DTI ECONOMICS PAPER NO. 7

Competing in the Global Economy – The Innovation Challenge

The DTI drives our ambition of 'prosperity for all' by working to create the best environment for business success in the UK. We help people and companies become more productive by promoting enterprise, innovation and creativity.

We champion UK business at home and abroad. We invest heavily in world-class science and technology. We protect the rights of working people and consumers. And we stand up for fair and open markets in the UK, Europe and the world.

Foreword

The recent DTI strategy showed that to be truly effective, policy must be based on a rigorous analysis of all the available evidence. At the start of the Innovation Review, economists and statisticians in DTI's Innovation Group came together to review the available evidence on the UK's innovation performance and the factors that help explain it. This paper sets out the findings of their assessment, and provides the evidence base and analytical framework for the overall Review. This paper is being published, as part of a general publication of the DTI evidence base, in advance of the full Innovation Review and the Lambert Review of Business-University Collaboration.

Many issues, such as innovation, cross the boundaries between different Departments' areas of policy responsibility. To ensure that this Review took into account the whole picture, officials from DTI, HM Treasury and other Government Departments worked together with research bodies – such as the Advanced Institute of Management (AIM). A distinguished panel of academic experts was also established to guide, and comment on the work as it progressed.

The paper identifies key UK strengths such as the strong Science, Engineering and Technology (SET) base. However, the main message is that UK innovation performance is, at best, average compared to its peers. It is likely that UK firms are unable to make best use of the advantages presented by the strong SET base because of low levels of innovation spend. Historic weaknesses in skills, macro-economic and competition policies, public sector procurement practices and the framing of regulations have also hindered performance.

On the basis of this analysis, two main policy conclusions are reached:

- Government financial support for innovation can, if properly designed and targeted at market or systemic failures, deliver wider economic benefits in addition to those that accrue to beneficiary firms; but
- A major change in UK innovation performance will require co-ordinated action across a wide range of policy areas - many of which fall outside the responsibility of DTI. This reinforces the case for greater 'joining up' of Government policies.

The challenge now is to build on this analysis. Making the changes suggested should help to improve the UK's innovation performance, which in turn will boost productivity and hence prosperity for all. I hope this paper will stimulate further debate amongst the academic, policy and business communities both here and also abroad, reflecting the fact that many of the issues facing the UK are also relevant, to varying degrees, to our trade partners in the EU and elsewhere.

Vicky Pryce
Chief Economic Adviser and Director General, Economics. DTI

Executive Summary

Innovation and productivity growth

- Businesses engage in innovation when they perceive profitable opportunities or are faced by problems. Innovation can lead to productivity growth through the development of more valuable products or services or new processes that increase efficiency. As such it is one of the five drivers of productivity used by Government to frame analysis of how policy can increase productivity. Innovations can also lead to improvements in people's lives through changes to the environment in which they live and work.
- Although there are difficulties in accurately measuring productivity, the evidence shows that UK labour productivity levels are below those of major advanced economies. The productivity gap is substantial and exists across almost all sections of UK manufacturing and services. Services account for most of the gap in line with their share of output. UK firms are generally less productive than their foreign counterparts.
- Differences in innovation performance explain a significant part of the productivity gap. Differences in R&D investment alone accounts for a quarter of the gap with the US. But measurement difficulties mean that this is likely to under-estimate the importance of innovation.

UK innovation performance

- There is no single indicator of innovation performance. A range of indicators is required. These provide our best estimate of innovation performance, but it is a partial picture since some aspects are not captured well.
- But across measures, covering R&D, patents and indicators drawn from innovation surveys, UK innovation performance is around average – or below average – of other advanced economies. Performance worsened during the 1990s, although business expenditure on R&D as a percentage of GDP stabilised after 1998. UK based firms, particularly larger firms, spend less on technological innovation compared to their major competitors and consequently receive less in the way of outputs. As a group, UK owned firms appear to be less creative and less able to introduce workplace changes because they lack skills and appear to place less emphasis on developing a learning culture. In some areas the UK lags in the adoption of new business best practices. The data show the potential for improved innovation performance and higher levels of productivity across, and within, all sectors.

Key factors determining UK innovation performance

- Innovation systems are a set of actors (e.g. firms), institutions, markets and networks which jointly and individually contribute to the development and diffusion of new technologies. And which provide the framework within which governments form and implement policies to influence the innovation process.
- The performance of an innovation system can be assessed by its capacity to generate innovation and translate that innovation into economic growth. The system includes incentives provided by the economic and regulatory environment, access to critical inputs and the internal capacity to seize market and technological opportunities. Innovation systems do not usually coincide with national boundaries. They can exist in a variety of geographical settings. But national Governments have an impact on system performance through national policies. The main role for Government is to improve the efficiency of innovation systems and facilitate their formation.
- To provide a structure for policy analysis a small number of critical success factors, determining the strength of innovation systems, have been identified. All are, to varying degrees, amenable to favourable Government influence. They are:
  - **The capacity to absorb and exploit knowledge** defines a firm's ability to turn knowledge into profitable goods and services. Firm capacity depends on investments in human and physical capital and the flexibility of its strategy, culture and organisation in the face of change. Central Government funds and delivers skills and education provision.
  - **The regulatory framework affects** the possibilities and incentive structures for innovation. Central Government and the Devolved Administrations set this framework in partnership with local and international bodies.
  - **The competition regime**, which the Government helps determine, can remove impediments to market entry. The degree, intensity and nature of competition decides which innovations will be successful in the market place. Levels of **entrepreneurship** help determine the intensity with which firms compete and the ability of firms to spot opportunities and manage risks.
  - **Access to finance** because all investments in new products, services or processes have to be financed in advance of production. The Government influences this by setting the macro-economic framework and through a range of fiscal measures.
  - **Sources of new technological knowledge**, such as the Science and Engineering Base, which is largely financed by central Government, and design, play an important role in shaping innovation systems.
  - **Networks and Collaboration.** Firms rely on a variety of knowledge sources as inputs to the innovation process. Networks help them access these and Government may have a facilitating role.
  - **Customers and suppliers.** Demanding customers and suppliers put pressure on firms to deliver better quality goods and services. Government is a major consumer of goods and services.
- It could be argued, with some truth, that a whole host of other factors (such as transport) affect productivity or innovation performance and which are also influenced by Government policies. But in any assessment of this sort the difficulty lies in trying to keep its scope within manageable bounds. This has obviously constrained the choice of success factors, which have been selected on the basis that they seem to be the most important.

- The analysis suggests the following strengths and weaknesses in the UK Innovation system:
  - **Capacity to absorb and exploit knowledge.** Poor skills have hindered innovation performance. The UK is particularly weak in basic and intermediate skills. This delays innovations and investment programmes or hampers the transfer to full product development. UK managers are, on the whole, less well qualified than their peers. On average, the culture within UK firms places less emphasis on creativity and this is influenced by management. The causes of this are not entirely clear. But improvements are not easy to bring about given that there is no such thing as 'one size fits all' best practices.
  - **Regulatory framework.** OECD comparisons show the UK to be relatively lightly regulated, although more could be done to make regulations more outcome focused to encourage innovative compliance. Smaller firms particularly appear to lack understanding about the system of intellectual property rights. The costs of enforcement and uncertainty over their value also deter many from acquiring such rights.
  - **The competition regime and entrepreneurship.** Weak competition policies in the past have put UK firms under less pressure to use new technologies and find ways to improve their performance. This may help to explain why entrepreneurship rates in the UK are at best moderate despite some important advantages in the business and regulatory environment. The effect of recent reforms to competition policy is likely to take time to feed through.
  - **Access to Finance.** UK capital markets are well developed. Lower levels of innovation expenditure are probably more due to a lack of incentives and capacity to innovate rather than a lack of funding. Although some gaps exist in the provision of early stage finance. A past history of macro-economic instability reduced incentives to invest and innovate. Recent reforms to fiscal and monetary policy could in time have a significant impact on innovation performance. Weaknesses in skills have probably affected the demand for, and success in obtaining, finance for innovation. UK firms appear to prefer corporate strategies that focus on mergers and acquisitions rather than organic growth. The new tax incentives for R&D are comparable or better in terms of generosity compared to those in other OECD countries. It is too soon to assess their impact.
  - **Sources of new technological knowledge.** Science and Technology and Design are important inputs. The UK Science, Engineering and Technology Base is highly productive. This knowledge, when exploited, can lead to the development of new products or processes or generate wider improvements in society (e.g. better health). Relatively low levels of innovation spend mean that UK businesses generate less new technology and are less well placed to exploit research carried out in the Science, Engineering and Technology base.
  - **Networks and Collaboration.** UK firms appear to have many network relationships although there is variation between sectors. In areas linked to innovation, such as supplier and customer engagement, the UK performs strongly. But network relationships can be intermittent and driven by short-term decision making. The network infrastructure in the UK is patchy.
  - **Customers and suppliers.** Customer demand and technological opportunities provide the incentive to innovate. These vary widely between sectors. UK output does not appear to be concentrated in sectors where there are fewer technological opportunities. Many UK based firms compete in global markets and the UK is an attractive market for innovative firms from abroad. Public sector procurement could be more effective in stimulating innovation while achieving spending objectives and value for money.

Challenges facing the UK

- The opening up of world markets to trade, industrialisation in lower cost countries and rapid advances in technological change continue to pose key challenges for the UK innovation system. These trends look set to continue.
- UK firms need to adapt to this environment. Some markets for UK goods and services will expand, others will contract. Generally changes in demand are leading to a shift towards higher value added production. Market forces provide the incentives for change but significant problems of structural adjustment may occur. Weaknesses in innovation systems can increase the costs and duration of adjustment.
- There is however no evidence of a relationship between the employment rate and innovation at the aggregate level. Over the longer term unemployment has been unaffected as consumers have spent higher incomes on labour intensive services, such as healthcare and personal services.
- Services, which account for around 70% of output, are becoming increasingly innovation intensive particularly through the use of ICT. At the same time, the boundary between manufacturing and services is becoming increasingly blurred. UK innovation policy has been traditionally focussed on the manufacturing sector. Some specific service sector issues need greater attention such as: IPR protection, lack of Government support for trade, innovation and internationalisation and difficulties in financing innovation.
- Service sector innovation should not be seen as ineligible for Government support. Support for technologies should be informed by the potential for new applications in the service sector. But part of the innovation agenda should be to ensure that manufacturers are able to exploit opportunities in service markets.
- The UK Science, Engineering and Technology Base continues to attract foreign investors from abroad. Inward investment by foreign-owned knowledge intensive firms may offer the scope for the transfer of knowledge and expertise to UK based firms. UK based firms are looking abroad for sources of comparative advantage, such as cheaper input costs, research collaborations or other sources of knowledge. There will continue to be powerful incentives to re-locate whole operations or part of the production process overseas.
- Firms will continue to seek greater value from research budgets but they will be forced to conduct research into a wider portfolio of technologies as the complexity of products increases. This will act as a spur to greater collaboration, with other firms, universities or contract R&D services. The scientific content of innovation will remain substantial. Leading edge firms will continue to target universities with the highest rankings for research.
- Reducing damage to the environment, caused by CO2 emissions, requires significant changes in the way we live. But the UK, in common with other industrialised economies, exhibits some lock-in to a carbon intensive system. A wide range of policy instruments is needed, including taxes and quotas, procurement policies and regulatory incentives, to support the development and diffusion of more environmentally sustainable technologies. This is an area where innovation, regulatory and environmental policies can jointly contribute to improving quality of life.

What can government do to improve innovation performance?

- Government influences innovation through policies which shape innovation systems (e.g. regulation, competition policy, education) or via the provision of subsidies to encourage innovation or knowledge transfer.
- The strength of the economic rationale determines the effectiveness of Government subsidies for innovation. This will vary on a case by case, project by project, basis and requires independent and informed expertise, based on learning from previous interventions, to ensure that resources are well targeted. Changes to the delivery of DTI business support should increase the impact, and clarity, of DTI interventions aimed at increasing innovation.
- But DTI programme spend is not sufficient by itself to address weaknesses in the UK's innovation performance. It is likely that a mix of policies is required to address these, reflecting the wide influence Government has over innovation systems. Many policies will rest outside DTI's responsibilities. Other parts of Government can therefore help address some of the weaknesses.
- Based on the analysis carried out for the review, the main priorities for cross Government action to achieve a sustainable increase in innovation performance are:
  - Improve the supply of, and demand for, skills;
  - More outcome based regulations, which encourage innovative compliance;
  - Consolidate improvements in the areas of competition policy, macro-economic stability and employment relations;
  - Improving policy co-ordination between different levels of Government (national, regional and EU);
  - Better public sector procurement.

Contents

Introduction

This paper sets out the evidence reviewed and analysis conducted during the Innovation Review. Early on in the Review officials identified four key questions which this paper seeks to address:

- What are the links between productivity growth and innovation?
- What is the UK's innovation performance and how do we compare to our competitors?
- What factors, that Government can favourably influence, most impact on innovation?
- What can the Government do to increase levels of innovation in the UK?

During the course of the Review officials were helped in their task by an academic panel, chaired by Professor Stan Metcalfe of Manchester University (Annex A). They provided helpful comments on successive drafts during the course of the Review. We are greatly indebted to them. The contents of this report, however, do not necessarily represent the views of the panel collectively, or of individual members.

Part I: Innovation and productivity growth

Innovation involves the development of new ideas and their economic application as new products or processes. Businesses and other organisations engage in innovation when faced by problems or when they perceive profitable opportunities. Innovation provides opportunities for productivity growth through the development of more valuable products or services or the development of new processes that increase efficiency. It also drives improvements in peoples' lives through changes to the environment in which they live and work.

Measuring quality: hedonic prices

Real output is calculated by deflating output measured in today's prices by a price index which captures how prices have changed over the period. Inaccurate deflators will therefore affect estimates of real output and therefore productivity.

Price indices are constructed by comparing prices of sampled products between two periods in time. To achieve reliable estimates two conditions need to be met. Firstly the sample of products is representative of the whole product group. Secondly the sample of products is comparable between periods. Rapid technical change, for example in computers, means that changes in models leads to non-identical products.

Hedonic pricing methods try to account for changes in quality and a number of countries use these methods to measure the output of ICT products (e.g. US). By observing a sufficiently large number of computer models, it is possible to establish a systematic relationship between price and characteristics. Using this, one can infer a hypothetical price for an old computer model, even if it is no longer on the market, and obtain an approximation to the true price change.

Source: OECD Computer price indices and international growth and productivity, Statistics Directorate, April (2001).

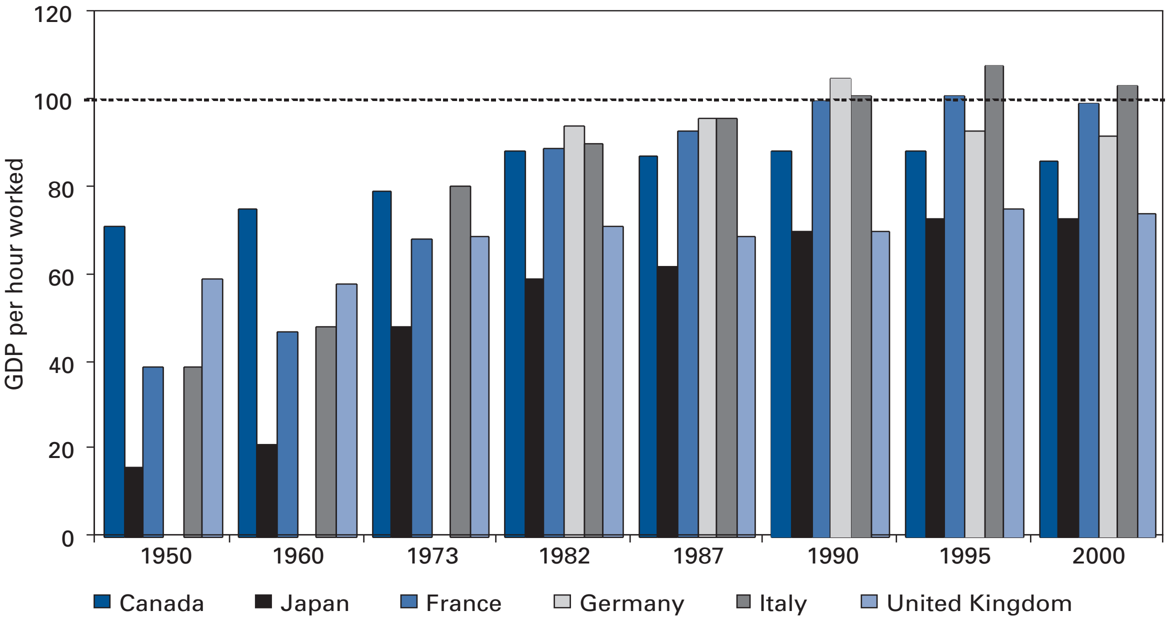
But measuring productivity growth (and the potential for innovation to influence it) is something of a dark art. Productivity data is the best available source to measure changes in living standards but it is subject to health warnings. Measures of productivity – such as GDP per worker – are ratios where both the numerator and denominator are subject to measurement error. The measurement of output is problematic, particularly in services, and quality change is difficult to measure (see box). There are similar difficulties with measuring the volume of labour used. Whilst it is relatively straightforward to measure the number of bodies employed, it is much more difficult to identify the quality of labour services.

Despite these caveats, concerns about the UK's relative productivity performance go back a long way[1]. From being the richest country in the world in the mid nineteenth century, relatively slower UK growth rates meant that she was overtaken by the US and Germany by 1914. Post WWII the UK productivity lead over France and Germany was eroded and lost over a couple of decades (Fig 1.). Although there was a relative improvement during the 1980s and 1990s (Fig 2.), the concern that the UK has a 'productivity problem' still persists[2].

1 Barnett C, The Lost Victory, Pan Publishing (1995). Discusses past attempts to understand Britain's relatively poor productivity performance.

2 Porter ME and Ketels CHM, UK Competitiveness: Moving to the Next Stage, DTI Economics Paper No.3 (2003).

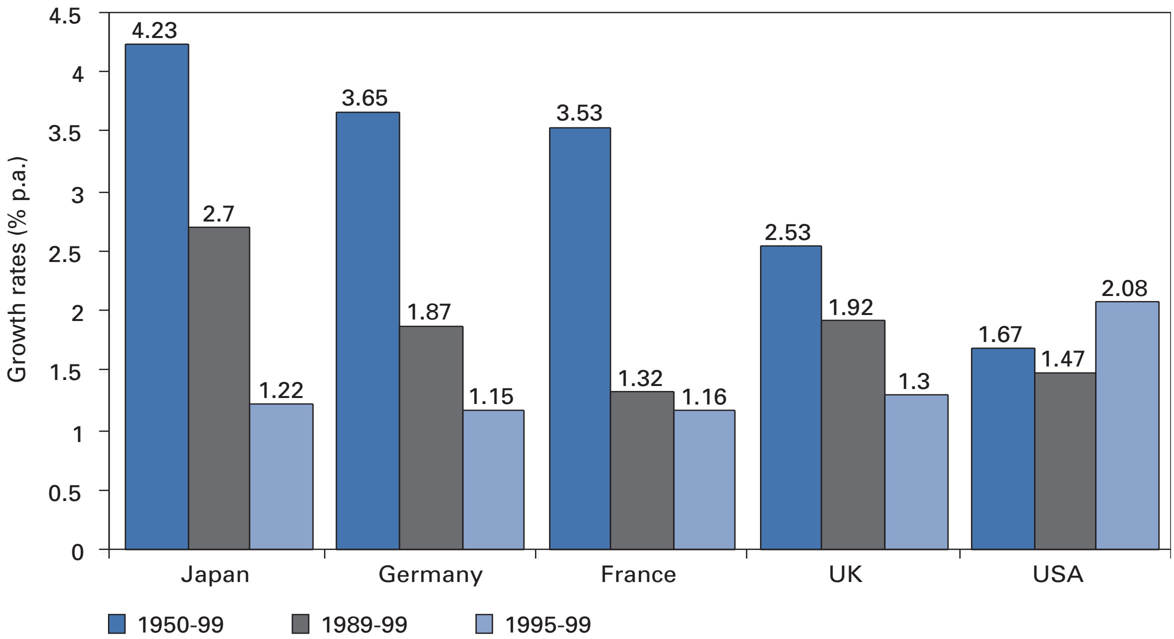
Fig 1. Income and productivity level indices in the OECD, 1950-2000, United States = 100



Source: OECD.

Furthermore the recent strong relative improvement in US productivity growth[3] has led to a re-evaluation of policies to improve productivity in the UK and Europe.

Fig 2. The UK's Relative Labour Productivity Position - GDP per hour worked growth rates

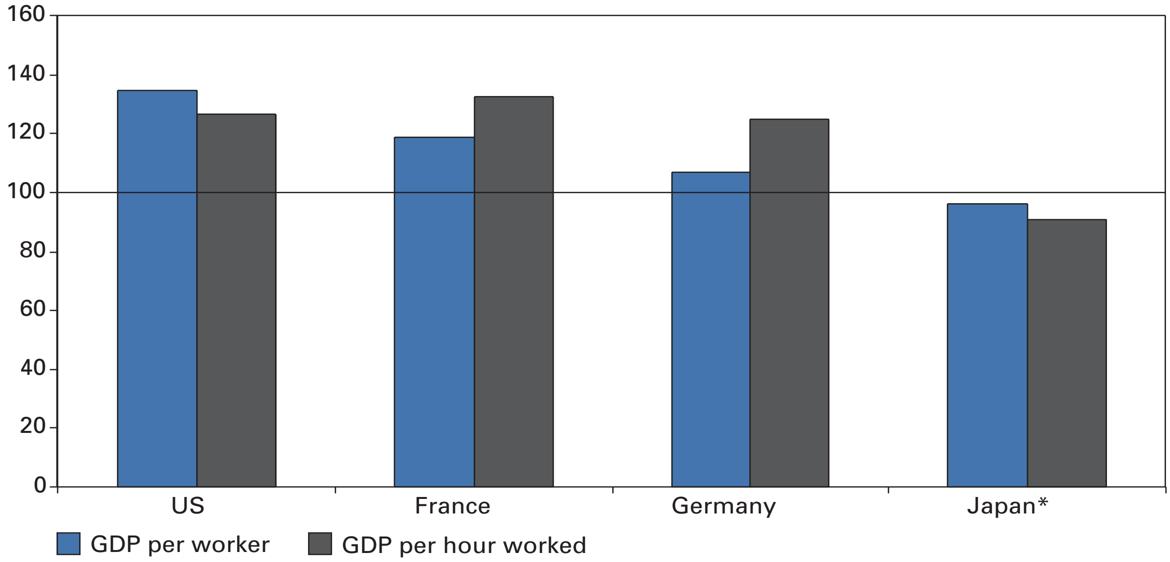


Source: N Crafts and M O'Mahony 2001.

