK companies in the top 16. By way of comparison, US companies make up two thirds of the international ICT sector list, and account for over a quarter of the 130 US companies in the Scoreboard. Similarly, in the electronic and electricals areas, only GEC (now Marconi) features.

A.30 Below the top 16, the mix effect (including lower intensity sectors) is also important in explaining the gap between the UK and international levels of investment. However, under investment is also more apparent. Dividing the UK group roughly by size into FTSE listing categories shows the FTSE mid 250 group of 83 companies with the lowest R&D intensity (1.3%) of all the listing categories.

A.31 There are some smaller UK companies investing on a par with international counterparts. These are especially in the biotechnology related areas, although they also appear in the IT and electronics areas.

A.32 In the high-tech physics based industries in the UK, automobiles and IT hardware sectors account for only 10% of total R&D whereas they make up nearer 50% of the total R&D shown by the top international companies.

A.33 These results point to a relative dearth of big technology companies in the UK and especially in the physics based sectors, some of which are of vital

[36] *The UK R&D Scoreboard 1999,* DTI, June 1999.

significance to the future economy. The lack of some really big UK companies in high-tech sectors (outside pharmaceuticals) was confirmed by the bubble charts in the Scoreboard, which also showed that UK profitability levels were at least comparable with those shown internationally.

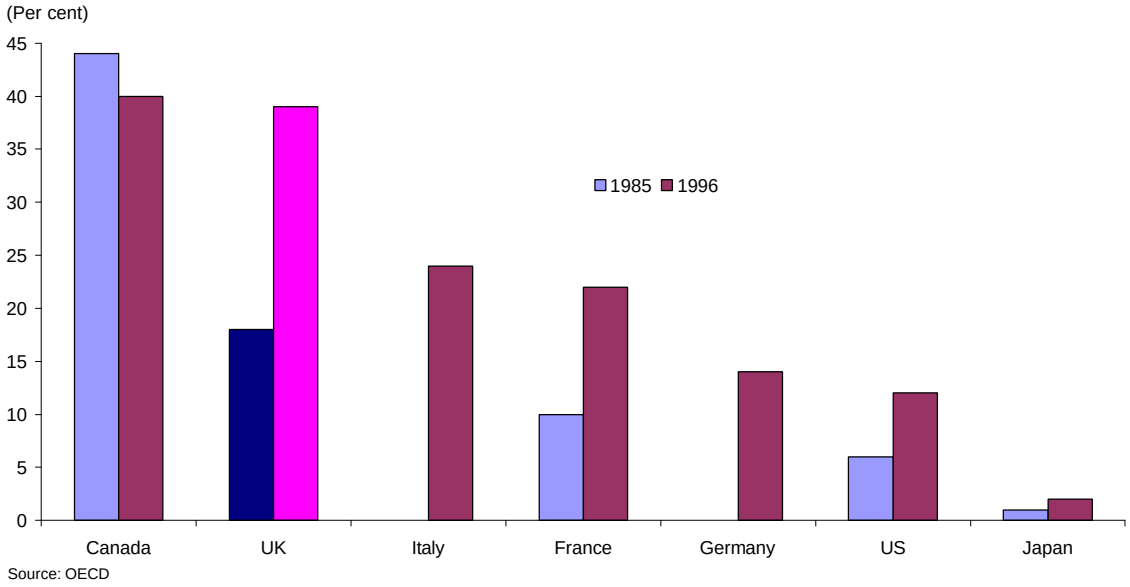
A.34 While profit levels need to be treated with care (especially due to differences in accounting), this does raise the question whether UK companies are perceiving, if not experiencing pressures to constrain investment for growth in order to return high, short term profitability levels. If true, this could have grave consequences for the longer term health of the UK economy.

A.35 For instance among the 550 UK companies in this Scoreboard, some 30 fell into a group which shared the common features of having sales of over £10m, an R&D intensity in excess of 2%, profitability of 10% and sales growth of at least 40% since 1994.