3 This jump appears to have been due to a boom in investment, particularly in information technology, as well as a reversion of total factor productivity to higher historic levels. The latter reflects factors such as technological change, efficiency gains or economies of scale. Lalonde R and Lecavalier D, The US Miracle, mimeo (2001). Other sources suggest that the introduction of hedonic prices for ICT equipment in US productivity calculations had only a modest effect on GDP and productivity figures. OECD, Computer Price Indices and International Growth and Productivity, Statistics Directorate, April (2001).

Relatively weaker performance has led to a large productivity gap between the UK and its major competitors (Fig 3.). US GDP per worker exceeds UK levels by over 30%. In France and Germany the figure is just under 20%, whereas compared to Japan the UK leads by a small margin. As French and German workers work fewer hours than their UK (and US) counterparts so French and German levels of GDP per hour worked are much higher.

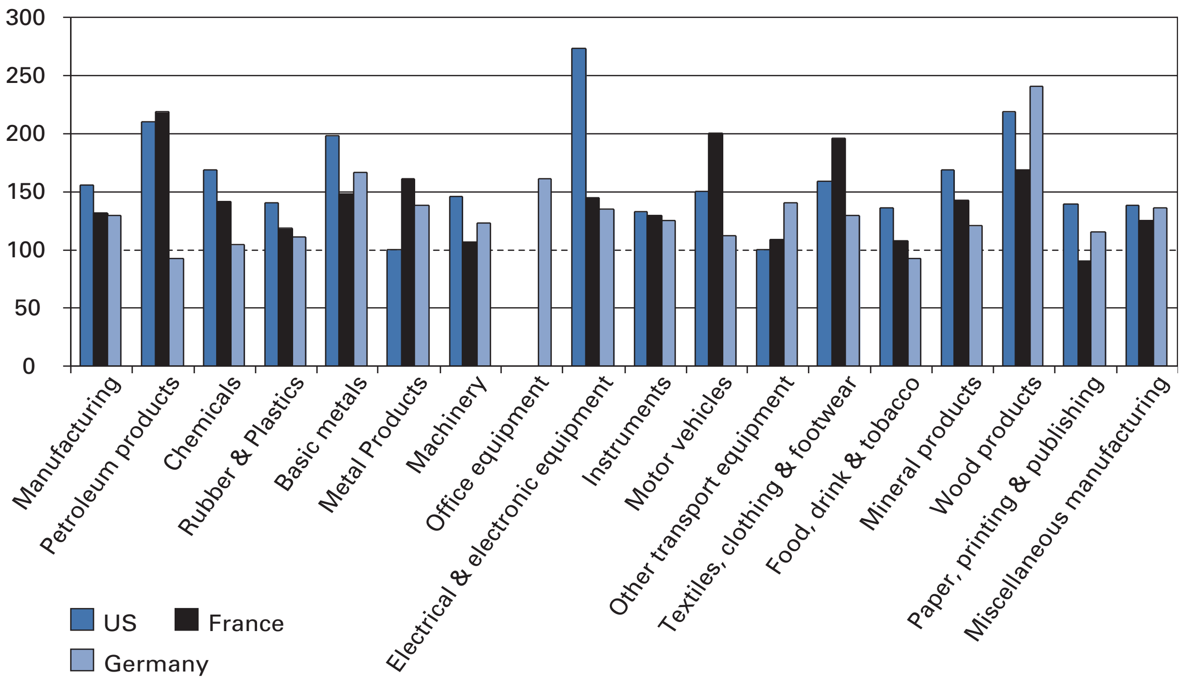
Fig 3. UK Productivity Gap – level per worker and levels per hour worked 2001, UK=100



Source: ONS.

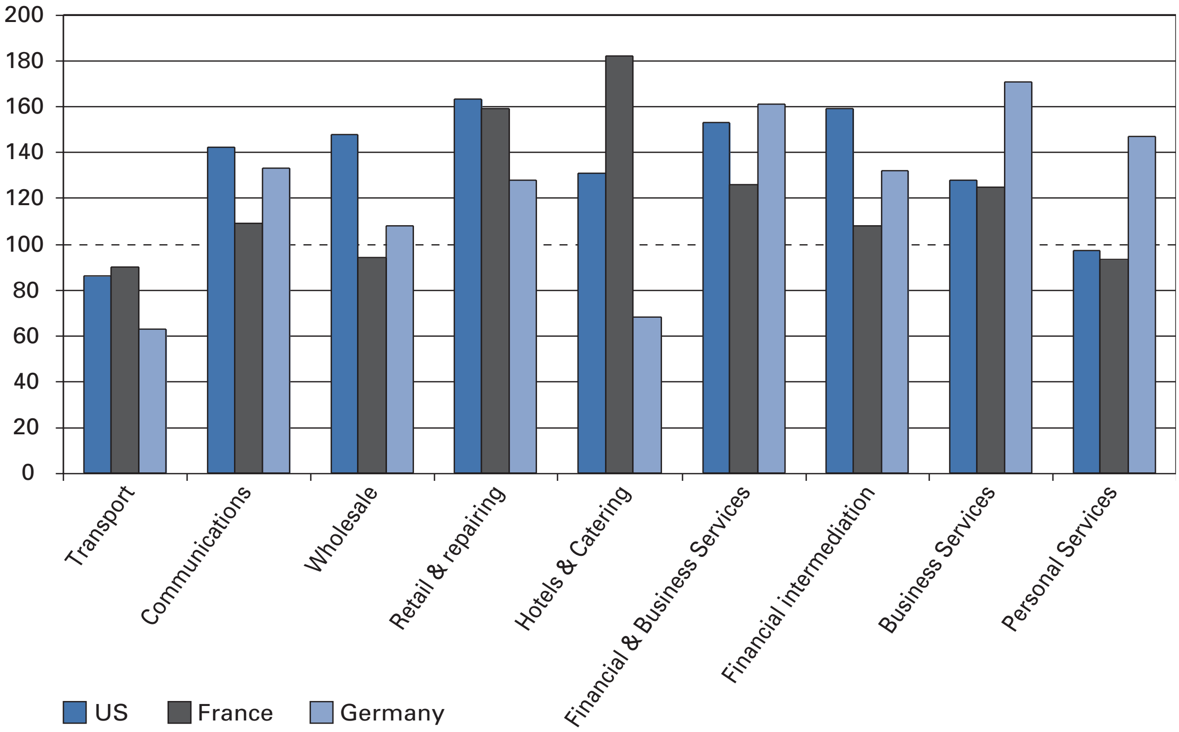
Almost all sections of UK manufacturing and services display a productivity gap (Figs 4&5), even in sectors where the UK is considered to possess internationally successful industries – for example Financial services and parts of Chemicals, such as Pharmaceuticals.

Fig 4. Relative labour productivity: Industry results 1999 (UK = 100)



Source: M O'Mahony and W de Boer 2002.

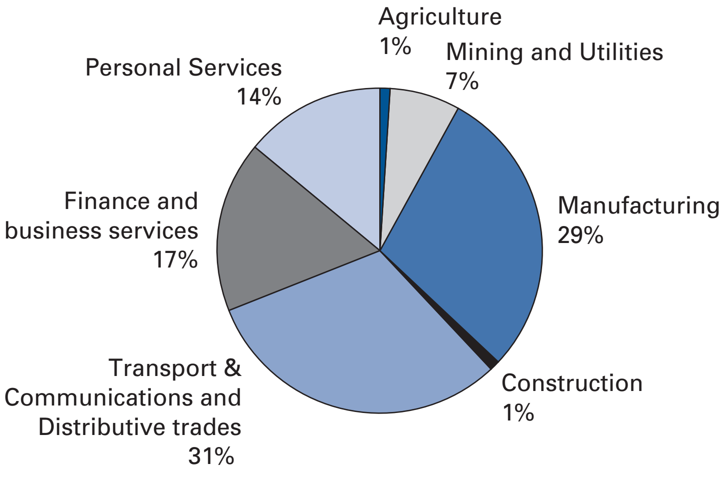
Fig 5. Relative Labour Productivity: Market Services 1999 (UK = 100)



Source: M O'Mahony and W de Boer, 2002.

The data also shows that services account for most of the UK's productivity gap roughly in line with their share of economic output (Fig 6).

Fig 6. Sector contribution to UK Productivity Gap with US, Private Sector only, 1999



Source: M O'Mahony and W de Boer, 2002.

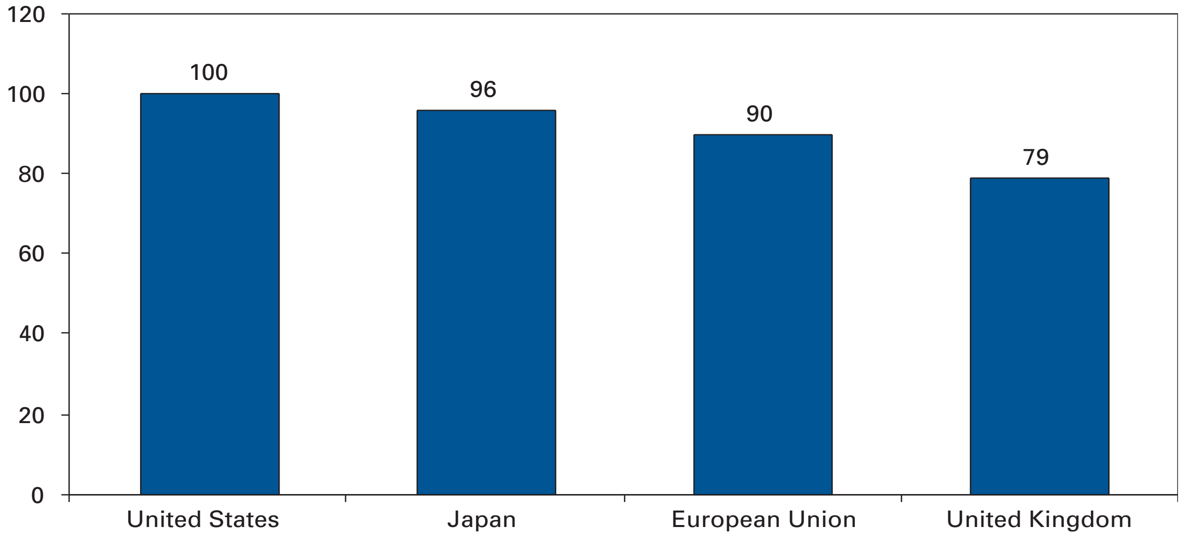
Recent research sheds light on potential explanations for the productivity gap. There is a significant variation in labour productivity between best and worst manufacturing establishments in the UK – the best are around 5 times more productive than the worst[4]. But foreign owned establishments have a wider labour productivity spread than

4 Haskel J and Martin R, The UK Manufacturing Productivity Spread, CERIBA discussion paper (2002). The study also showed that productivity would rise by only 8-10% by raising the lowest performers to the median productivity level in their industry, barely closing the labour productivity gap.

UK owned establishments. And similar productivity distributions have been found in other OECD countries. This suggests that the UK does not have an especially 'long tail of under-performing firms' that lowers the UK average relative to other countries[5].

Some of the difference between the UK and European countries is probably due to differences in labour market structures and costs. Comparatively the UK labour market is lightly regulated. Excessively strict or complicated labour market regulations can discourage employment and raise unemployment. Attempts to artificially reduce the supply of labour – for example the use of early retirement programmes or forced reductions in hours worked – might lead to increases in average productivity in the short-term. But these differences are not an adequate explanation for the productivity gap that exists with the US, which is considered to have one of the most flexible labour markets in the OECD area and integrates a slightly larger share of its workforce into employment than the UK.

Fig 7. Indices of hourly compensation costs for production workers in manufacturing, 2001



Source: US Department of Labor.

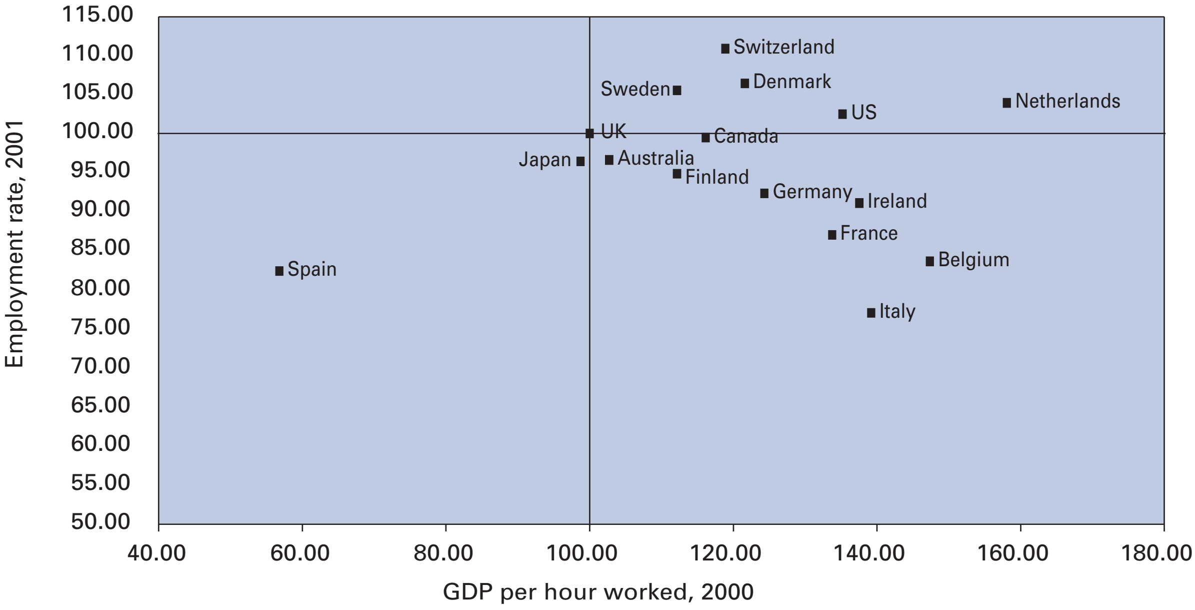
Higher labour costs in Europe[6] (Fig 7) may create incentives to substitute capital goods for labour, raising output per person employed although these differences in labour costs also reflect differences in levels of human capital[7]. But a number of European countries have also been able to combine high labour productivity with high employment rates (Fig 8).

5 The USA for example has a wider productivity spread than the UK. The ratio of labour productivity of the fourth quartile to the first quartile in the US is 4.86, compared to 3.97 in Great Britain. OECD Firm Level Productivity Project.

6 International Comparisons of Hourly Compensation Costs for Production Workers in Manufacturing 1975-2001, US Department of Labor, Bureau of Labor Statistics (2002).

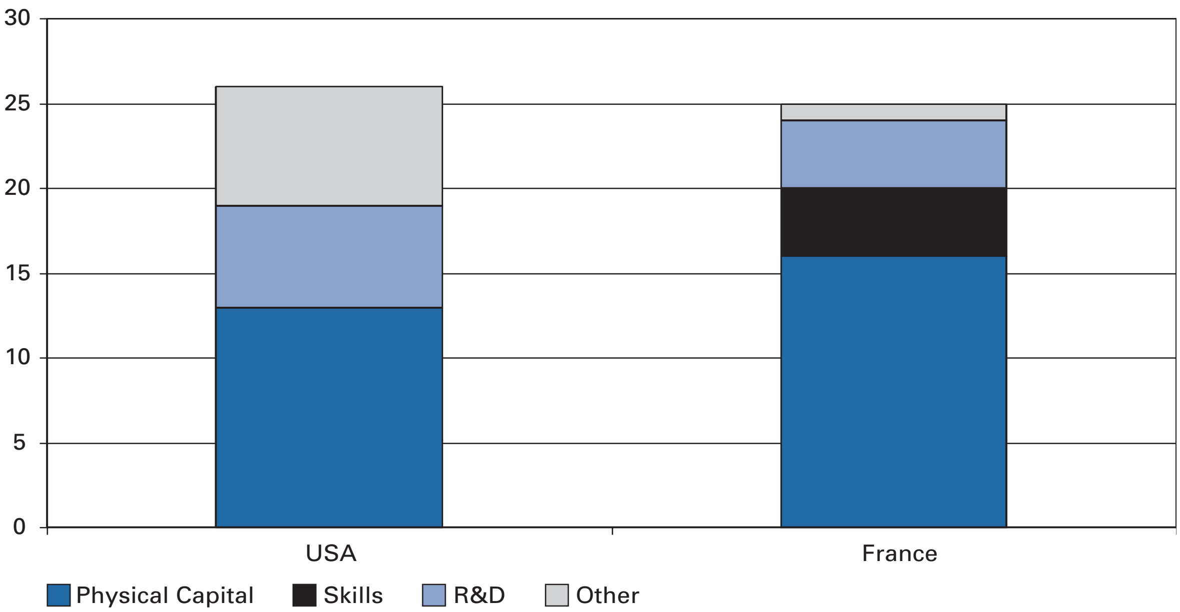
7 They also provide one explanation why UK businesses competing in internationally tradable markets have often in the past been able to achieve satisfactory financial returns.

Fig 8. Employment rates plotted against labour productivity UK = 100



Source: OECD.

Fig 9. Sources of UK productivity gap, 1999



Source: N Crafts and M O'Mahony, 2001.

Growth accounting studies[8] have been able to break down the productivity gap into component parts (Fig 9) although there are formidable measurement problems in so doing. Differences in the amount of physical capital and skills per worker explain nearly all the productivity gap with France and Germany. Differences in innovation performance – as measured by investment in R&D – account for around a quarter of the gap with the US and a sixth of the gap with France[9]. These figures probably under-estimate the impact of differences in innovation performance, some of which will also be captured in the residual, unexplained part of the productivity gap[10]. The empirical literature has consistently shown a positive relationship between innovation indicators and measures of economic performance, such as productivity (Annex B). Even these estimates are likely to be biased downwards given that national accounts under-estimate the effects of innovation on economic output (Annex C).

The analysis therefore suggests that innovation is one of the most important influences on productivity growth alongside changes in skills and capital intensity. In recognition of this, innovation is one of the five drivers of productivity used by Government to frame analysis of how policy can increase productivity[11].

8 Crafts N and O Mahoney M, A perspective on UK Productivity Performance Fiscal Studies vol 22 no 3 pp271-306 (2001).

9 A sizeable residual gap remains with the US. In the literature, this gap is usually attributed to things such as higher quality capital or management. But it is also likely to reflect greater economies of scale in the US and other sources of innovation as well as institutional factors (e.g. differences in regulation).

10 Even the innovation element, proxied by R&D, captured in the residual is likely to be an under-estimate.This stems from the fact that capital deepening is not an independent contributor to growth, rather it is contingent on the rate of technical progress. See Metcalfe JS, Knowledge of Growth and the Growth of Knowledge in Change, Transformation and Development, ed JS Metcalfe and U Cantner, Physica Verlag (2002)

11 HM Treasury, Productivity in the UK: The Evidence and the Government's Approach, HM Treasury, November (2000).

Part II: UK innovation performance

The previous section established that innovation is a major determinant of productivity performance and that differences in innovation performance are a significant cause of the UK's relatively weaker productivity performance. This section reviews the available statistical evidence on the UK's comparative innovation performance.

No single innovation indicator gives a comprehensive picture of performance so it is important to look across a range of indicators. The main shortcomings in the data are:

- Inputs to the innovation process, such as patents and R&D, are easiest to measure. But they do not tell the whole story. Some sources of knowledge (like firm learning) are not captured well and the coverage of non-technological innovation (e.g. changes to business practices) must be measured in a more qualitative way.
- The relevance of different indicators will vary from sector to sector. In science-based sectors, scientific research, carried out by universities, and R&D, carried out within the firm, are important sources of innovation and are covered by the data. Other sectors[12] draw on different knowledge. For example, services will draw heavily on suppliers of equipment and customers, and learning within the firm[13]. Aspects of innovation performance in these sectors are likely to be captured less well and need to be treated in a different way.
- There are wide differences between firms in their ability to turn inputs into innovations. Data on the returns to innovation shows that the quality of innovation also varies greatly[14].
- The coverage of surveys, e.g. of different sectors or size of firm, is sometimes incomplete.

More innovation is not necessarily better. Innovation involves the investment of resources for an uncertain return in the future and, like all investments, is likely to be subject to diminishing returns. In this sense there must be some point where firms gain little or no benefit from additional investment. But the data shows that, in terms of innovation investment or activity, UK firms are around the average – or below average – of firms in other advanced countries. And UK performance worsened during the 1990s. Given this, and other data in section III, we judge that there is scope for the UK to improve.

The available indicators, which provide our best estimate of performance, fall roughly into the following groups:

- Direct measures of innovation such as indicators derived from the Community Innovation Survey,
- Indicators of inputs to the innovation process, such as R&D and patents,
- Indicators of innovations in business organisation.

12 Pavitt K, 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory' Research Policy 13 (6) pp 343-373 (1984).

13 PREST/CRIC, Services and Innovation: Dynamics of Service Innovation in the European Union, University of Manchester/UMIST (2001). This paper argues that standard measures of innovation – which are based on definitions of technological innovation – are less than ideal for studying services since many firms do not see themselves as engaged in technological activities.

14 Scherer, FM and D Harhoff, Technology Policy for a World of Skew-distributed Outcomes, Research Policy 29, 559-566 (2000). Using data on innovations and inventions the authors show that 10% of innovations account for between 48-93% of the total sample returns.

Community Innovation Survey

The Community Innovation Survey provides comparisons of innovation performance for a range of EU Member states, although internationally comparable data are only currently available for the mid 1990s.

The survey asks firms whether they have introduced an innovation during a three-year period. It asks firms about an output – a new product or process – rather than an input, such as R&D, or an intermediate output, such as patents, which do not cover innovations protected by other forms of intellectual protection (e.g. secrecy, speed to market). The data shows that the share of UK manufacturing enterprises that routinely introduced innovations exceeded the EU average, while the share of innovative UK service sector enterprises was roughly equal to the EU average (Fig 10).

The Community Innovation Survey (CIS)

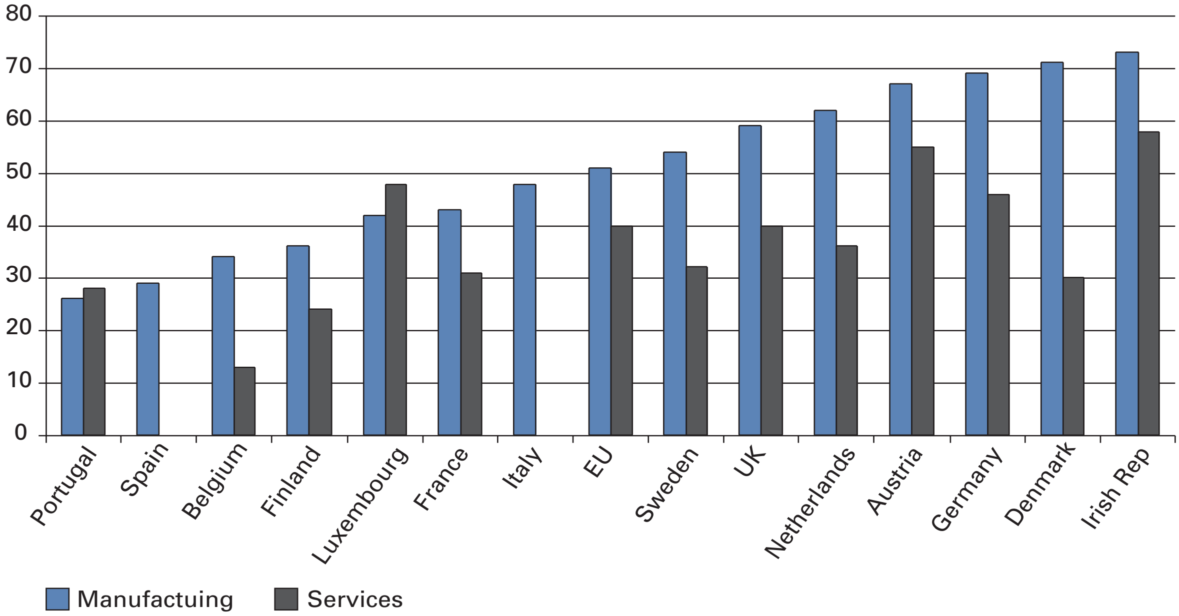
The CIS is a periodic survey of businesses designed to measure innovation activity, sources of innovation, knowledge transfer and the effects of innovation on businesses. As its name implies, it is a survey co-ordinated by the European Commission, although carried out by Member States. In the UK, the Office for National Statistics has carried this out on behalf of DTI. There is some common content – which means that many of the results are in principle comparable across Europe.

The second CIS (CIS2) was carried out in 1997 and collected data for the period 1994-1996. This is the latest survey for which international comparisons are available. The third CIS (CIS3) was carried out in 2001 and collected data for the period 1998-2000. Care has to be taken in comparing the results of CIS2 and CIS3 because of differences in sample design and response rates.

The CIS is a survey of businesses. CIS3 collected data from just over 8,000 businesses with 10 or more employees. All sectors of the economy are covered apart from the public sector and retail distribution and hotels and catering. Further information on the CIS can be found at www.dti.gov.uk/iese/science.htm. Analyses of CIS data can be found at www.dti.gov.uk/iese/ecslist.htm.

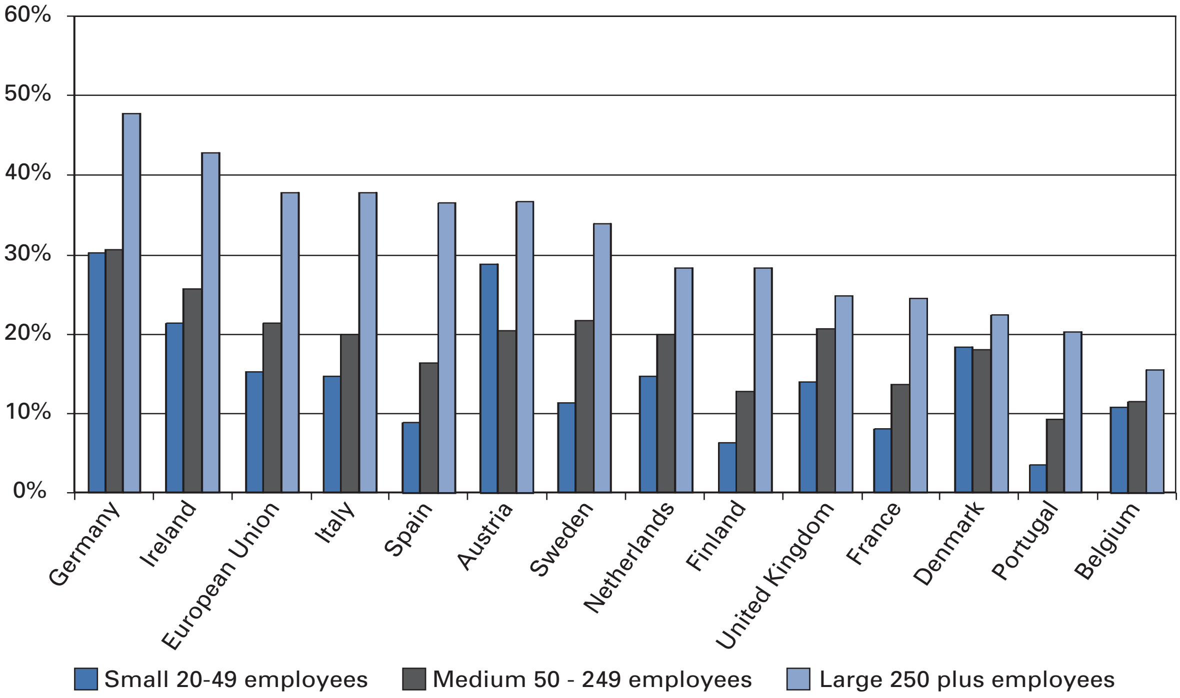
It also shows that the share of turnover in UK businesses accounted for by new products was lower than average, notably among firms with 250 or more employees (Fig 11).

Fig 10. Proportion of enterprises that bring new products or services to market or develop new process technologies, EU comparison, 1994 - 1996



Source: CIS 1994-1996.

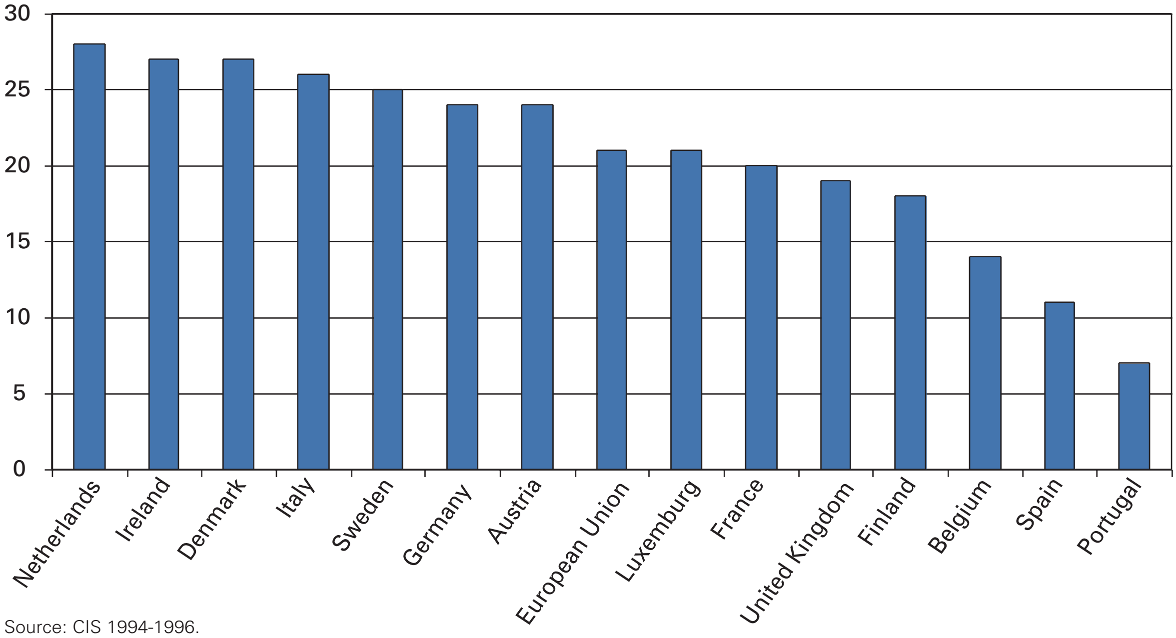
Fig 11. Proportion of sales from new or improved products, by country and size class, manufacturing sector, 1994 - 1996



Source: CIS 1994-1996.

The data also shows that the share of UK firms introducing novel innovations – those that are new to the firms' market – is below the EU average (Fig 12).

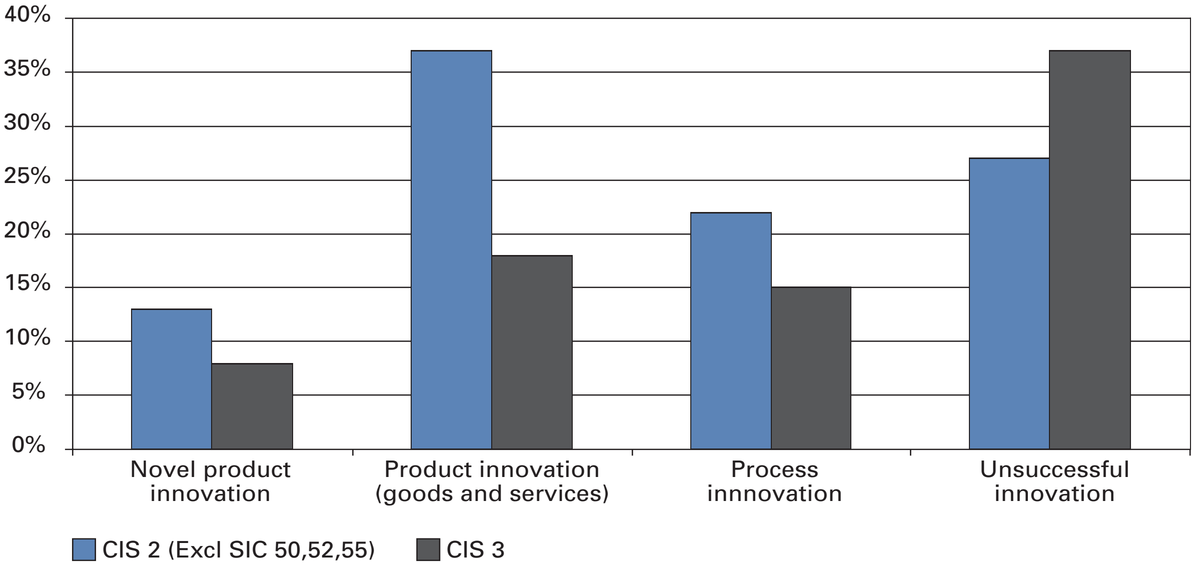
Fig 12. Proportion of 'novel' innovators by country, manufacturing sector, 1994 - 1996



Source: CIS 1994-1996.

There is evidence that innovation by UK enterprises declined between the two Community Innovation surveys[15] with lower incidences of novel product innovation, product and process innovations and higher incidences of unsuccessful innovations[16] (Fig 13).

Fig 13. Output measures of UK innovation in CIS 2, CIS 3 and changes.

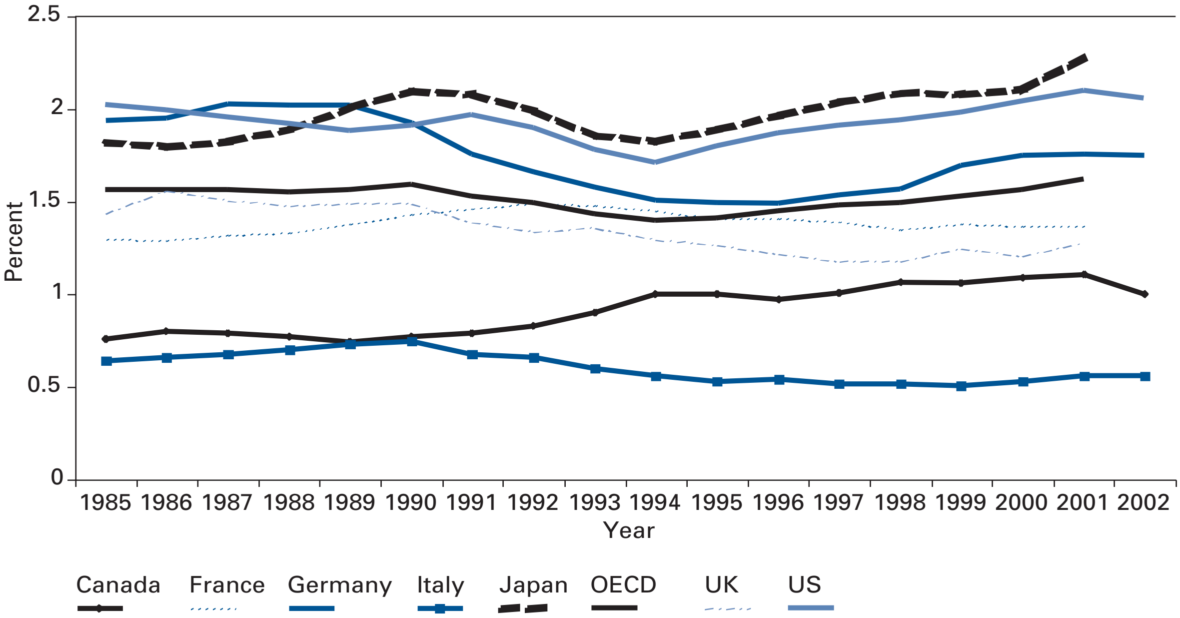


Source: M Frenz, 2002.

Indicators of technological innovation inputs

Business expenditure on R&D (BERD) and patent data are typically used to measure countries technological performance. The data broadly shows that UK ranks fifth in the G7 in the share of national income invested in R&D[17] and below the average for all OECD countries (Fig 14). BERD intensity declined during the 1990s but stabilised after 1998.

Fig 14. Business Enterprise Research and Development as a percentage of GDP



Source: OECD.

15 This effect is more than a statistical sampling effect. Enterprises that completed both the CIS2 and CIS3 questionnaire also reported a lower incidence of innovation in CIS 3 compared to CIS2.

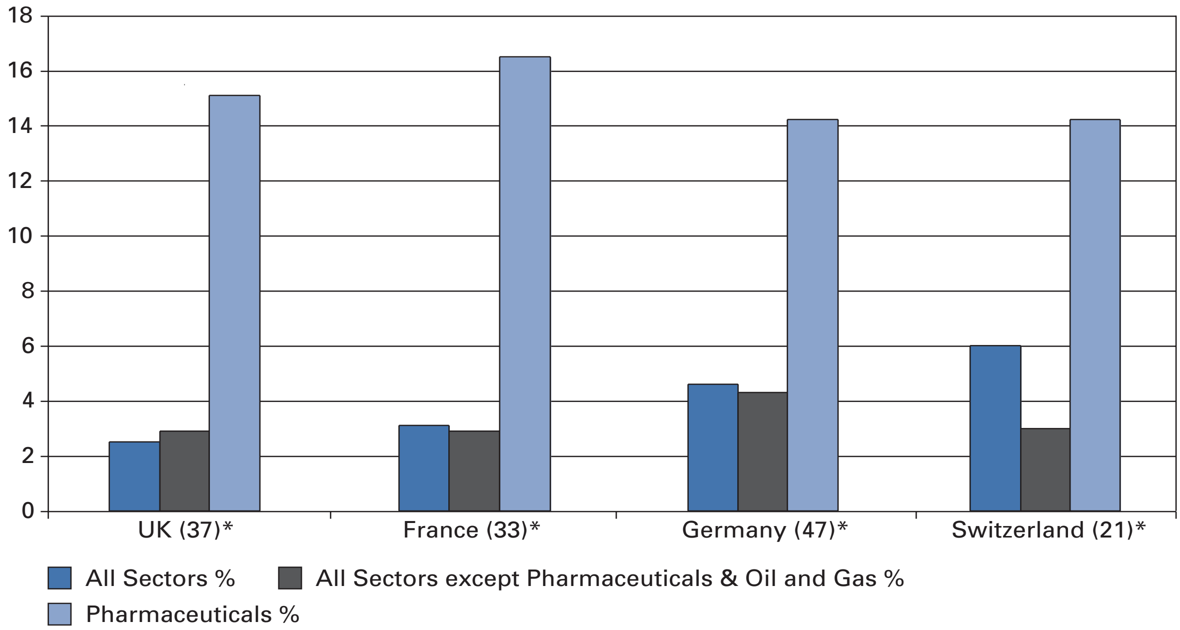
16 Frenz M, A Comparison of the Second and Third UK Community Innovation Survey, Unpublished paper available on dti.gov.uk\tese (2002).

17 Although R&D typically only accounts for 40% of all UK firms spending on innovation. Source: Community Innovation Survey.

One study suggests that the decline in the share of manufacturing R&D between 1993 and 2000 was due to weak output growth, declining levels of government funding for private industry and the appreciation in the real exchange rate since 1996.[18] Analysis of the BERD components shows that declines in R&D intensity coincide with real cuts in government funding of defence R&D during the 1980s. One study[19] has shown however that during the 1990s the principal reason for the UK's continuing relative decline vis a vis the US was due to the decline in industry funded BERD. This was due to weak within sector growth in R&D rather than a shift in output towards low-R&D sectors. The relative decline in R&D intensity was concentrated in a few industries, machinery, equipment and transportation.

The 2003 R&D Scoreboard[20] shows a similar picture with those UK companies in the top 700 international firms tending to invest less in R&D when compared to their European counterparts (Fig 15).

Fig 15. R&D intensities for firms in the top 700 – European comparison



Source: R&D Scoreboard 2003.

The data also shows that, compared to many of its competitors, the UK relies heavily on the R&D efforts of foreign firms based in the UK who locate R&D facilities here in order to tailor products to the UK market or, increasingly, to gain access to a source of knowledge such as the Science, Engineering and Technnology Base[21] (Fig 16).

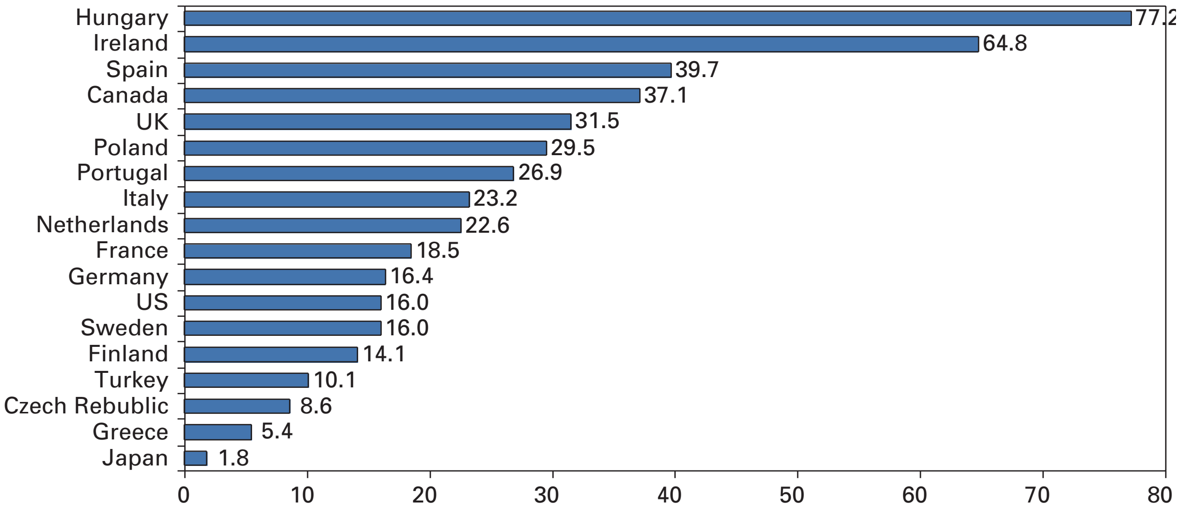
18 Becker B and Pain N, What Determines Industrial R&D Expenditure in the UK, National Institute of Economic and Social Research (2002).