A.36 This group was also characterised by a history of consistent R&D investment, typically well above their sector average. But even so only 10% of them are investing at an R&D intensity above 10% compared to around 40% of the some 250 companies in the equivalent group among the US firms[37].

A.37 Almost 40% of UK Business R&D is undertaken by foreign affiliates:

Share Of Foreign Affiliates in Industrial R&D (1985 and 1996 or nearest years)



Source: OECD

[37] I*ndustry & R&D,* Tubbs M, Physics World, October 1998.

A.38 Other notable features are:

- UK large firms perform a higher share of their technological activities outside the UK than those based in other countries of similar size : nearly 50% of US patenting by UK firms comes from subsidiaries or branches outside the UK. The US is the most popular location for UK companies.

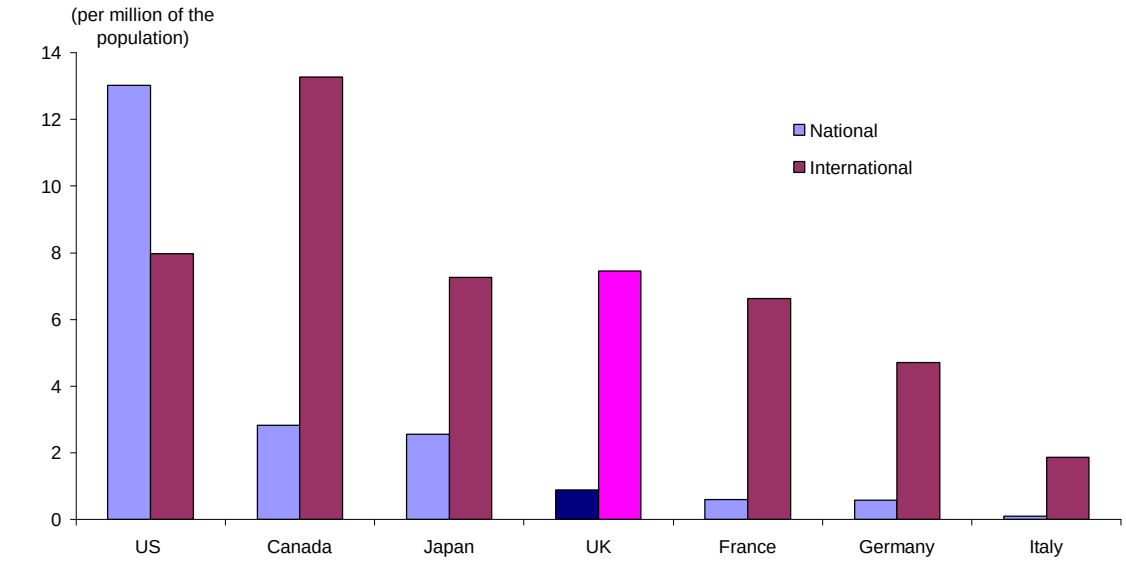
- Studies of the internationalisation of research and technology suggest that the increased globalisation of markets will speed up the process of localisation of innovation to certain world-leading clusters of linked actors.

- Firms' strategies are leading to a concentration of research and innovation activities in those countries where attractive markets, highly developed production structures and excellent research conditions coincide.

- The UK's record in attracting Foreign Direct Investment in R&D suggests that we are well placed to take advantage of these trends. The UK attracts the greatest proportion of US and Japanese R&D facilities in Europe and a recent study on the location of mobile R&D in Europe shows that universities in the UK are at the forefront of attracting cohabitive R&D activities from overseas companies[38].

- UK firms are well connected internationally, broadly on a par with the US and Japan, when relative size is taken into account.

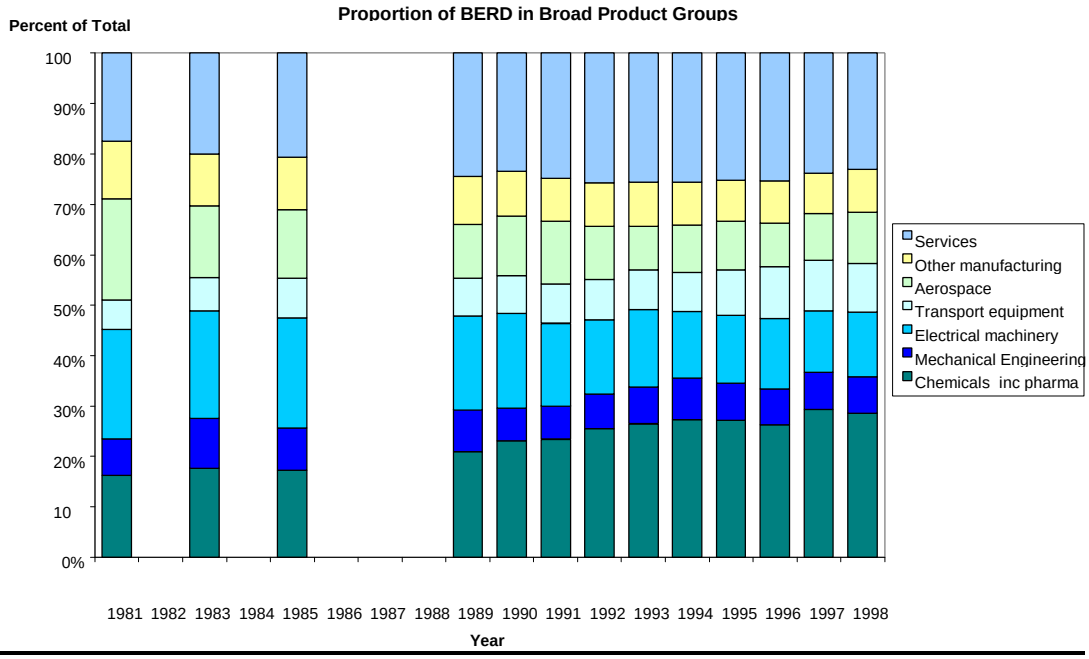
Number of Technological Alliances Between Firms, National and International, 1992-1995



Source: MERIT

6 "Britain's Research and Development Capability" Invest in Britain Bureau 1998, ref. IBB/PUB/R&D/1998 URN 98/620

- There are no reliable time series revealing changes in the numbers of UK companies spending money on research and development. The changes which have occurred across broad product groups are:

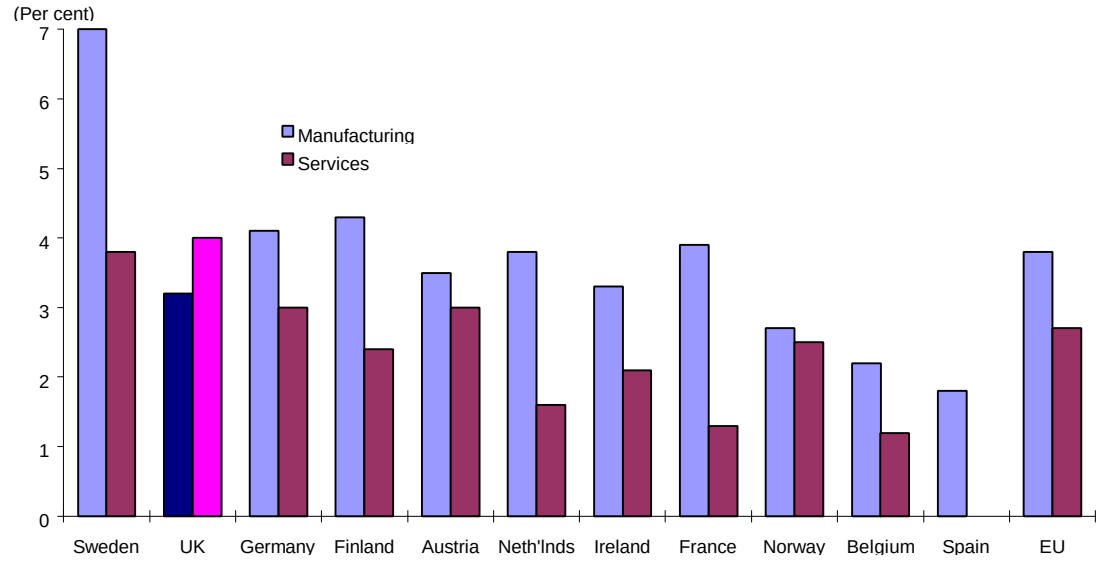


(g) International Comparisons[39]

(i) Manufacturing

A.39 UK Business Expenditure on Innovation is near the bottom in manufacturing.