19 Griffith R and Harrison R, Understanding the UK's Poor Technological Performance, IFS Briefing paper no 37 (2003).

20 DTI, The 2003 R&D Scoreboard, Commentary and Analysis (2003).

21 OECD, Science, Technology and Industry Outlook (2002).

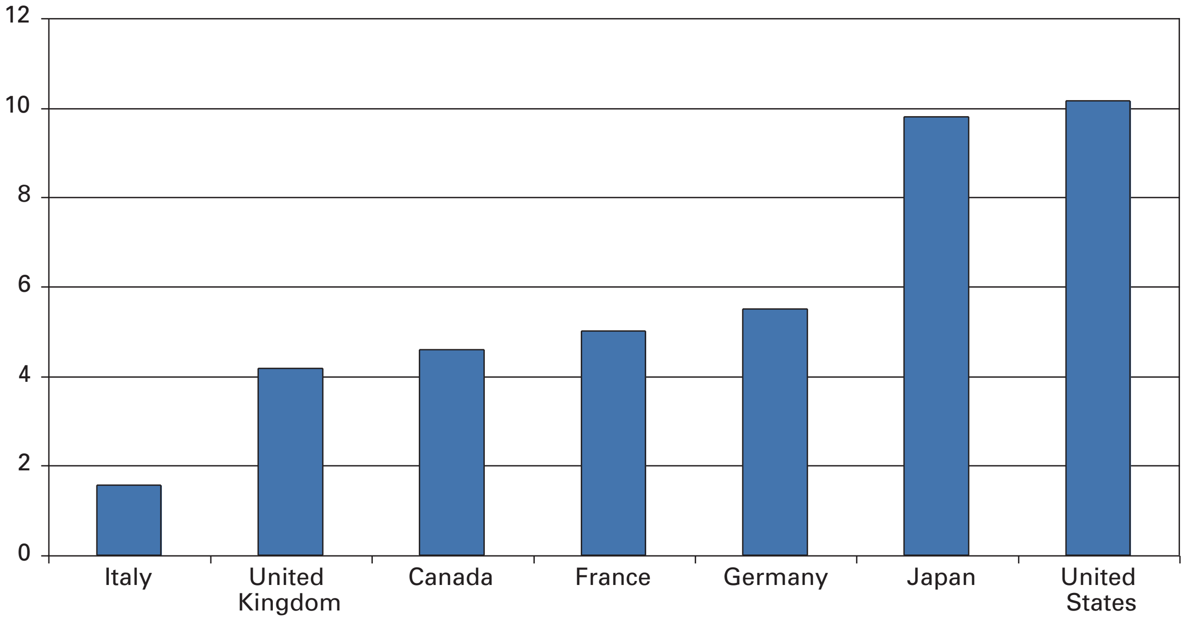
Fig 16. Share of foreign affiliates in manufacturing R&D, % 1998 or latest available year



Source: OECD.

R&D expenditure does not necessarily measure the intensity of R&D activity. But the relatively low levels of employment of researchers in UK industry[22] – less as a share of its workforce than any of the G7 bar Italy – suggests that UK businesses achieve a real R&D effort commensurate with the amount they spend (Fig 17).

Fig 17. Business Enterprise researchers per thousand employment in industry, 2000

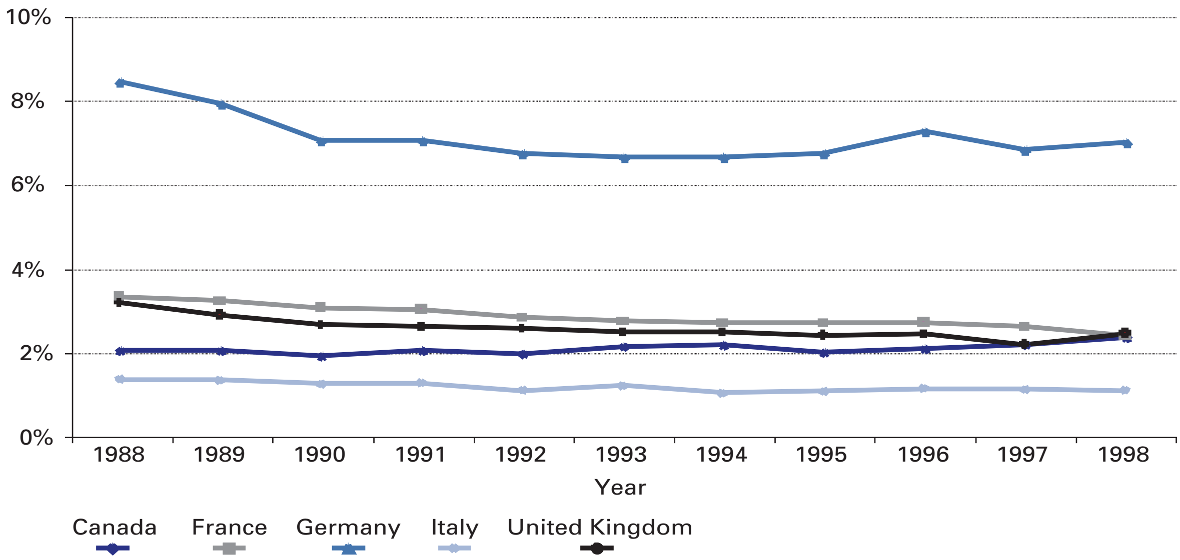


Source: OECD.

22 The OECD defines researchers as professionals engaged in the conception or creation of new knowledge, products, processes, methods, and systems and also in the management of the projects concerned. It is based on occupation data. It gives a different picture to qualifications data which shows that the UK does well on international comparisons of numbers of qualified scientists and engineers. The difference between the two reflects that scientists and engineers have a wide range of job opportunities outside corporate R&D laboratories.

Patent-based indicators provide a measure of inventions.[23] Although a number of studies have shown how the propensity to patent varies by industry and country – Japanese companies for example have a high propensity to patent[24]. According to this measure the UK lags a long way behind the larger economies. So the UK's performance in patents is also consistent with the lower level of resources they dedicate to innovation activities (Figs 18&19).

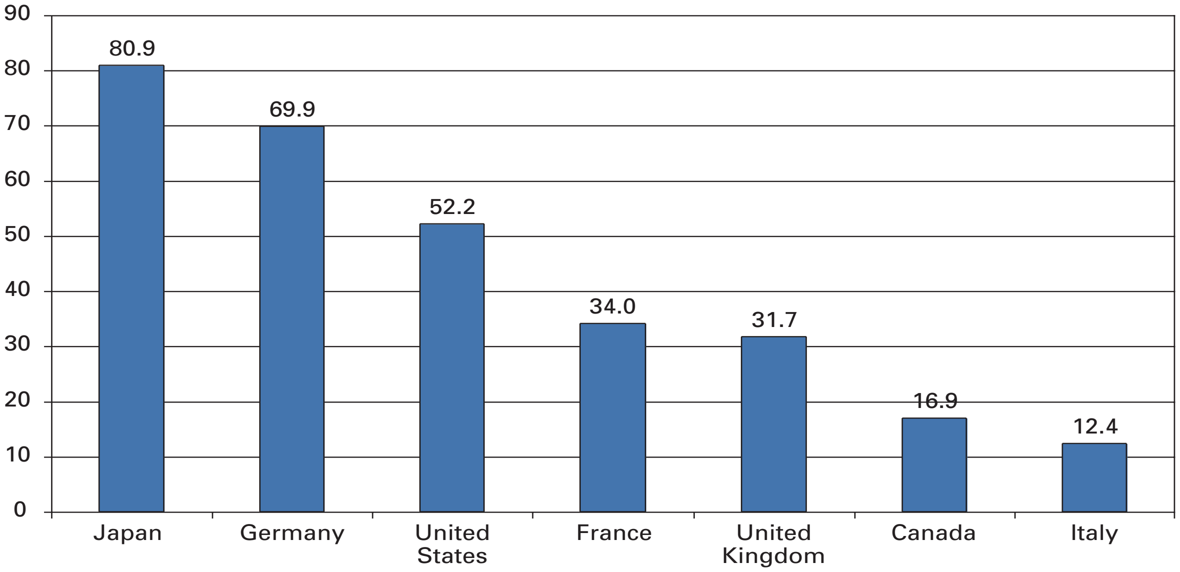
Fig 18. Proportion of parents granted by the USPTO to OECD countries



Source: OECD.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Japan	24.5%	24.3%	24.2%	23.0%	22.1%	22.0%	20.4%	21.2%	22.0%	21.4%	20.1%
United States	50.9%	51.9%	53.8%	54.6%	56.1%	56.0%	57.3%	55.9%	54.1%	55.3%	56.8%

Fig 19. Number of "triadic" patent families per million population 1998



Source: OECD.

23 Significant caveats apply to using patents as a measure of innovation performance. Some patents may have no obvious or immediate commercial application while others may be very valuable. Many innovations are not patented at all and others may be patented at different stages of development. Furthermore there is a significant home advantage to patenting (it tends to be cheaper and easier for domestic companies to patent). For greater international comparability we look at patent families which are sets of patents taken in various countries to protect a single invention. Indicators of patent families relate to patents applied for at the European, US and Japanese patent offices. Griliches Z, Patent Statistics as Economic Indicators: a Survey, Journal of Economic Literature 28 (1990).

24 See Taylor C and Silbertson A, The Economic Impact of the Patent system, Cambridge, Cambridge University press (1973). Also Mansfield E, Patents and Innovation: an Empirical Study, Management Science, 32, 173-81 (1986).

Analysis[25] of patents and other IP registrations taking effect within UK jurisdiction shows that very few UK incorporated firms appear in the top 100 firms that register patents in the UK. In contrast, British firms, operating mainly in the fields of media services, other aspects of ICT and consumer products and retailing, dominate the top 10 in the UK Trade Mark scoreboard. The contrast between patent and trademark performance suggests that innovation in the UK may be more focused on achieving incremental improvements in new products or product quality, which justify new brand names but not patents.

According to evidence presented by AIM management research forum[26], UK firms also appear to produce fewer radical innovations. For example[27] out of 64 radical innovations in the consumer electronics and home appliances industry over the 1850-2000 period the vast majority of innovations were first commercialised by US firms (40 out of 64 or 62%). The next most innovative firms were from Japan with 10 (16%). In comparison, UK firms were less innovative, responsible for commercialising only 4 out of 64 (6%), on par with France, Holland and Germany. UK firms[28] were relatively good at radical innovation in terms of counts of drugs[29] introduced in the US market between 1991-2000. Of the 15 most innovative firms, two were UK based: GlaxoSmithKline and AstraZeneca, with 19 and 8 out of a total of 226 breakthrough drugs commercialised. However, in terms of the value generated by these drugs, the UK firms performed less well. Of the top 10 most valuable drugs introduced in this period, only 1 UK firm's product entered the list, at number 9 (GlaxoSmithKline's Relenza).

Measures of innovations in business organisation

Innovation will usually involve changes in business organisation. These may be required to turn technologies into a new product or process. Or they may be valuable in their own right – for example just in time manufacturing.

International comparisons on the UK's relative performance at these aspects of innovation are harder to come by. But there are signs in some areas that the UK lags behind others in the adoption of new business practices. For example, a recent study[30] examined the speed with which banks across 6 European countries adopted the internet and other digital media as vehicles for their retail financial services. The study found that UK banks were on average the slowest of the 6 countries studied: the average number of months of internet banking experience they had by December 2001 was 28.3 in comparison with 55.7, 45.6, 36.2, 35.0, and 29.9 months for Finland, Sweden, France, Germany and Denmark respectively. The study also found that UK banks lagged in the number of alternative digital media they had employed to provide retail financial services.

25 Greenhalgh C and Longland M, Intellectual Property Scoreboards for the UK in 2000, part C of the research project titled 'The Extent and Value of Intellectual Property in UK firms (2003).

26 Birdi K, D Denyer, K Munir, A Neely and J Prabhu, Post Porter: Where Does the UK Go From Here? Summary report from the AIM management research forum, June (2003).

27 Chandy R.and Tellis G, "The Incumbent's Curse? Incumbency, Size and Radical Product Innovation," Journal of Marketing, 64 (3), 1-17 (2000).

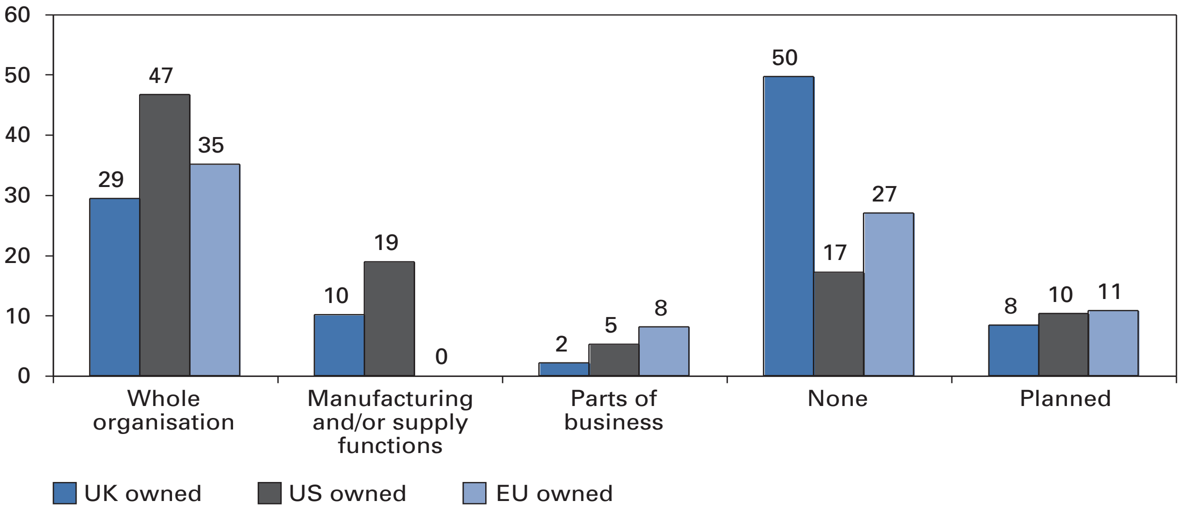
28 Sorescu, A, Chandy R and Prabhu J, Sources and Financial Consequences of Radical Innovation: Insights from Pharmaceuticals, Journal of Marketing, (2003).

29 Radically new drugs – those that involved both new molecular entities as well as new therapeutic uses and were therefore both technological and market breakthroughs.

30 Schlie E, Prabhu J and Chandy R, Legacy Effects in Radical Innovation: A Study of European Banking, Judge Institute of Management working paper (2003).

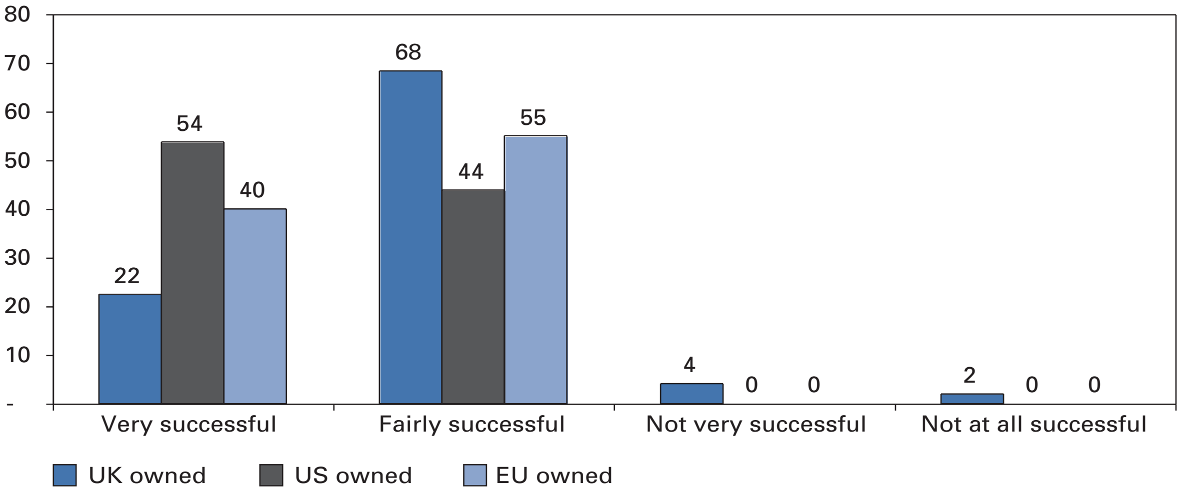
An international survey[31] of modern manufacturing practices showed that the UK lagged significantly behind Australia, Switzerland and Japan on the uptake of best practices and report less effectiveness with them. They also report less planned future investments in best practices. Survey evidence[32] shows that US and EU owned firms operating in the UK are more likely to adopt lean manufacturing[33] methods than their UK peers (Fig 20).

Fig 20. Percentage of respondents undertaking/planning to undertake any form of lean manufacturing



Source: EEF/NOP productivity survey 2001.

Fig 21. Percentage of firms undertaking lean manufacturing that say it has been...



Source: EEF/NOP productivity survey 2001.

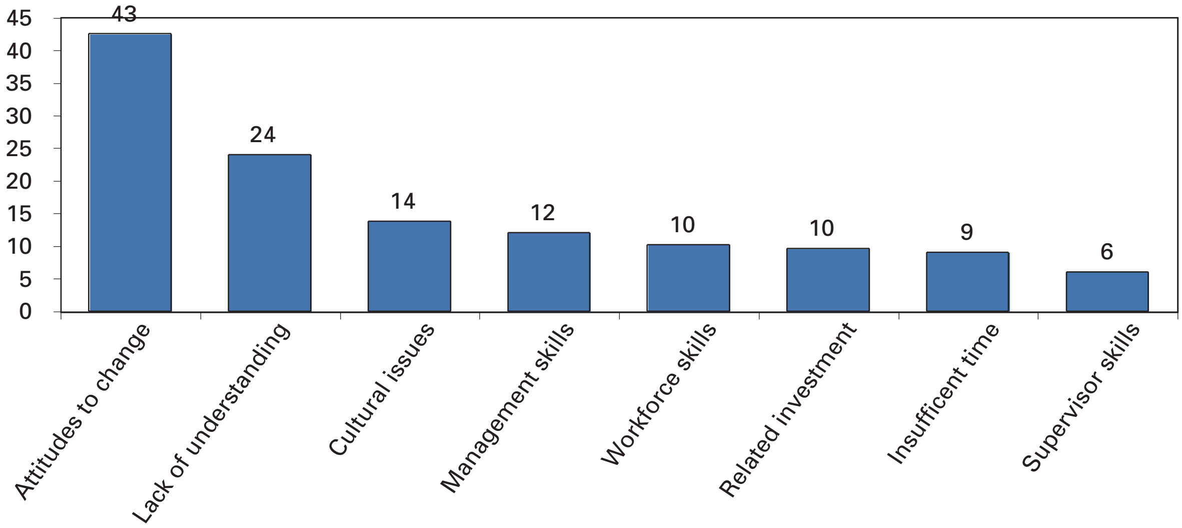
And US and EU firms are more likely to say that lean manufacturing methods are very successful – over a half of US owned firms believe they make a tangible difference compared to around 20% of UK owned firms (Fig 21). Respondents cited attitudes to change, lack of understanding, cultural issues and a lack of management skills as the most significant barriers to implementing lean manufacturing (Fig 22).

31 Clegg et al., An International Study of the Use and Effectiveness of Modern Manufacturing Practices, Human Factors and Ergonomics in Manufacturing, 12, 171-91 (2002).

32 Engineering Employers Federation, Catching up with Uncle Sam – the Final Report on US and UK Manufacturing Productivity (2001).

33 Lean manufacturing is based on reducing waste within the company and along its supply chain. It involves taking steps to reduce stocks, minimise defects and reducing excessive transportation costs and inefficient or inappropriate processes.

Fig 22. The barriers to lean manufacturing; percentage of firms already undertaking lean manufacturing



Source: EEF/NOP productivity survey 2001.

A recent study suggests that UK companies are less likely to adopt modern management practices and, on average, compete less on unique value and innovation than their peers from other countries[34]. Another study[35] comparing the uptake of modern management practices (e.g. Total Quality Management, supply chain-partnering, integrated computer-based technology) across a total of 880 UK, Australian, Japanese, and Swiss manufacturing companies produced similar results. UK firms could also be more effective in their people management processes. For example, while over half of all businesses have a business plan, only a quarter have a training plan, 17% have a training budget, and only 15% have a human resources plan that ties their skill requirements to their emerging business needs.[36]

34 Porter M E and C H M Ketels, *ibid*, (2003).

35 Clegg, C.W. et al, *ibid*, (2002).

36 DfES, Learning and Training at Work Survey (2002).

Part III: Key factors determining UK innovation performance

Innovation systems

The performance of an 'innovation system'[37] [38] can be assessed by its capacity to generate innovation and translate that innovation into economic growth. Performance[39] depends upon the incentives provided by the economic and regulatory environment, access to critical inputs (through markets or interactions with networks and clusters of knowledge based organisations) and the internal capacity of firms to seize market and technological opportunities.

National Innovation Systems

National innovation systems are defined as the "...set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies." (Metcalfe 1995)

From this perspective, the innovative performance of an economy depends not only on how the individual institutions (e.g. firms, research institutes, universities) perform in isolation, but on "how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, legal frameworks)." (Smith 1996)

The innovation system approach rests on three theoretical advances which have helped shape the understanding of innovation processes and their contribution to economic growth. These are:

- New growth theory which stresses the importance of increasing returns to the production of knowledge and its exploitation in producing innovations.[40];
- Evolutionary and Industrial economics which shows that knowledge accumulation is path dependent, and involves interactions between multiple actors at different stages of research and innovation. It is therefore shaped by the interplay of market and non-market institutions[41];

37 Metcalfe S. The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives, in P.Stoneman, ed., Handbook of the Economics of Innovation and Technical Change, pp. 409-512, Blackwell, London (1995).