Business spend on innovation as a proportion of turnover in 1996



Source: Eurostat (Community Innovation Survey)

[39] Unless otherwise indicated the main source for this data is the Community Innovation Survey

- The share of turnover in UK manufacturing devoted to a range of technological development activities, including intra-mural and extra-mural R&D, purchase of external technology, investment in connection with innovation and industrial design, is on average lower in the UK than the rest of Europe, at **3.2%** of turnover against a European average of **3.8%.** This difference is mostly accounted for by large enterprises:

	UK	EC Average
Small	3.3	2.3
Medium-sized	2.9	2.3
Large	3.2	4.4

- The proportion of innovators in small manufacturing firms in the UK is above the EU average, while at the same level as medium and larger enterprises:

Shares of Manufacturing Enterprises who are Innovators, by Size and Country				
Group	Germany	France	UK	EC Average
Small	63	34	54	44
Medium-sized	70	48	59	59
Large	85	75	81	81

- The contribution of innovation to manufacturing turnover is substantially lower in the UK than in most other EU countries.

Shares of innovations in sales in manufacturing, by size and country.					
Country	Germany	France	UK	EC Average	
Total	43	21	23	31	
Small	30	8	14	15	
Medium-sized	31	14	21	22	
Large	47	25	25	35	

(ii) Services

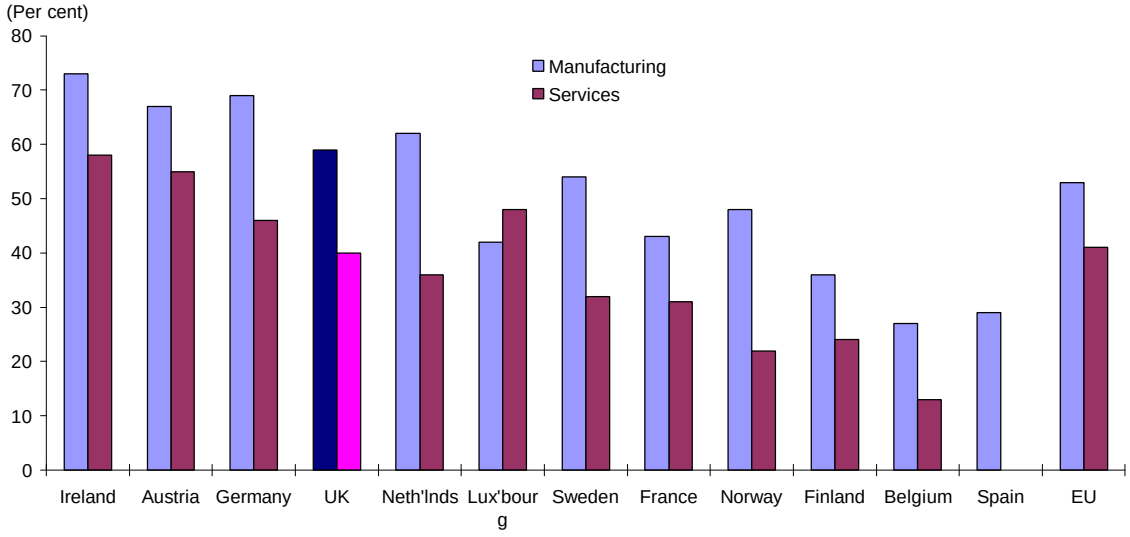
A.40 The UK innovator share is similar to the EC average for services, while the comparison across company sizes shows medium and large UK service enterprises with a lower share of innovators than the EC average.