38 Smith K, The Systems Challenge to Innovation Policy, in W.Polt and B.Weber, eds., Industrie und Glueck. Paradigmenwechsel in der Industrie-und Technologiepolitik, Vienna (1996).

39 OECD, Managing Innovation Systems (1999).

40 Aghion P and Howitt P, Endogenous Growth Theory, MIT Press, Cambridge, Massachusetts (1998).

41 Metcalfe S, *ibid*, (1995).

- Institutional economics which shows how growth leads to increasing specialisation of tasks leading to complex inter-dependencies and requiring greater co-ordination of institutions[42].

Innovation systems can operate at many levels. Generally however systems do not coincide with neat national boundaries. They are often based around groups of firms – which will cross sector boundaries – and will often include overseas firms and institutions.

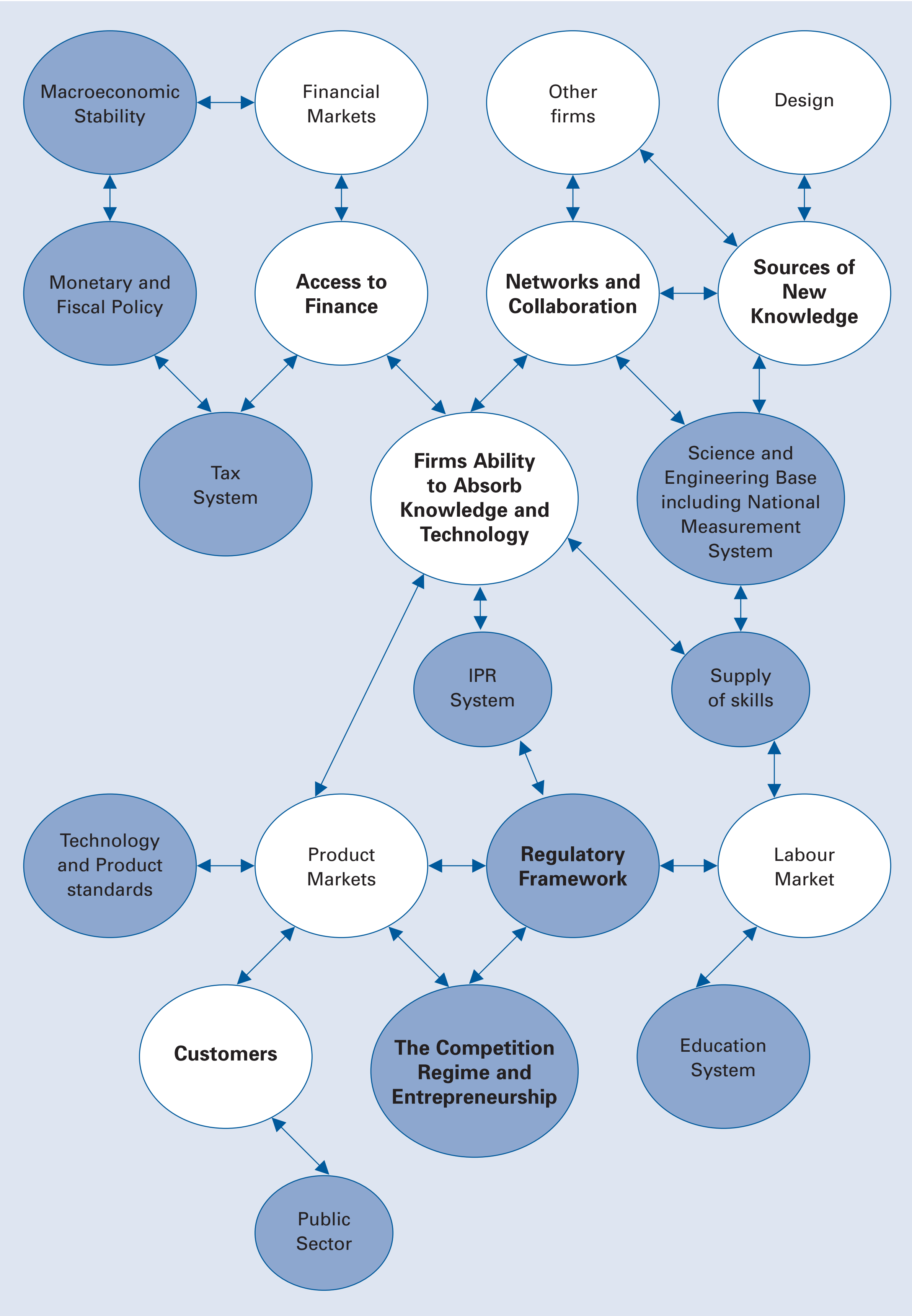
Sectoral or cluster based analysis is the most relevant for understanding the dynamics of a particular industry. There is clearly a role for regionally based analysis, especially given the diversity of regional economic structures and the increased activity of regional and local bodies in innovation policy.

A national focus to innovation studies, which this report provides, helps to draw out the many things that firms throughout the UK have in common. The evidence shows that firms throughout the UK look beyond their immediate location when they describe their customer base or when they look for specialised sources of knowledge or collaboration opportunities (Annex D). Furthermore, there is merit in looking at innovation systems in a national context particularly to identify how central Government can improve the effectiveness of innovation systems and to facilitate their formation. After all national Governments have an impact on the performance of systems through nationally determined policies (e.g. tax, regulation, education).

Innovation systems provide a framework for analysing strengths and weaknesses as well as a guide for policy formulation. It is possible to map the national system on the basis of flows of knowledge or transactions which take place when firms engage in innovation. The mapping, shown overleaf, captures both market and non-market interactions.

42 North D, Institutions and Economic Development, Paper presented at the OECD workshop on 'Institutional Framework and Economic Development, Paris, November (1995).

Institutional mapping of the UK Innovation System – areas of Government influence shaded



The mapping of the 'national innovation system' shows that a wide variety of factors influence the innovation performance of an economy. A number of these, marked in bold, have been used to brigade critical inputs and interactions. It could be argued, with some truth, that a whole host of other factors (such as transport) affect productivity or innovation performance and which are also influenced by Government policies. But in any assessment of this sort the difficulty lies in trying to keep its scope within manageable bounds. This has obviously constrained the choice of success factors, which have been selected on the basis that they seem to be the most important. They are:

- **The capacity to absorb and exploit knowledge and technology.** As knowledge is tacit and embedded in people, firm capacity depends on investments in intangible and tangible business assets. In house R&D serves to maintain and develop a firm's capability to absorb new knowledge[43]. This absorptive capacity is critical for firms to act as intelligent customers (of external research) and for monitoring emerging scientific and technological fields. Flexibility in terms of strategy, culture and organisation in the face of change is also important. Worker training, organisational structures and managerial ability are important determinants of productivity at firm level[44]. And the successful introduction of new technologies often depends on introduction of new work practices[45].
- **The regulatory framework** affects incentives to innovate, for example through the IPR regime, and the ability of firms to deploy their resources effectively.
- **The competition regime**, which the Government helps determine, can remove impediments to market entry, prevent excessive concentration and eliminate unfair or undesirable factors which firms adopt to shield themselves from competitors. By enabling the entry and exit of firms, the degree, intensity and nature of competition decides which innovations will be successful in the market place. Levels of **entrepreneurship** help determine the intensity with which firms compete and their ability to spot opportunities and manage risks.
- **Access to finance.** The risky nature of innovation and the – often – heavy initial investment required to bring a project to fruition suggests that issues of finance are likely to particularly crucial for successful innovation[46].
- **Sources of new technological knowledge.** New knowledge, resulting from investments in science, technology, engineering and design[47], has an important role in shaping innovation systems. It complements knowledge gained from the performance of products in use, users and suppliers. The movement of knowledge between sectors increases innovation opportunities.
- **Networks and collaboration.** Firms rarely innovate alone[48] and rely on a variety of organisations such as other firms, Universities and educational bodies, Government labs, Research and technology organisations (RTOs) and IPR organisations, for information to augment their internal innovation activities. They are increasingly seeking co-operative agreements of various kinds with other firms and institutions both horizontally and vertically[49]. To remain competitive firms need to

43 Cohen W and Levinthal D, Innovation and Learning: Two Faces of R&D, Economic Journal, 107,139-49 (1989). Rosenberg N, Why do Firms do Basic Research (With Their Own Money)? Research Policy 19, 2, pp 165-174 (1990).

44 OECD, *ibid*, (1999).

45 OECD, Technology, Productivity and Job Creation: Best Policy Practices (1998).

46 Arrow KJ, Economic Welfare and the Allocation of Resources for Invention in RR Nelson (ed) The Rate and Direction of Inventive Activity: Economic and Social factors. Princeton: Princeton University Press (1962).

47 A number of surveys carried out on behalf of the Design Council point to a correlation between investments in design and business performance.

48 Lundvall B-A , National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, Pinter, London (1992).

49 Horizontal co-operation between competitors normally take the form of contractual agreements on R&D. After co-operating in the research phase, firms compete to commercialise products from the research. Vertical co-operation agreements exist between firms and suppliers or customers/users. Co-operation centres around improving products or production processes.

master[50] an increasing stock of knowledge across a wide range of technological areas[51]. Accelerating R&D costs, higher levels of risk and shorter product cycles[52] also play a role as collaboration allows firms to share resources and risk.

- **Customers.** Demanding customers put pressure on firms to deliver better quality and better value goods and services. Often they will identify problems that need solving. They are an important source of external knowledge and information for innovation. The ability to sell new products and services abroad will often be vital to achieve economies of scale.

Assessment of the UK Innovation system

CAPACITY TO ABSORB NEW KNOWLEDGE

If firms do not have access to sufficiently skilled workers, they may be unable to develop and adopt innovations, implement new investments or organisational improvements. As well as influencing economic growth, workforce skills are one determinant of how well the economy adapts to structural change. As the economic structure evolves, some industries decline, and some new industries emerge. As a result the ability of an economy to foster lifelong learning and career mobility in the face of changing skill needs is paramount.

The evidence suggests that low levels of skills are one of the main barriers that UK firms face when trying to become more innovative. There is also emerging evidence that the interaction of demand and supply coupled with the complementary nature of skills to investment and innovation, means that some firms become locked into a 'low-spec' trap. This is where firms adopt low value-added, low skill, low innovation product strategies. As result, individuals do not see any incentive to acquire higher skills (since there is little demand from firms for those skills). Consequently, when firms seek to adopt more productive product strategies, they cannot acquire the skills from their local labour market, so do not undertake the investment or adopt the innovation.[53]

Lower average skill levels in the UK account for a fifth of our productivity gap with Germany.[54] Although the UK has a similar proportion of graduates as Germany, the UK has a much higher proportion of lower skilled workers. The UK has a higher proportion of intermediate skilled workers than the US, but the US has a substantially higher proportion of graduates. The main message is that for the UK, the problem is not one of 'skills shortages' – which tend to be a small proportion of total employment and short term in nature – but that the UK has a generally low level of skills across the economy. A series of cross-country comparisons by the National Institute for Economic and Social Research (NIESR) suggest that this weakness leads to highly qualified people spending time dealing with problems caused by skill deficiencies. This could affect innovation by delaying process innovations or hamper the transfer to full production stage of new product development.[55]

50 Nelson, R.R and Winter, S, An Evolutionary Theory of Economic Change, Cambridge, MA, Harvard University Press (1982).

51 Grandstand O. P. Patel and K. Pavitt, Multi-technology Corporations: why they have 'distributed' rather than 'distinctive core' competences" California Management Review, Vol. 39 (1997).

52 Ciborra, C, Alliances as Learning Experiments: Co-operation, Competition and Change in High-tech Industries, in L. Mytelka "Strategic Partnerships and the World Economy, London, Pinter (1991).

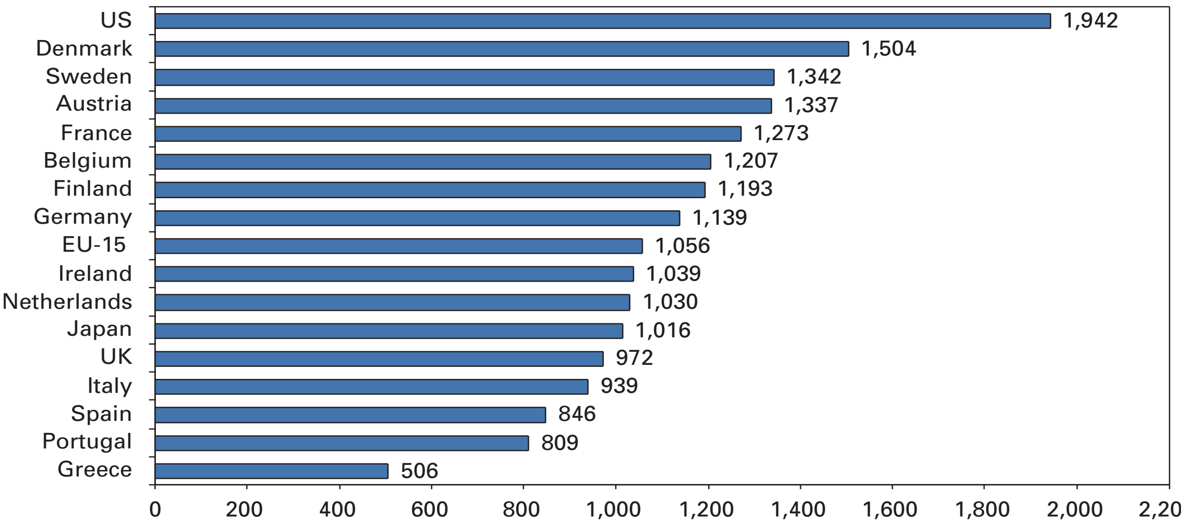
53 Hogarth T and Wilson R, Tackling the Low Skills Equilibrium: A Review of Issues and Some New Evidence, Draft Report to DTI, October (2003).

54 O'Mahony M., and de Boer W, Britain's Relative Productivity Performance: Updates to 1999, National Institute of Economic and Social Research, London (2002).

55 Summarised in Keep E, Mayhew K and Corney M, Review of the Evidence on the Rate of Return to Employers of Investment in Training and Employer Training Measures, Report to DTI, (2003).

The UK has for a number of years lagged behind other developed economies in terms of the development of basic skills. Up to seven million adults are functionally illiterate, this translates to 20% of adults reading less well than the average eleven year old. The UK performs poorly on basic skills when compared to our competitors. Low skills present a barrier to the acquisition of additional skills, as workers with low skill levels are less likely to engage in adult education and training.[56]

Fig 23. Intensity of educational expenditure in the EU-15, Japan and the US in 1999: Educational expenditure in euros per inhabitant (PPS1995)



Source: Third European Report on S&T indicators, 2003.

The amount of resources dedicated to education is – by international standards – relatively low (Fig 23) which has probably led to the perception that the quality of publicly funded schools is low in the UK[57]. Reforms to schooling have increased the proportions of children attaining the expected standards for their age in both literacy and numeracy. The Programme for International Study Assessment found that the performance of UK young people was significantly above the OECD average in all three of the subjects covered – 'reading literacy', 'mathematical literacy' and 'scientific literacy'. But it will be some years before the beneficial effects of these improvements are felt on innovation performance.

The overall weakness in terms of basic skills extends to adult skills levels more generally. NIESR analysis suggests that the UK's skills gap arises from a relative lack of *intermediate* skills, especially at level 3[58]. The UK has one-third fewer people qualified to level 2 than either France or Germany and only half as many people qualified to level 3 or above than Germany. Interestingly, the US has a better productivity performance than the UK but appears to have a similar skills distribution to the UK. A low share of the workforce with intermediate skills and correspondingly higher shares with high or low skills[59]. It has been suggested that a major factor in US productivity leadership is down to the size of its markets and the economies of scale in production that resulted[60].

56 Moser C, Improving Literacy and Numeracy for Adults: A Fresh Start, An independent review for HM Government (1999).

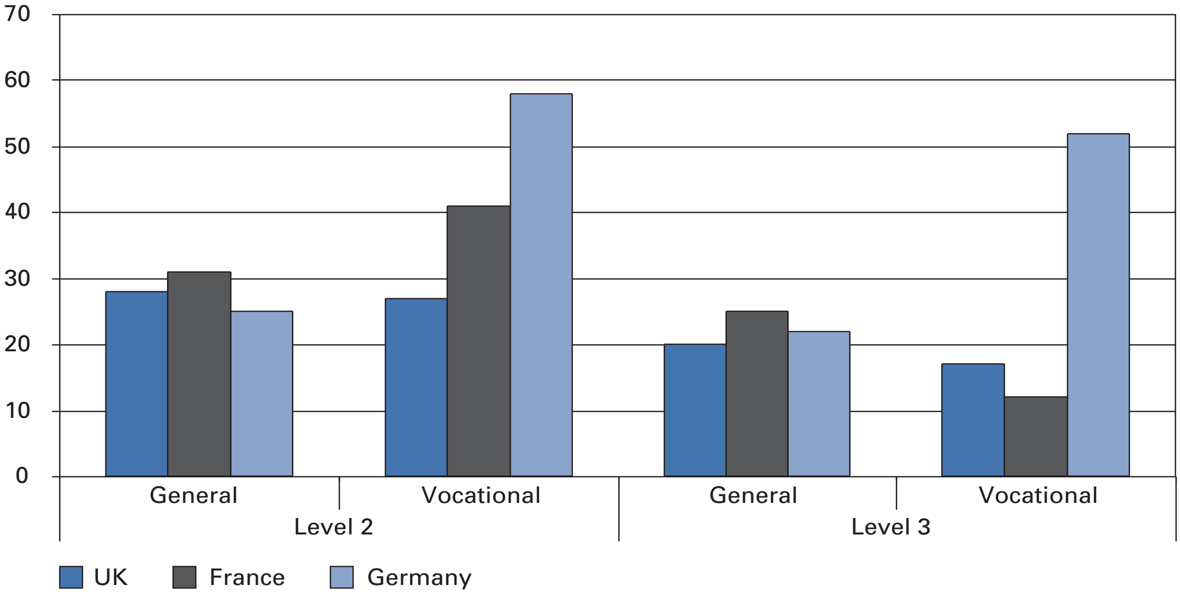
57 Porter M E and C H M Ketels, *ibid*, (2003).

58 Level 5 is equivalent to degree level; level 4 is higher education below degree level; level 3 is A level/apprenticeship; level 2 is GCSE grade A-C or equivalent; level 1 is GCSE below grade C.

59 Crafts N and M O'Mahony, *ibid*, (2001).

60 Keep E, Mayhew K and Corney M, *ibid*, (2003).

Fig 24. Qualifications at level 2+ and 3+ or equivalent



Source: Dr H Steadman, LSE.

The UK is some way behind Germany and France in terms of the percentage of the workforce with **vocational** qualifications at level 2 and above (Fig 24). In the UK the low take up partly reflects the relatively low returns, in the form of wage premia, to vocational qualifications compared to academic qualifications[61]. Government instruments designed to create a vocational route to high-level skills – e.g. Modern Apprenticeships – have been criticised for providing little or no general skills component with much of the training geared to meeting a checklist of competencies within the firm. Lacking in external accreditation and common standards many of the qualifications are not transferable and unattractive to students[62].

In terms of higher level skills, the UK has a large graduate output, a direct result of government encouragement and the perceived high returns to gaining a degree. Although there are pressures on university finances, teaching quality and infrastructure as costs per student have fallen sharply[63 64]. The UK has a large stock of Scientists and Engineers[65] although many are not attracted to careers in research and development – mostly because employers offer insufficiently competitive remuneration packages.[66] The financial services sector and the public sector are the largest employers of S&T graduates[67] (Fig 25).

61 Dearden L et al, The Returns to Academic, Vocational and Basic Skills in Britain, Skills Task Force Research paper 20 (2000).

62 Ryan P and Unwin L, Apprenticeship in the British Training Market, National Institute Economic Review No 178 October (2001). Eraut M, The Role and Use of Vocational Qualifications, National Institute Economic Review No 178 (2001).

63 Rolfe H, University Strategy in an Age of Uncertainty: the Effect of Higher Education Funding on Old and New Universities, National Institute for Economic and Social Research Discussion paper 171, December (2001).

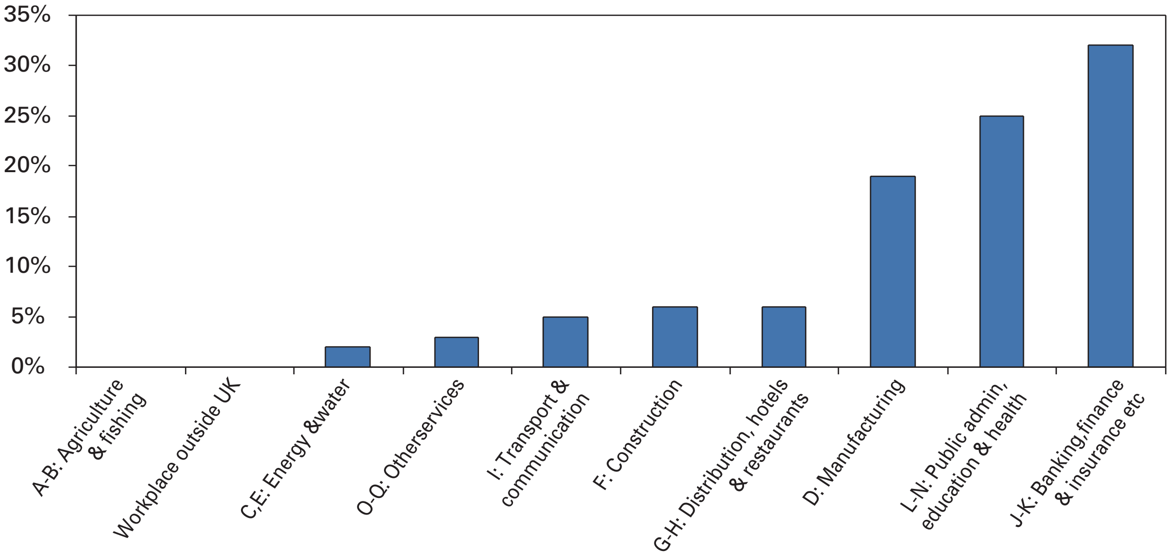
64 Mason G, Graduate Utilisation and the Quality of Higher Education in the UK, National Institute of Economic Research Discussion paper 158, October (1999).