Shares of Services Enterprises who are Innovators, by Size and Country					
	Country	Germany	France	UK	EC Average
10-49	Small	41	25	40	37
50-249	Medium-sized	60	33	37	49
250 +	Large	83	73	55	73

- In certain “high-technology” services sectors - transport and telecommunications services and R&D and technical service sectors, UK spending on innovation at 3.8% of turnover is higher than the European average of 2.7%.

- UK businesses in services sectors are more innovative than in manufacturing.

Proportion of enterprises that bring new products or processes to market or develop new process technologies

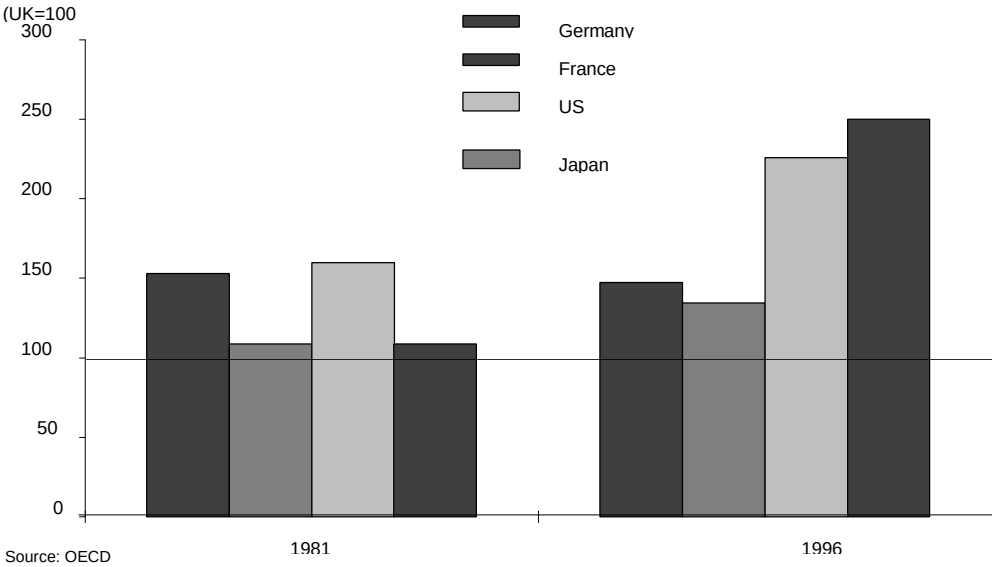


Source: Eurostat (Community Innovation Survey)

(iii) Business Expenditure on R&D

A.41 UK Business Expenditure on R&D per worker is among lowest of G5 countries.

Real G5 Industry Funded BERD per worker relative to the UK



Source: OECD

- Even allowing for the fact that R&D spending tends to vary by sector and the sectoral differences across countries, UK businesses' current overall R&D performance is weak with comparable (or better) performance to their major competitors in only two industries: drugs and metal products.

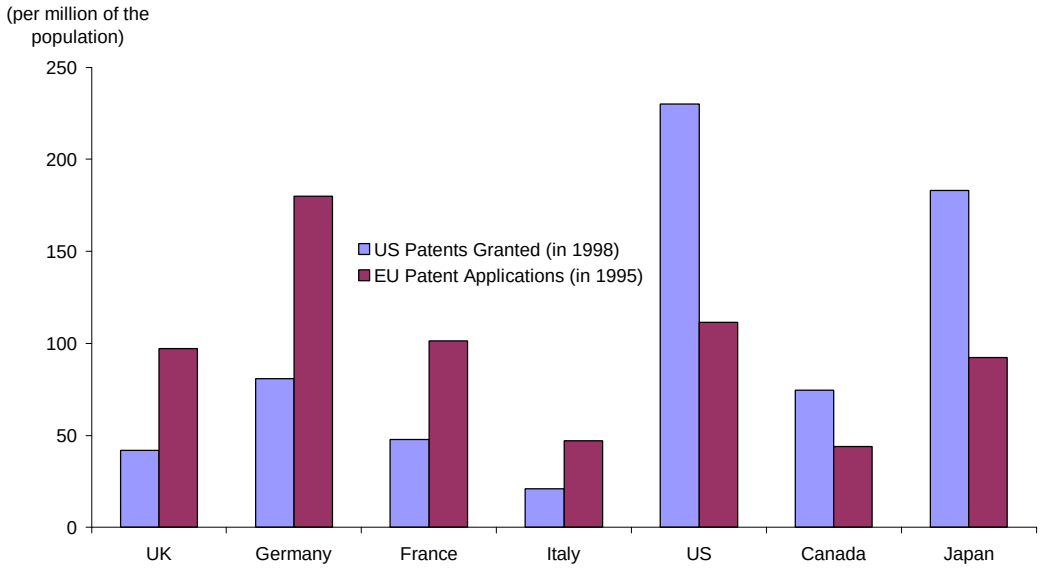
- R&D spending tends to vary by sector, so poor performance could reflect different mix of economic activity across countries.