65 The UK possesses 1620 science graduates per 100,000 in the youth (ages 25-34) labour force compared to 2063 in France, 835 in Germany and 1098 in the US. OECD Education Outlook. Data on Flows also shows that ovver 25% of new degrees awarded are science and engineering.

66 DTI, HMT and DFES, Investing in Innovation: a strategy for Science, Engineering and Technology, July (2002).

67 S & T graduates include first degrees in biological science, physical/environmental sciences, Mathematical sciences and computing, Engineering, Technology & Architecture and related subjects.

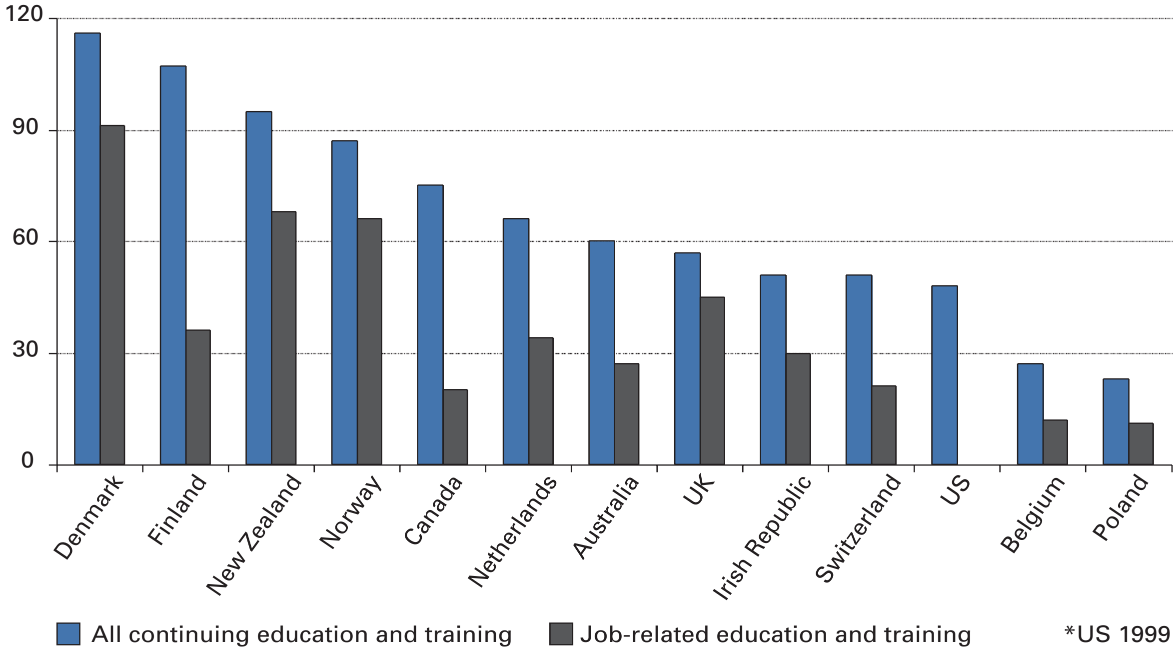
Fig 25. Share of total S & T graduates employed in each sector



Source: Labour Force Survey, Autumn (2002).

The acquisition of skills does not begin and end at school. Individuals develop skills over the course of their working lives, both through formal and informal ('on-the-job') training. The UK performs relatively well in terms of job-related training, the International Adult Literacy Survey shows the UK performing ahead of the US but behind Canada in terms of hours of all continuing education and training undertaken (Fig 26).

Fig 26. Average hours of continuing education and training, by type of training 1994-1998



Source: OECD.

A firm's ability to turn innovative ideas into profitable new products and processes will depend on management related factors such as:

- The corporate strategy and its implementation in practice. Many companies, including foreign owned companies, have difficulties in effectively executing strategies[68].
- A culture that encourages employees to try out new ideas and reward systems that acknowledge employees efforts. Organisations that actively encourage continuous learning and development in their employees are more innovative[69]. The CBI (2001) innovation survey concluded that the most innovative organisations had the most positive culture.
- An outward orientation in which organisations actively undertake systematic approaches to locate and assess good practice elsewhere in attempts to improve their own performance. Organisations that benchmark their operations frequently tend to be more innovative[70].
- Whether organisations encourage participation in decision-making to generate a wider range of viewpoints and ideas from which to choose. This also helps motivate employees by giving them a sense of ownership and control over changes at work, as opposed to them resisting imposed changes. A survey[71] of 500 UK organisations showed that those that conducted extensive internal and external discussion and negotiation prior to idea implementation, were more likely to produce successful innovations.
- A culture that accepts a degree of risk taking by encouraging experimentation, showing a tolerance for errors and rewarding effort as well as outcomes. Learning from any mistakes that are made by instigating regular reviews and reflective practices. These factors, and others, are set out more fully in work produced by the AIM Management Research Forum in support of the Innovation Review[72].

The evidence presented in Section II suggests that UK firms are less able, or willing, to implement changes to business organisation. This is likely to be influenced by management. Evidence on the quality of UK management vis a vis its competitors is hard to come by. What is available suggests there are some weaknesses[73]. For example:

- Somewhat old evidence[74] suggests that UK managers performed particularly badly in terms of their adaptability, entrepreneurial and technical skills when compared with US, German, French and Japanese managers.
- Another study shows that – compared to the US and other European countries – UK firms were more likely to report lost working time due to inadequate management supervision and an inappropriately qualified workforce[75].
- Despite the increase in management education, a recent UK survey[76] indicated that nearly half of all junior managers rated the quality of leadership in their organisations as poor, but few Chairmen and Chief Executives believe there are any weaknesses in this area.

68 Charan R and Colvin G, Why CEOs Fail, Fortune magazine, 21st June (1999).

69 Shipton, H, West M A, J Dawson, J Patterson, & K Birdi, Organisational learning as a predictor of innovation, submitted to Human Resource Management Journal (2003).

70 Leach D, P Totterdell, K Birdi, C Clegg, S Wood and T Wall, Innovation at Work: Findings from a Survey of Innovation in UK Organisations, Sheffield: University of Sheffield (2001).

70 Leach D et al, *ibid*, (2001).

72 Birdi K, et al, *ibid*, (2003).

73 CBI/TUC, Productivity Report (2001). Council for Excellence in Management and Leadership, Managers and Leaders, Raising Our Game (2002).

74 Savery L, T Mazzarol and P Dawkins, How Others See Us Competitively, Perth: Institute for International Competitiveness, Curtin University (1994).

75 Proudfoot Consulting ,Untapped potential: Global productivity study, October (2002).

76 Horne M and Stedman Jones D, Leadership: The Challenge for All, Institute for Management, (2001).

- Furthermore, employees[77] feel there are still notable skill deficits e.g. 24% of managers were classed as poor at dealing with work problems and 34% as poor at responding to suggestions from employees.
- There are signs of improvement however. A study[78] of management development indicated that significant improvements had been made since the 1980s. For example, more organisations rated management development as important, participation rates had increased and the use of formal qualifications was more common. The trend has continued over the last few years. In 1996 23% of managers had a degree, while in 2001 that went up to 30%[79] and the number of MBAs grew from 8,000 per year in 1995 to 11,000 in 2000[80].

A recent review[81] of the promising business practices literature by AIM scholars suggests however that there is no such thing as a one size fits all best practice which firms can draw upon to improve their innovation capabilities and performance. Indeed capabilities are usually a highly specific combination of behaviours and artefacts. Imitation is extremely difficult and simply copying others represents superficial rather than fundamental change[82]. It is also quite possible that many successful firms find it difficult to identify the precise reasons for their success.

Although the evidence supports the proposition that UK firms lag behind competitors in terms of the adoption of promising practices, the AIM review was unable to identify studies which address the causes for this. The most policy relevant question remains unanswered. Are UK firms just less effective at finding and implementing promising practices or have external factors, such as historic weaknesses in the competition regime or employment relations framework, reduced incentives to acquire such practices?

REGULATORY FRAMEWORK

For the purposes of this review the regulatory framework includes:

- Product and labour market regulation
- IPR regime

Product and labour market regulation

Regulations may erect barriers to entrepreneurship by limiting competition and constrain firms' ability to adapt to changing market circumstances or provide unfair advantage to particular firms. Labour market regulations may also influence innovation performance because industrial relations regimes are likely to influence the human resource strategies of innovating firms. Where wage negotiations are decentralised and uncoordinated, firms recruit skilled labour from the labour market. In more centralised systems, wage differentials between skilled and unskilled workers tend to be compressed, and firms, finding it more difficult to attract skilled labour, gain more from training their own workers. In addition countries with centralised or sectoral wage bargaining systems also tend to have higher hiring and firing costs[83].

77 Workplace Employee Relations Survey, DTI, ESRC, Policy Studies Institute (1998).

78 Thomson A et al, Management Development, The Association of MBAs (1998).

79 Tamkin P, J Hillage, and R Willison, Indicators of Management Capability, The Institute for Employment Studies (2002).

80 Council for Excellence in Management and Leadership, *ibid*, (2002).

81 Leseure MJ, J Bauer and K Birdi, Adoption of Promising Practice, a Review of the Evidence, a Systematic Review, AIM Management Research Forum, August (2003).

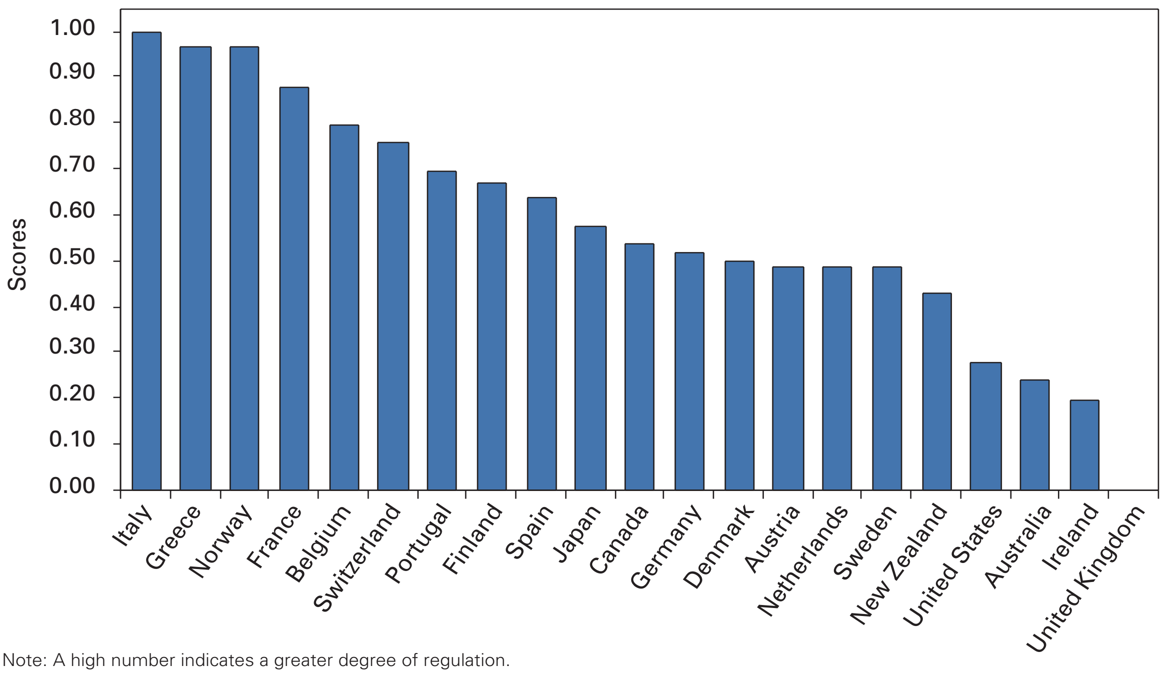
82 Bessant J, S Caffyn and J Gilbert, Learning to Manage Innovation, Technology Analysis and Strategic Management 8, 59-70 (1996).

83 Scarpetta S and T Tressel, Productivity and Convergence in a Panel of OECD industries: Do Regulations and Institutions Matter? OECD Economics Department Working Papers (2002).

Various studies by the OECD suggests that regulations have an adverse impact on innovation performance.

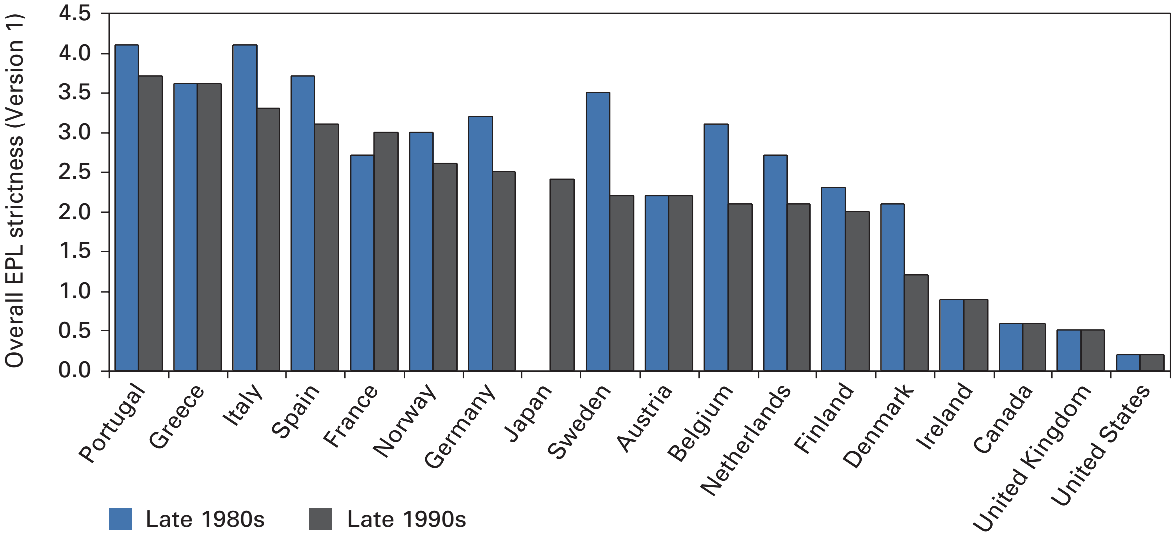
- An anti-competitive regulatory environment and delays in implementing pro-market reforms, including improved market access and state retrenchment, are associated with relatively poor total factor productivity performance.
- Regulations limiting private governance and competition tend to have greatest adverse impact the further a country is from best-practice technology because it hinders the adoption of existing technologies, the absorption of spillovers or the entry of new firms.
- Regulations that promote competition can explain more than a third of the excess R&D intensity in the US, Japan, Germany and Sweden relative to the OECD average and provide a large positive contribution to the UK, Canada and Ireland.
- There is evidence of a negative impact on multi-factor productivity of tight employment protection legislation when wages or internal training do not offset the higher adjustment costs.

Fig 27. Subjective and objective measures of economy-wide product market regulation, late 1990s



Note: A high number indicates a greater degree of regulation.
Source: Nicoletti and Pryor 2002.

Fig 28. Summary indicators of the strictness of employment protection legislation



Note: A high number indicates a greater degree of regulation.
Source: OECD Employmennt Outlook 1999.

The UK scores well on measures of regulatory burden[84] (Figs 27&28). But regulations are one instrument which Government can use to achieve its economic and social objectives, although there may be alternative approaches to achieve the same goal, e.g. use of taxes or subsidies which may have lower costs. Regulations can stimulate technological advances and create new markets[85]. Equally there are examples where overly proscriptive regulations and inadequate guidance have hindered firms' efforts to engage in innovation to meet the regulatory requirements[86]. Regulators also influence the operation of industries, particularly the privatised utilities. The use of price controls have led to rapid efficiency gains post privatisation, although their too rigid application over the longer term may reduce incentives to innovate by reducing the potential for returns. Equally the definition of what is an appropriate price to pay for a service may be difficult. For example should energy prices reflect short-run costs, as a result of competitive pressures, or long run costs which also make allowance for the maintenance of infrastructure?

Intellectual property rights

Intellectual property rights (IPR) provide incentives for innovators to invest in new products and processes by guaranteeing them a period where they can recoup a return from their investment unchallenged by their competitors. Patents are arguably one of the best incentive systems because they also help diffuse technology since they force innovators to disclose information regarding the underlying technology. However, IPR are not wholly costless. The exclusive rights they confer may distort competition and the efficient allocation of resources, particularly if the scope of protection is too broad or the period is too long. Diffusion of the technology, during which most of the economic benefits are realised, may be slower than otherwise.

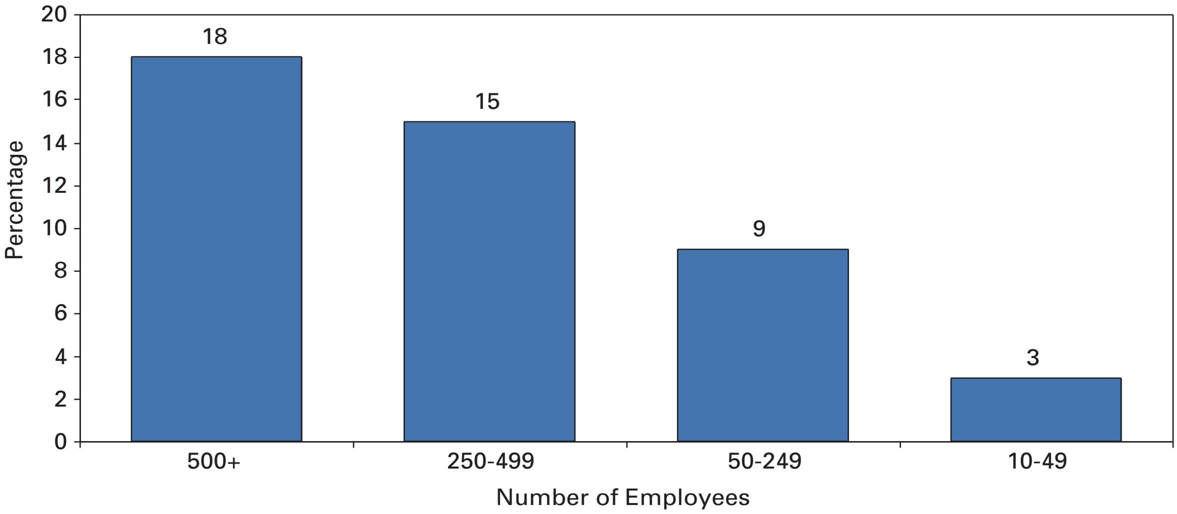
84 Nicoletti G and S Scarpetta, Regulation, Productivity and Growth: OECD Evidence, Economics Department Working papers no 347.

85 Though these should be seen as an unexpected benefit of the regulation, rather than the aim of regulations generally. For example we have regulations to cut pollution, despite costs on polluting businesses, because they reduce the costs to firms and others affected by the pollution. Not because we believe that the regulation would give the UK a lead in environmental technologies.

86 Innovation is best facilitated by regulations that define desired outcomes – rather than precisely how these outcomes are to be achieved – combined with clear implementation timetables and clarity on what is required to comply.

But formal IPR – such as patents – is only one of the means a firm can use to appropriate the benefit from investments in knowledge. If knowledge can be easily documented then it is patentable. If knowledge is difficult to replicate, for example because it is embodied in work processes or in staff skills, firms may seek to protect that knowledge using informal methods such as speed to market or secrecy.

Fig 29. Proportion of enterprises taking out patents by size



Source: CIS 1998-2000.

In knowledge intensive business services their key knowledge asset is embodied in their employees and informal methods of appropriating the benefit are likely to be the most important. The service is tailored to the client, hence confidentiality and measures to retain staff are generally more important than formal IPR, though copyright is important where the output has general applicability[87]. And there is some evidence from Europe that services are less concerned with imitation than manufacturing firms; the exception is software providers[88].

Generally data for the UK indicates that most firms do not place great deal of emphasis on formal methods protecting intellectual property. They appear to prefer to use informal methods because they are more cost effective[89]. Although large firms are more likely to (Fig 29) and there is a great deal of sectoral variation, both in terms of the proportion of firms taking out patents as well as the ratio of patents to R&D expenditure[90] (Figs 30, 31 & 32).