- However, even taking this into account, UK businesses' R&D performance is weak with comparable (or better) performance to their major competitors in only two industrial sectors, pharmaceuticals and electrical machinery.

(iv) Patenting

A.42 Notwithstanding the caveats which surround the use of patent data, the data suggests that the UK has some way to go to catch up with German and US innovative capacity. The US is pulling ahead, at least in terms of patents granted in its own market, and the UK is not catching up with Germany. This may reflect relatively low levels of R&D spending although there is also some evidence that business perceptions of the strength of intellectual property protection in the UK are below the average for other countries surveyed.[40]

US and EU Patents



Source: US Patent and trademark Office, European Patent Office

- The relatively poor showing of the UK in patenting is consistent with the results of a study carried out for the US Council on Competitiveness[41].

- The US Council's index, based on patents data and determinants of innovation performance, shows the UK languishing at the bottom of the table of countries surveyed, with an expected patent output per head only about one third of the level of top-tier innovators.

[40] "World Competitiveness Yearbook", Institute for Management Development, Geneva, June 1999.
[41] Michael Porter and Scott Stern "The Innovation Index - New Challenges to America's Prosperity", US Council on Competitiveness,

(v) Sources of Information and Innovation

A.43 Data from the Community Innovation Survey also suggests that UK firms draw on extensive range of information sources for innovation, with a strong customer focus. Around:

- 10,000 (c 8% of the total) draw on the science base as a direct source of technological knowledge.
- 3500 do R&D, employ Qualified Scientists and Engineers (QSEs)[42] and use science base sources;
- another 4000 use the science base, undertake R&D, but have no QSEs;
- around 500 use the science base with QSEs but no R&D.

- Whether UK firms use the science base as a direct source of knowledge for technological innovation depends on their own in-house resources. Undertaking R&D appears to be the dominant factor in their capacity to access science base knowledge. Around:

  - 1200 do R&D, employ QSEs and collaborate formally with the science base;
  - a further 1500 collaborate with the science base, undertake R&D, but have no QSEs;
  - firms with QSEs but no R&D rarely collaborate formally with the science base.

- These figures suggest that undertaking R&D is normally a pre-requisite before firms participate in collaborative projects with the science base i.e. they first need to develop the capacity to adapt and develop science and technology.

- A significant number of firms access science base knowledge, or engage in formal collaborations, without employing QSEs. This may reflect the fact that many universities are offering short courses (e.g. in IT)[43] which place less demands on the competencies of beneficiary firms.

- Indirect sources of science base derived knowledge are of quantitatively greater significance than the direct links with the science base. This applies to "Knowledge Pools" – such as computerised technical databases, professional conferences and patent disclosures, and to standards and regulations. Around

  - 9000 enterprises do R&D, employ QSEs and derive information from knowledge pools;

  - a further 11000 derive information from knowledge pools, and undertake R&D, but have no QSEs;

[42] The survey defines a QSE as someone who holds at least a first degree in a science or engineering subject.
[43] See 'Industry-University Co-operation Survey', Department of Trade and Industry, 1996.

- some 3000 have QSEs but no R&D and derive information from knowledge pools.