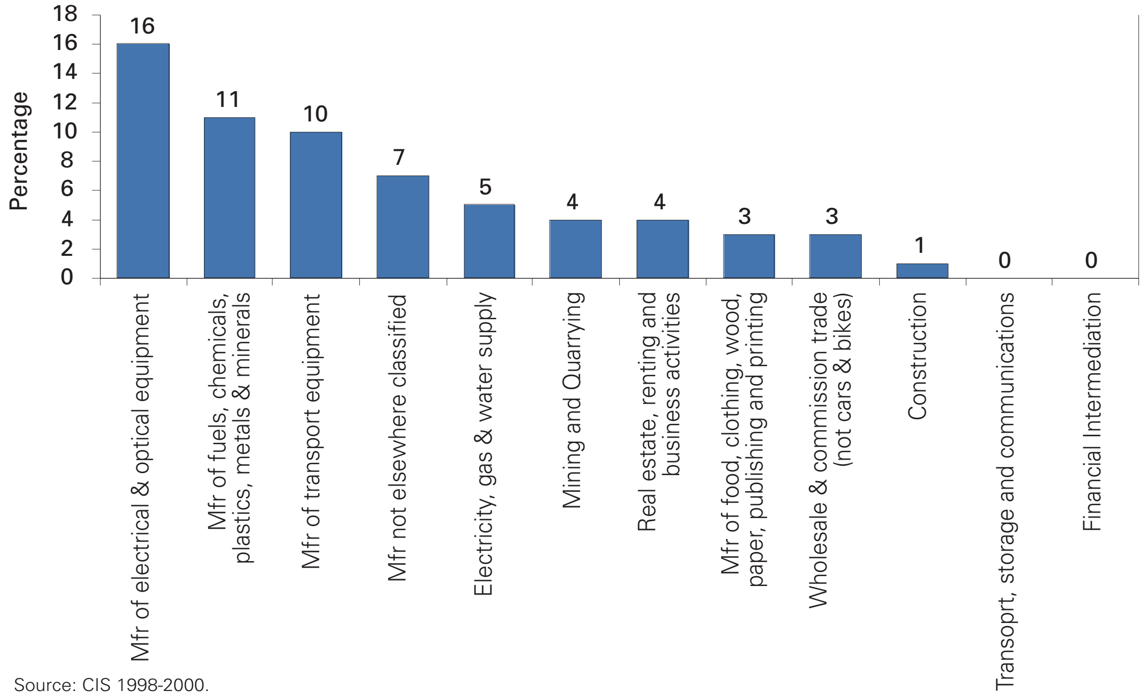
87 Andersen, Howells, Miles and Boden, Service Production and Intellectual Property, International Journal of Technology Management (1999).

88 Licht et al, Results of the German Service Sector Innovation, Manheim, ZEW (1997).

89 Blackburn and Kitchling, Managing Intellectual Property in SMEs: Experiences of Owner – Managers and Policy Implications, Paper presented to the DTI (1998).

90 Analysis in the 2003 R&D Scoreboard shows that there is significant variation in the ratio of US patents taken out per £10 m R&D expenditure for international companies in R&D active sectors. Firms in the electronic and electrical sector generate approximately 7 US patents per £10m of R&D spend compared to around 1 in Pharmaceuticals and Automotive sectors and 4 in Chemicals.

Fig 30. Proportion of enterprises taking out patents by sector



Source: CIS 1998-2000.

Although, improved productivity and market value are associated with taking out patents or trademarks, especially if the patents are highly cited by others taking out patents[91 92], other studies have shown that relatively few patents are valuable. One study found that in Europe half of all estimated value was accounted for by 5 – 10 per cent of patents[93]. Furthermore, the costs of identifying infringement and enforcement act as a deterrent. And licensing is generally unpopular because of the costs of negotiating terms and subsequently monitoring agreements[94].

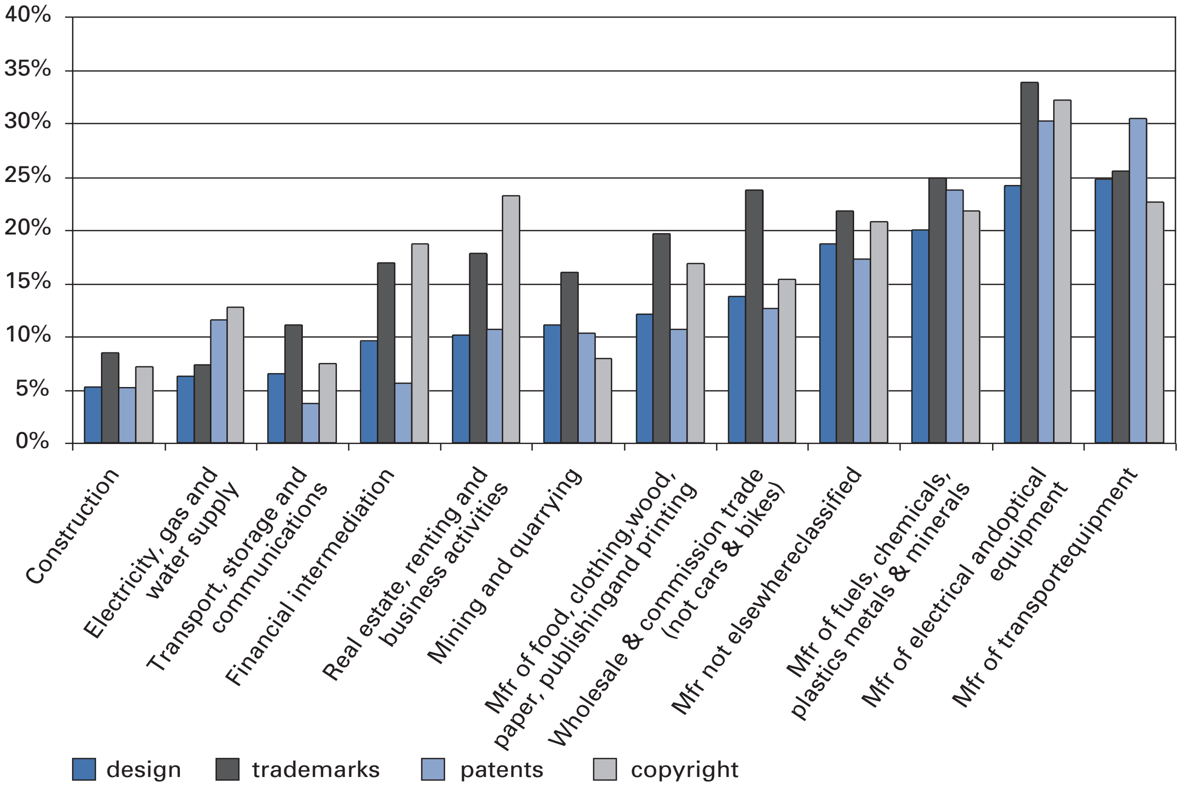
91 Greenhalgh and Longland, Running to Stand Still? – Intellectual Property and Value Added in Innovating Firms, Oxford Institute of Intellectual Property Working Paper (2002); Bloom and Van Reenan, Real Options, patents, productivity and market value: evidence from a panel of British Firms, IFS Working Paper 00/21 (2002); Hall, Jaffe and Trajtenberg, Market Valuation and Patent Citations, Conference in commeration of Zvi Griliches, (2001).

92 Cockburn and Griliches, Industry Effects and Appropriability Measures in the Stock Market's Valuation of R&D Investment, American Economic Review (1998); Bosworth, Wharton and Greenhalgh, Intangible Assets and the Market Valuation of UK Companies: Evidence from Fixed Effects Models, Oxford Institute of Intellectual Property Working Paper (2000); Dixon and Greenhalgh, The Economics of Intellectual Property: A Review to Identify Future Research Themes (2002).

93 Pakes and Schankerman, The rate of obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources (1986); Schankerman, How valuable is patent protection? Estimates by Technology Field, The Rand Journal of Economics (1998); Bureau of Industry Economics (Australia), The Economics of Patents, Occasional Paper 14 (1994).

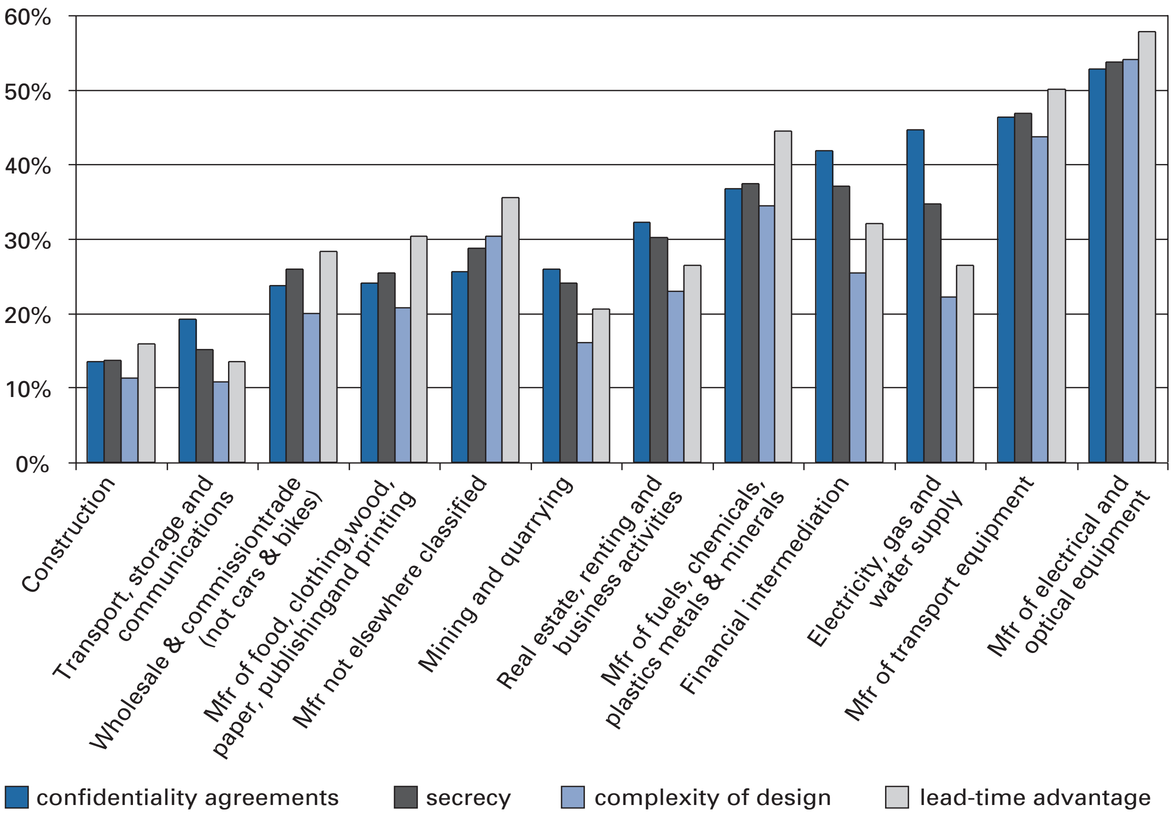
94 Pickering, Matthews, Wilson and Kirkland, The Strategic Management of Intellectual Property, NIESR Discussion Paper 129, (1998).

Fig 31. Proportion of UK enterprises who attach some importance to formal IPR, all sizes



Source: CIS 1998-2000.

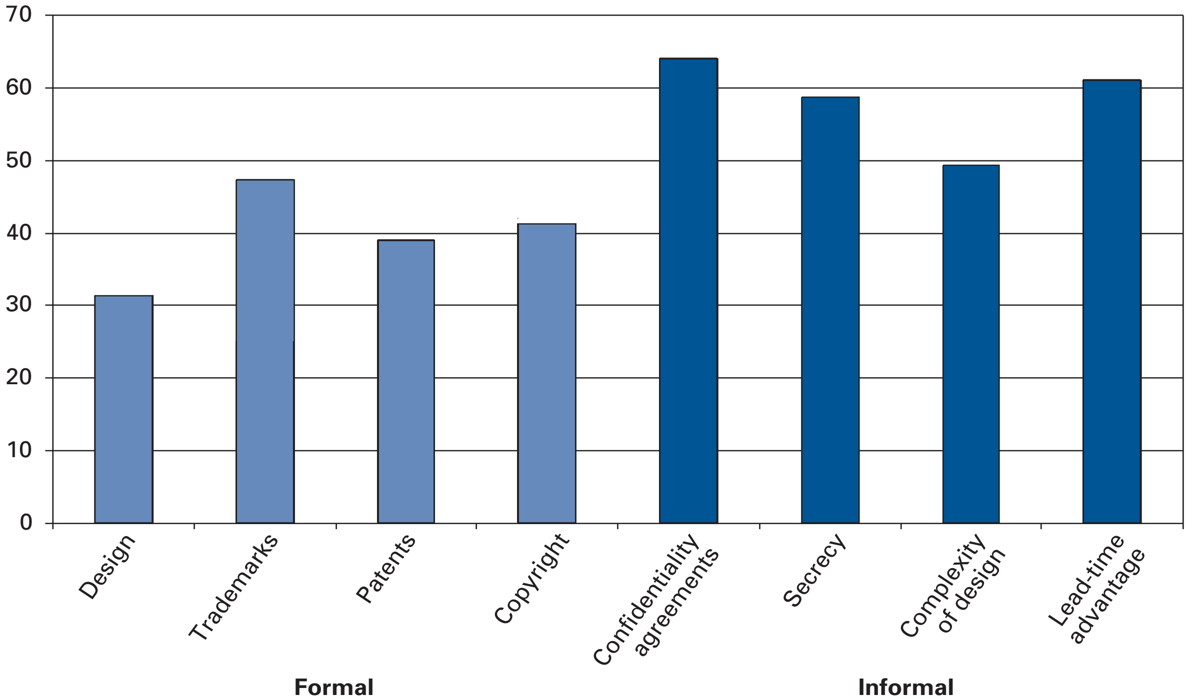
Fig 32. Proportion of UK enterprises who attach some importance to informal IPR, all sizes



Source: CIS 1998-2000.

But firms appear to base their decision on very limited information about the IPR system. One study shows that the majority of SMEs who don't patent, don't search patents, hence they don't know if their R&D will result in a product that they can make and sell[95 96]. SMEs do not generally use the patent system as a source of information although they are more likely to do so if they have taken out a patent[97]. However there is little evidence to suggest that not using patents as information sources has an impact on innovative activity.

Fig 33. Percentage of enterprises who attach some importance to IP protection - large firms (500+)



Source: CIS 1998-2000.

Like firms, universities appear to regard informal methods as the most appropriate and cost effective. They lack the resources to police and enforce IPR[98]. And they may lack the incentives to take out IPR as well although Government policies have tended to encourage IPR use. Universities' often lack the expertise to develop an IPR strategy,[99 100] and their expectations about the value of their IP are often unrealistic[101]. This can lead to additional barriers to Science – Industry collaboration. Excessive pressure on universities to commercialise their IP is also likely to hinder knowledge transfer and reduce the economic benefit derived from publicly funded research[102].

95 Blackburn and Kitchling, *ibid*, (1998).

96 Hall, Oppenheim and Sheen, Barriers to the use of Patent Information in SMEs, Final Report to ESRC (1998)

97 MacDonald and Lefang, Protection and Dissemination? The contribution of the Patent System to SMEs, Final Report to ESRC (1998).

98 Webster, University Spin – offs, SMEs and the Science Base: The Effective Use of IP, Final report to ESRC, (1998).

99 Pickering, Matthews, Wilson and Kirkland, *ibid*, (1998).

100 Gourlay, Hergreaves, McCraken, Seaton and Weyman – Jones, Comparative Study of Systems for IP Management in HEIs in the UK, USA and Germany (1998).

101 HM Treasury, Lambert Review of Business University Collaboration: Summary of consultation responses and emerging issues (2003).

102 Tether B & Swann P, Sourcing Science: The Use by Industry of the Science Base for Innovation; Evidence fro the UK's Innovation Survey, (2003).

The competition regime and entrepreneurship

Competition is a major driver of innovation in firms. At the same time innovation is one of the main ways in which entrepreneurial firms compete. The relationship between competition and innovation is interactive, complex and dynamic.

Some firms innovate in order to differentiate themselves from their competitors and enjoy a temporary period of enhanced market power and the ability to charge higher prices. In time competitors succeed in copying or surpassing these innovations and the market power is eroded. Really successful firms produce a sequence of innovations thus continually restoring the market power which competition continually erodes. The commercial success of each innovation provides the financial resources to fund its successors. Technological and commercial success are thus mutually reinforcing.

Most firms innovate or adopt new technologies in response to innovation by others or to counter some other competitive threat such as the entry of a foreign firm into the domestic market. Competitive pressures thus play a major role in stimulating the development and diffusion of new technologies.

This interactive process of competition and innovation varies in intensity and is driven by different forces in different sectors. It also varies in the same sector over time tending to be most intense in new industries with fast growing markets and technologies with the potential for rapid development. Many such industries start out with many firms but over time become dominated by a few large firms. Increased concentration may only affect the degree of innovation with a lag as firms, which are used to competing and innovating, take time to learn 'bad habits'. Indeed there are examples of sectors with a high degree of oligopoly where innovation is if anything on the excessive side.

Firms may use innovation to preserve their market position and keep actual or potential rivals at bay. Indeed a monopolist may spend heavily on innovation in order to make it difficult for new firms to enter the market. At the same the development of radical new technologies, products, processes and services may enable a firm to break into an market and overcome the competitive advantage previously enjoyed by incumbent firms. In particular so-called disruptive technologies which incumbent firms find difficult to adopt can provide the means by which new entrants can achieve a major market share in a relatively short period of time.

Of course technological innovation is not the only means by which firms compete. Michael Porter argues[103] that many UK firms are good at competing by means of cost cutting and increased efficiency. Such an approach may involve incremental improvements in business processes and the adoption of existing technologies that are new to the firm. But it is less likely to involve the investments in in-house technological capabilities, human capital and other intangible assets which are necessary if the firm is to be able to adopt a more radical innovation strategy in the future. Indeed the elimination of such investments may be a central plank of a cost-cutting strategy. Competition of this kind between UK firms in a sector will eventually leave them ill equipped to cope with a major new competitive threat from outside, originating either from novel technology or the entry into the market of firms from low wage countries. In Porter's view this is not the kind of strategy which UK firms should be adopting from now on.

103 Porter M E and C H M Ketels, *ibid*, (2003).

There is usually no simple way of demonstrating the relationship between the competition and innovation in any given situation or what policy action, if any, is appropriate. Static economic models offer no conclusive answer to the question of whether competition is conducive or harmful to innovation. At one extreme are models where more monopolistic firms are more active in innovation because of less market uncertainty and high profits. Greater competitive pressures would reduce their incentives to invest. At the other extreme are models where competition forces firms to innovate to survive. An intermediate position is also possible. At low initial levels of competition, increases in competition stimulate innovation. At some point however increasing competition erodes the rents from innovation reducing the incentives to innovate. This leads to an inverted U shape relationship between innovation and competition.

A recent OECD review of the extensive literature concludes that the positive impact of competition-enhancing policies cannot be appreciated by concentrating on short run static efficiency gains. "Competition has persuasive and long lasting effects on economic performance by affecting economic actors' incentive structure, by encouraging their innovation activities and by selecting more efficient ones from less efficient ones over time."[104] This points to the importance of a dynamic market where entry and exit and the differential growth of firms is part of the selection process for successful innovations. Market exit occurs when firms innovate unsuccessfully, or where they lack the competencies to produce goods and services profitably in the long run. Entry occurs when an entrepreneur is able to innovate by combining firm specific capabilities with inputs to produce a good for which there is a demand. Differential growth occurs when more profitable firms can expand their market share at the expense of their less innovative rivals. This process results in the 'churning' of firms and a shift in resources from the least to the most efficient, leading to improvements in productivity growth. So, an effective competition policy will, by enabling the entry and exit of firms, therefore encourage innovation[105]. Conversely, well-targeted interventions to increase the innovative capacity of firms could increase competition[106].

The international empirical evidence suggests that the link between innovation and competition is positive. Although there are difficulties in finding measures of competition, which are independent of market structure[107], and in defining the actual market. The OECD review cited above finds that claims that market concentration is conducive to innovation are not supported by recent empirical findings and that there is little support for the view that large firm size or high market concentration is associated with a higher level of innovative activity. The UK evidence supports this[108].

104 OECD, Competition, Innovation and Productivity Growth: A Review of Theory and Evidence (2002).

105 It is sometimes argued that ex ante market power, conferred by industrial concentration, promotes R&D but a recent survey concluded that empirical research offers little support for this view. See W Cohen, 'Empirical Studies of Innovative Activity' in P Stoneman (ed), Handbook of the Economics of Innovation and Technological Change (Oxford, 1995), pp 182-264.

106 Harris R and C Robinson, A Critical Review of Empirical Research on Hindrances to Business Development and Productivity Growth and the Relative Importance of Different Constraints on UK Business, Report to DTI, April (2001).

107 Concentration ratios (e.g. share of the market held by top 5 firms) are often used as an indicator of competitive conditions. With high ratios assumed to reflect weaker competition pressures. But at least one study has shown that an increase in competition is likely to result in an increase in the concentration ratio as the more marginal producers are forced to leave the industry. See Symeneonidis G, The Effects of Competition, Cartel Policy and the Evolution of Strategy and Structure in British Industry, MIT press (2002).

108 One study based on a panel of UK manufacturing firms between 1972 and 1982 found that while it is the firms with larger market share who are most likely to innovate, the effect of competition on innovation is positive (Blundell et al (1999) market share, market value and innovation in a panel of British manufacturing firms, Review of Economic Studies, vol 66, pp529-54.). Another study finds little evidence that market power leads to greater innovation. Using data on 1950's Britain they find that price fixing agreements prior to the 1956 Restrictive Practices Act had little impact on innovation and adverse effects on costs and productivity (Broadberry S and N Crafts (2000) Competition and Innovation in 1950s Britain, working paper in Economic History no 57, London School of Economics.). Using survey data, covering firms with less than 500 employees, another study finds that a high level of domestic competition is positively correlated with the probability of innovating. The study does find some evidence of a negative correlation at high levels of competition, which is principally a foreign competition effect (Kitson M, J Michie and M Quinn (2001) Markets, Co-operation and Innovation, University of Cambridge working paper No212.). Using data on UK firms patenting activity at the US patent office, one study provides evidence for an inverted U relationship between innovation and competition. It also finds that firms facing a higher threat of bankruptcy tend to innovate more on average, especially at lower levels of competition (Aghion P, N Bloom, R Blundell, R Griffith and P Howitt, Competition and Innovation: an inverted U relationship, NBER working paper 9269.(2002)).