- Generally firms look more to technology intermediaries for knowledge than to direct contact with the science base. This is because the intermediaries act as technology translators - partly because they "speak the same language" as the companies they seek to help but also because intermediaries offer "technology" as opposed to "science". Around

    - 6300 enterprises do R&D, employ QSEs and source technology from intermediaries;
    - a further 7700 undertake R&D, but have no QSEs, and derive technological information from intermediaries;
    - some 2300 have QSEs but do no R&D and derive technological information from intermediaries.

- Over 7000 enterprises use the science base and intermediaries, nearly 30000 use intermediaries solely and around 2800 use the science base solely.

Sources of S&T: % Ranking of Key Sources	Manufacturing sector		Service sector	
	UK	EU average	UK	EU Average
Sources within the enterprises	43	51	38	52
Other enterprises within the enterprise group	19	26	29	39
Competitors	17	18	20	19
Clients or customers	54	46	65	38
Consultancy enterprises	2	4	10	11
Suppliers of equipment; material; components or software	23	19	27	18
Universities or other higher education institutes	4	5	4	5
Government or private non-profit research institutes	2	3	7	3
Patent disclosures	4	3	0	1
Professional conferences; meetings; journals	5	8	8	15
Computer based information networks	3	4	9	11
Fairs and exhibitions	15	21	17	17

Typology

A.44 Broadly, a "technology" based company is one whose business growth and success is dependent upon the development of one or more technologies or on the development of products, processes or services which require significant technological innovation.

A.45 A number of different yardsticks are possible for identifying such companies. For instance, the so-called "Butchart" criteria, uses R&D intensity and the proportion of full time employees hold a first degree of equivalent in any scientific or engineering discipline (i.e. Qualified Scientists or Engineers (QSEs)) as follows:

(i) R&D/Sales ratio higher by 20% or more than average for all industries; or

(ii) R&D/Sales ratio above this average (but by less than the 20% mark) but with a ratio of administrative, technical and clerical staff above average.

A.46 A more limited set of criteria was adopted in the " Williams" Group Report[44] on the Financing of High Technology Businesses, (1998) to define a " high " technology company", namely one:

(i) which spends 10% or more of its annual sales revenue (expenditure) on research and development (according to the Frascati definition but excluding research in the humanities and social sciences) undertaken by itself in the UK and at a minimum annual cost of £50,000, or

(ii) for which at least 30% of its full time employees are qualified scientists or engineers whose work for the company is principally to develop or introduce new technology based products, processes or services.

A.47 More qualitative descriptors of course can also be used along the lines of " a technology based company is one whose products or services depend to a significant extent on the application of scientific or technological skills or knowledge, whether it be a novel application of advanced technology to provide a totally new product or service, or an application of existing technology in an innovative manner".[45]

A.48 This latter definition allows the following further distinctions to be made. These have been used in some of the tables above:

(i) Novel innovators i.e. companies which introduced a technologically new or improved product between 1994-1996 that was also new to their market;

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[44] Additionally, the EU definition of a small and medium sized enterprise was adopted by this Group to give meaning to the adjective "emerging", namely " an enterprise with not more than 250 employees, no more than 25% owned directly or through an intermediary organisation, by enterprises not satisfying these criteria; and with either a turnover of not more than ECU 40 million or a balance sheet of not more than ECU 27 million.

[45] *The Financing of Technology-based Small Firms,* Bank of England, 1996.

(ii) Follower Innovators i.e. companies which introduced a technologically new or improved product or process between 1994-1996 but excluding the Novel Innovators; and

(iii) Innovatively backward i.e. companies which did not introduce any new products or processes between 1994-1996.

ANNEX B

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ANNEX C

GLOSSARY OF TERMS

Basic Research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. This can be sub-divided into two categories:

Pure-basic Research is carried out for the advancement of knowledge, without working for long-term economic or social benefits, and with no positive efforts being made to apply the results to practical problems or to transfer the results to sectors responsible for its application. This is sometimes called “blue skies” or “basic, curiosity driven” research.

Orientated-basic Research is carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognised or expected current or future problems or possibilities. This is sometimes called “basic technological research”

Applied Research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. It can also be split into two categories:

Strategic-applied Research is directed toward practical aims, but has not yet advanced to the stage where eventual applications can be clearly specified.

Specific-applied Research will have quite specific and detailed products, processes, systems, etc., as its aims.

Experimental- Development Research is systematic work drawing on existing knowledge gained from research and practical experience that is directed to producing new materials, products or devices; to installing new processes, systems or services; or to improving substantially those already produced or installed.

Innovation is the process by which ideas and knowledge are exploited for business purposes, It encompasses not only the creation of a new product, production process or service but also the systems, processes, organisations, structures and all other aspects of a company’s existing or future competitive edge such as distribution, marketing, and branding and indeed the creation of a brand new market. The process draws on a range of intellectual and other inputs including knowledge of markets, customers, competitors, science, engineering and technology.

Science is the body of existing knowledge and understanding about way the world works , sometimes called the “laws of nature”, and is the result of basic scientific research, primarily motivated by the desire to add to the existing stock of knowledge for its own sake..

Engineering is the creative process and the "know how" of converting existing knowledge and experience into something useful.

Technology is the end product of the creative process by which existing knowledge and experience is developed and applied to produce something useful, for instance a product, process, system or methodology. Science and engineering produce technology which can be pushed by scientific research. Conversely scientific research can be pulled by technology.

Enabling Technology is generic or thematic in nature, offering a range of new technological opportunities for further research and development with the aim of commercial application and exploitation but not of nature which provides sufficient benefits to justify commercial investment in its creation. Using the above definitions, orientated basic and strategic applied research are the principal sources of such technology.

Technology based businesses are those that risk significant investment in the creation and application of technology to add value to their products, processes or services. It includes companies which invest in research and development, as well as those which procure technology, for instance in the form of a machine, and adapt substantially through their creativity for a new purpose or application. It also encompasses companies engaged in the development of new software. These sorts of businesses are normally identified by either or both the intensity of their expenditure on research or development and the proportion of qualified scientists and engineers in their work force. Between 5-10% of UK manufacturing companies fall with its scope at present.

Engineers and Technologists are people with the knowledge and skills to turn scientific knowledge into something practical and useful, whether that be a product, a process, a system or a methodology. (This report does not distinguish between engineers and technologists).

Exploitation is the application of science and technology by business to make money.

Clusters are concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries and associated institutions with a particular geographical area, sector of business or field of technology. The scale, intensity and nature of these interconnections determines the synergistic effects of this concentration but successful clusters share a number of common features, namely:

a strong science base
an entrepreneurial culture
a group of growing companies
the ability to attract key staff
premises and infrastructure
the availability of risk finance

excellent business support services
the presence of large companies in the same or related technology or business sector
a skilled workforce
effective networking among the constituents and others
a supportive policy environment

A nation's innovative capacity means the ability of its business base to produce a continuous stream of products, processes and services based on new technology. The main
main components are:

the number and quality of people engaged in technology development in the public and private sectors, as well as the nature and characteristics of their work;

the basic research and technological infrastructure including the science and engineering base; research and technology organisations; public policies and expenditure on science, technology, and education including that concerning technology transfer and diffusion, the "stock" of basic scientific technological knowledge and expertise for commercialising ideas; and the international connections;

businesses and their networks constituting the country's industries, sectors and clusters including the capacity and capabilities of these firms for absorbing and exploiting new science and technology;

the links and interactions between these firms/network and this basic research and technological infrastructure including such technology and knowledge transfer/diffusion mechanisms as industrial research and technology organisations, and as UK examples the new Faraday Partnerships and the Teaching Company Scheme;

the willingness and ability individual firms to invest in technology based growth. Ultimately, this latter element is the most imprint one in terms of the nation's prosperity and quality of life.

All OECD and many other countries are seeking to strengthen this national capacity by developing suitable policies for science, technology, technology diffusion and innovation. What seems to make the competitive difference is the cultural, institutional and organisational setting in which technological innovation occurs.