Most of the empirical evidence[109] suggests that innovation in the UK may have been adversely affected by low levels of competition and, potentially, weaknesses in corporate governance systems[110]. As a result UK firms have been under less pressure to use new technologies and to find new ways of improving their performance[111]. This may have resulted in UK managers being less willing to set up new businesses. Thus possibly explaining why entrepreneurship rates in the UK are at best moderate despite some important advantages in the business and regulatory environment (e.g. the cost and time taken to start a new firm in the UK is below the average for major industrialised economies)[112]. The effects of reforms to competition policy – the 1998 Competition Act and the 2002 Enterprise Act – are likely to take time to feed through. But a recent review by competition experts placed the UK in the top half of its peer group, behind Germany and the US, but ahead of the rest of the OECD[113].

Government can adopt a range of policies which can enhance competition. Competition policy can remove impediments to market entry, prevent excessive concentration and take action to prevent a variety of unfair or undesirable practices which firms adopt in order to shield themselves from competitive pressures. However competition policy cannot directly affect the intensity with which firms compete and the means by which they do so. Other policies including those concerned with entrepreneurship and new firm creation, regulation, education and training, public procurement and innovation policy itself can all influence in one way or another the ability and/or the incentive which firms have to compete.

In applying their powers the competition authorities also have an influence. They have to be aware of the complexities in applying competition principles to industries where competition is primarily innovation driven and based on the introduction of new products and processes rather than price. The authorities need to focus on trying to ensure that an undistorted process of rivalry takes place and in particular that it is not threatened by existing monopolists trying to deter rivalry. Where innovation is the driving force, anti-competitive agreements and behaviour can stifle innovation by making new entry more difficult, more costly and more likely to fail[114].

Access to finance

Finance for innovation is usually from internal sources – cash flow. However, for more substantial investments external finance may be sought. Markets may under-invest in investment projects. Levels of uncertainty are high and difficulties in assessing future cash flows means that the manager will have a much better idea about performance than outside investors. Outside investors may not trust the manager of the risky project to undertake activities that are in their best interests. Or investors find it difficult to identify good projects. Recognising this, good managers may sacrifice longer-term projects to provide higher short-term returns that less able managers cannot match. As a result more profitable long-term investments (e.g. R&D) would be sacrificed leading to under-investment. Economic theory[115] can therefore justify claims that investors and managers take short-term attitudes to investments in innovation.

109 One study finds that increasing competition has been an important factor in narrowing the total factor productivity gap between British and German firms since 1970s (Crafts N and TC Mills (2001) TFP growth in British and German manufacturing. ESRC programme Business Cycle Volatility and Economic Growth, Research Paper no 01/3.). Another shows that the existence of restrictive trading agreements reduced British industries' productivity growth between 1954 and 1963 (Broadberry S N and N F R Crafts (1996), 'British Economic Policy and Industrial Performance' Business History, Vol 38 No 4, pp 65-91.). Although there is conflicting evidence, which suggests there is no link between innovation and competition. Symeonidis G (2000) price competition, non price competition and the market structure. Theory and evidence form the UK, Economica, 67 (267), August pp 437-456.

110 Aghion P, M Dewatripont and P Rey, 'Corporate Governance, Competition Policy and Industrial Policy', European Economic Review, 41, pp 797-805 (1997). In the absence of a dominant external shareholder and where shareholders find it difficult to monitor managers, principle agent problems may result in particularly conservative firms which face less of an incentive to innovate.

111 S, Nickell and J. Beath, The Economic Record of the Labour Government, Oxford Review of Economic Policy (2002).

112 DTI, Productivity and Competitiveness indicators: Update, (2002).

113 Price Waterhouse Coopers, Peer Review of the UK Competition Regime, report to the DTI, (2001).

114 Charles Rivers Associates, Innovation and Competition Policy, Report presented to the Office for Fair Trading, March (2002).

115 For a review of the main models incorporating asymmetric information effects see Finance and Technical Change by Alan Goodacre and Ian Tonks, a chapter in the Handbook of the Economics of Innovation and Technological Change, Edited by Paul Stoneman, Blackwell (1995).

However if the economic models that support claims of short-termism are true then all firms – wherever located – should have similar problems in trying to communicate the benefits of potential projects to investors. Some argue that other national innovation systems – e.g. Germany – allow better information flow between investor and firm because of their different system of corporate governance (with Bank representatives sitting on company boards for example). But even under these systems, firms still report difficulties[116]. Nor does it explain why countries like the US, with apparently similar financial systems to the UK, deliver higher levels of R&D spend.

Although firms rate financing constraints as a significant barrier to innovation[117] the most recent CBR research suggests that when firms seek external finance they generally get it – and usually from banks[118]. Innovators are as likely to receive finance as non-innovators. Only 10% of the CBR firms were unsuccessful in obtaining external finance although older and larger firms tend to be more successful than smaller firms[118]. This should not come as a surprise since we would expect firms with a track record to be more successful. In general terms then, whilst UK firms may under invest in innovation related activities, it is unlikely that access to finance is the main reason[120].

Given the levels of uncertainty involved in the innovation process it is likely that, on occasion, investors take a cautious attitude to investments in innovative firms. This is reasonable. The issue for Government is simply whether the problem is particularly worse in the UK and whether it can improve upon the status quo.

Looking at the supply of finance it is difficult to argue that, generally, there is a shortage of finance for innovation. UK capital markets are well developed and equity markets are extremely strong. With a market capitalisation of £1523 billion the London Stock Exchange is one of the largest in the world. Apart from it, which tends to focus on the needs of larger firms, the UK also has secondary markets, such as AIM and OFEX, and private equity which acts as source of finance for smaller firms. The UK private equity industry continues to be the largest and most developed in Europe, accounting for 29% of total annual European Equity investment in 2001. The next largest industries are Germany (18%) and France (13%)[121].

Private equity

Private equity means the equity financing of unquoted companies at many stages in the life of a company from start up to expansion or even management buy outs or buy ins of established companies. Venture capital is a sub-set of private equity.

Source: BVCA

116 Firms in Germany do report difficulties in getting long-term partners to finance R&D and the acquisition of intangible assets. This may be due to the absence of instruments to spread risk, such as well developed equity markets. For example see the chapter on Germany in Technological Innovation and Economic Performance Edited by Benn Steil, David G Victor and Richard R Nelson. Princeton (2002).

117 For example, the second Community Innovation Survey showed that 10% of UK firms reported that they lacked appropriate sources of capital or that the cost of finance was a constraint on innovation. This figure was around twice the European average, and financial constraints disproportionately affected higher technology businesses. According to the CBR survey economic factors – such as costs of finance or length of payback period – tend to rank mostly highly as barriers to innovation.

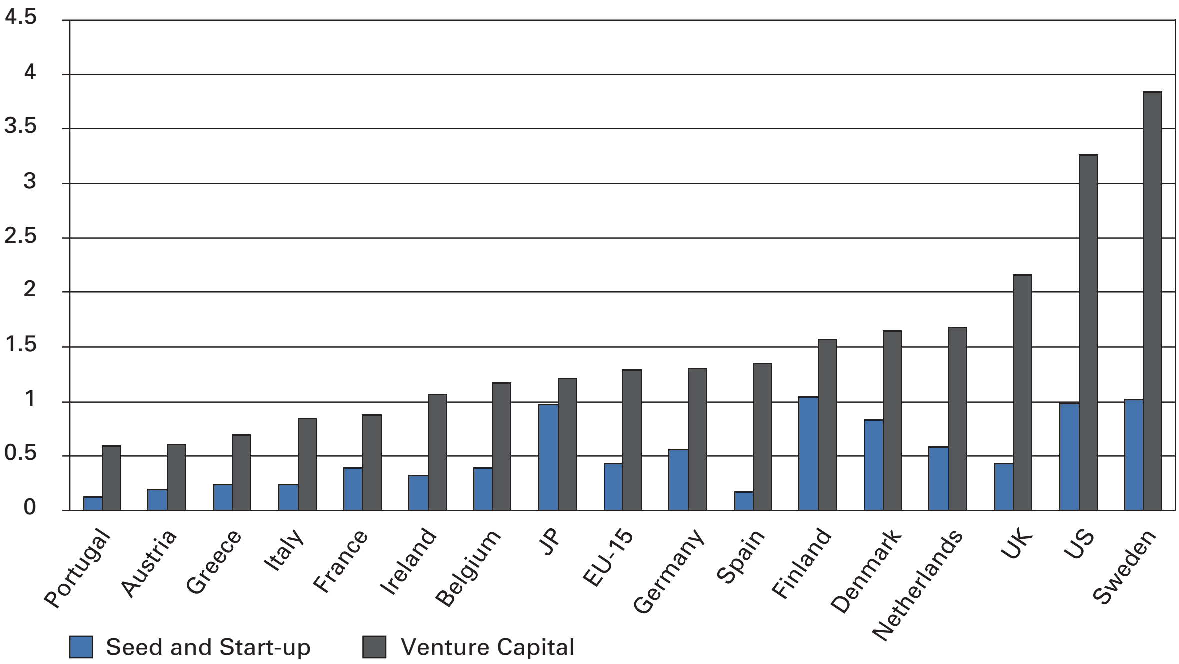
118 Cosh A and A Hughes, Enterprise Challenged: Policy and Performance in the British SME Sector 1999-2002, ESRC Centre for Business Research, University of Cambridge (2003).

119 For SMEs, CBR show that the most important source of finance is banks. 79% of firms seeking finance do so from banks with less than 10% of firms seeking finance from all other sources apart from HP/leasing businesses. Their analysis of failure rates showed that whilst a statistically significant proportion of bank finance applications failed, this was not surprising given the volume of bank finance relative to other sources. Taking account of this, CBR show that failure rates are higher for venture capital. Firms of different sizes also have different patterns of financing. Venture capital is more likely to be sought by larger firms. Micro firms are more likely to seek finance from banks and are more likely to fail to obtain it.

120 Researchers have also used R&D data to test for the existence of financial constraints. If firms are financially constrained, because of imperfections in capital markets, they would be unable to attract sufficient external funds and would be reliant on internal funds to finance investment in R&D and this should result in the level of R&D spending being sensitive to changes in internal finance. Overall the results of empirical studies are inconclusive. See Becker B and N Pain, What Determines Industrial R&D Expenditure in the UK? National Institute of Economic and Social Research, working paper (2002).

121 British Venture Capital Association, The economic impact of VCTs (2003).

Fig 34. Venture capital investment as % of GDP in 2001



Source: Third European Report on Science and Technology Indicators, 2003.

Venture capital (VC) is one source of private equity. The UK VC market is large (Fig 34) and funds tend to focus on highly profitable, and productivity enhancing, management buy-outs[122] rather than start-ups, which are considered riskier and less liquid[123]. The volume of finance invested in early stage deals is consistent with the longer-term risk-reward profile[124]. And transaction costs are relatively high for early stage deals which require smaller investments, given the high due diligence such investments need. This is reflected in the distribution of deal sizes. The majority of venture capital deals are clustered in the range of £200k – £5 m[125]. Fewer transactions occur below the £200k threshold (around 20%). In the UK support for start-ups and early stage businesses, which require smaller amounts of capital, is seen as a valid target for Government support (e.g. through subsidised Venture Capital)[126].

However regulations may have played a role in reducing the supply of private equity. Major institutional investors in the UK have tended to invest less in VC compared to their US counterparts – most probably because financial regulations[127] biased investment against private equity. Problems of illiquid investments – in part caused by relatively fragmented and under-capitalised European second tier stock markets – have also reduced the attractiveness of private equity to institutional investors.

122 Research cited in the Myners report also suggests that MBOs generate sizeable one off productivity effects. This suggests that the discipline of private equity forces companies to capitalise on under-utilised assets. See Thompson and Wright, 'Management Buy Outs in the Short and Long Term', Journal of Business Finance and Accounting (1995).

123 Poor investment returns in the early 1980's led to a migration away from early stage finance in the UK. Some respondents to the Myners review suggested that poor returns were in part due to channelling investment through the major clearing bank's own in-house equity firms which hindered the development of a diversified equity portfolio and reduced competition between firms.

124 Bank of England, Financing of Technology Based Firms, Bank of England (2001).

125 OECD, Venture Capital Country Note: United Kingdom, (2002).

126 HM Treasury, Small Business Service, Bridging the Finance Gap: a Consultation on Improving Access to Growth Capital for Small Business (2003).

127 The 1986 Finance Act excluded the majority of UK pension funds from investing directly in private equity funds. In addition the Minimum Funding Requirement – which came into force in 1997 – required schemes to hold a minimum level of assets, mainly government debt, to meet liabilities.

Turning to the demand for finance, it is likely that poor performance in other parts of the innovation system results in businesses having fewer innovative projects. For example skill deficiencies – amongst management and the workforce – is likely to have a detrimental effect on the development, implementation and financing of innovation strategies. According to the second CIS, businesses cite shortages of technical and management skills as important constraints to innovation.

A past history of macro-economic instability has probably affected investment incentives. It in part explains why UK firms have tended to face, on average, higher costs of capital, particularly for R&D projects[128]. This instability raised real interest rates and increased uncertainty, reducing incentives to invest and to plan for the long term. One study suggests that, for every permanent one percentage point rise in real interest rates, the volume of business R&D expenditure is reduced by 12.5%[129]. This suggests that reforms to monetary policy since the mid 1990s, such as independence for the Bank of England, could in time have a significant impact on innovation performance. For example, there is evidence to suggest that the real rates of return required by companies to justify investments have fallen since 1994[130].

UK companies also tend to prefer corporate strategies which focus on mergers and acquisitions, rather than organic growth[131]. For example, UK owned firms spend a larger share of value added on both dividends and acquisitions than firms in other European countries[132]. And UK owned firms across R&D active sectors tend to spend more than twice as much on acquisitions as they invest in R&D and capital expenditure. The ratio for US firms is around 0.6[133]. A recent review[134] noted that performance metrics for UK fund managers were based on short run indicators and 'peer group' benchmarks provided incentives to herd. This could lead to fund managers rationing finance for longer-term projects[135].

Tax regimes also affect firms and individuals incentives through their ability to retain income to invest in new ventures. Overall, however, it is difficult to believe that this is a major factor. The UK system of business taxation, including capital gains tax, is generally competitive. Levels of tax are slightly lower than in many other advanced economies, although this advantage has decreased in recent years[136]. Up until recently the UK's tax treatment of R&D investment was – by international standards – ungenerous. New R&D Tax Credits, however, provide an incentive comparable to, or better than, many other major OECD countries (Fig 35). It is however too soon to assess the actual impact of recent UK tax changes on R&D investment.

128 See Coopers and Lybrand, Final report for the Study of International Differences in Cost of Capital for the European Commission, April, Brussels, European Commission (1993) and McCauley Robert N and Steven A Zimmer Explaining International Differences in the Cost of Capital Federal Research bank of New York Quarterly Review Summer: 7-28 (1989).

129 Becker B and N Pain, *ibid*, (2002).

130 Godden G, Investment Appraisal in UK Manufacturing: Has it Changed Since the Mid 1990s? CBI discussion paper (2001).

131 See Bond S, C Meghir and F Windmeijer, Productivity, Investment and the Threat of Takeover. Mimeo, Institute for Fiscal Studies, London (1998). The evidence suggests that the threat of takeover forces managers to institute changes to improve total factor productivity, particularly if the threat is hostile.

132 DTI, The Value Added Scoreboard (2003).

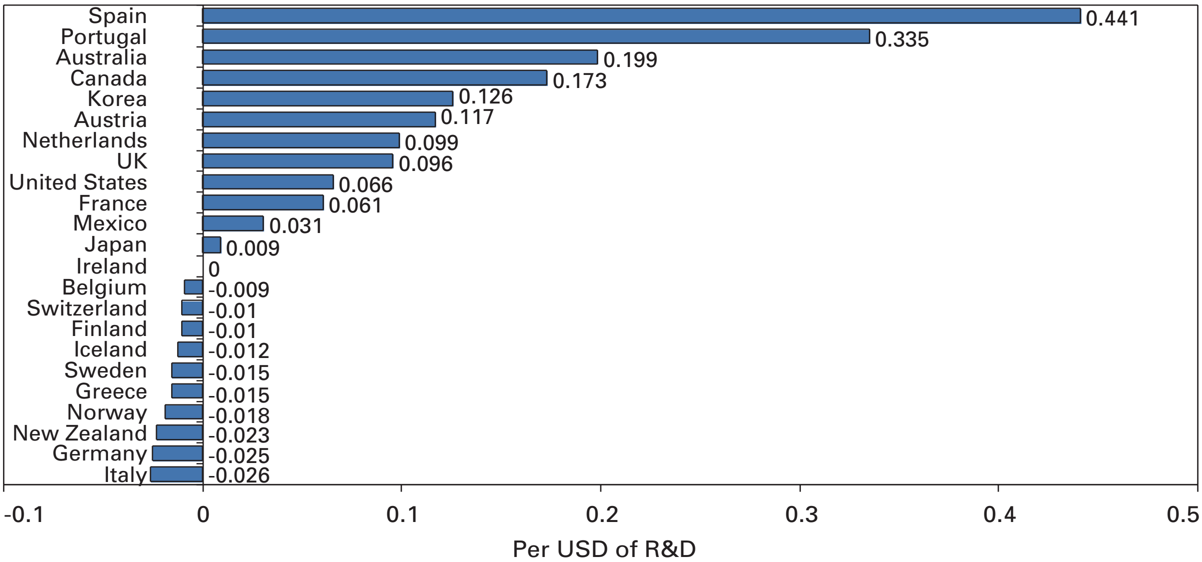
133 DTI, The R&D Scoreboard (2003).

134 See Myners review of institutional investment, HM Treasury website.

135 Recent experience however suggests that pressures to be part of the herd may on occasion outweigh pressures to achieve short run returns. For example the 'irrational exuberance' as investors brought into IT related stocks, which did not offer the prospect of immediate cash flows, in response to rapidly increasing prices.

136 Porter ME and CHM Ketels, *ibid*, (2003).

Fig 35. R & D tax subsidies in manufacturing companies per USD of R&D, 2001 - Large Firms



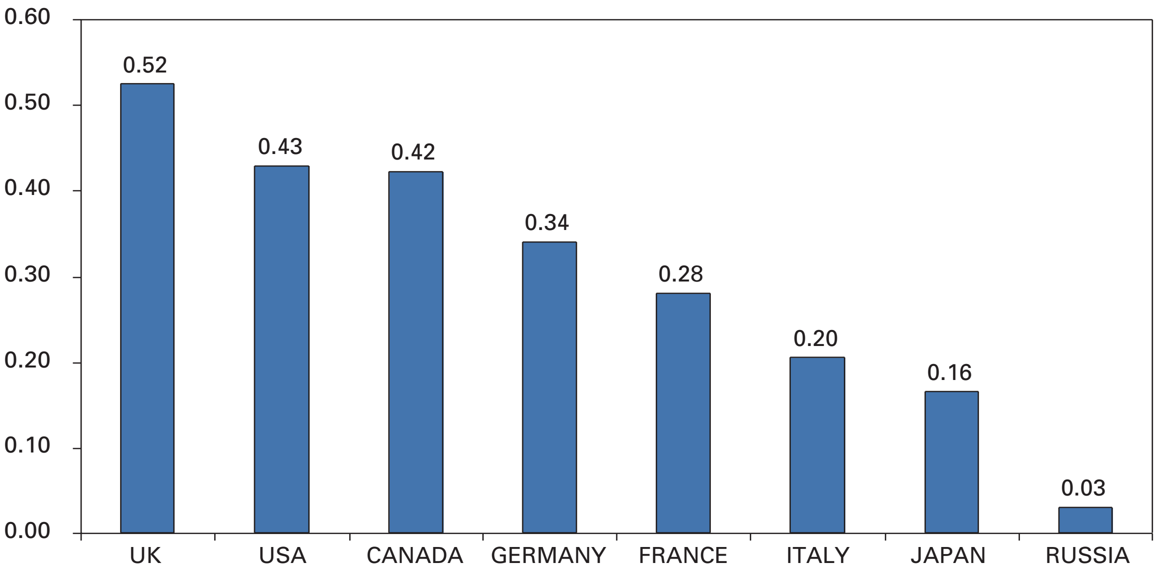
Source: OECD.

Sources of new technological knowledge

SCIENTIFIC AND TECHNOLOGICAL KNOWLEDGE

Science and technology is one source of knowledge for innovation, although it will often need to be complemented by others – such as knowledge of business organisations or market opportunities – before it delivers economic benefits. The ability to combine these different sources of knowledge rests with entrepreneurs whose role is to apply that knowledge to solve problems or exploit opportunities.

Fig 36. Citations per 1000 population, 2002



Source: Evidence Ltd/Thompson ISI.

Despite lower levels of funding compared to our major competitors the UK science base has been extremely successful[137]. The quality is high compared to its G7 competitors as demonstrated by a share of citations second only to the US[138]. Although Germany and Japan are catching up[139]. The UK leads the G7 in terms of citations relative to both population and gross expenditure on R&D (Fig 36). This performance is probably not sustainable in the long term[140]. Slower real growth in spending between 1986-1997 has put pressures on the infrastructure, although increased funding for university physical capital and for Research Councils should go someway to addressing this[141].

Knowledge generated by publicly funded basic research has a large positive payoff when it or resulting technologies and skills are disseminated within firms[142]. A recent study by the OECD found that 1% growth in public R&D leads to a 0.17% increase in total factor productivity in the long run[143]. Another found at least a 30% return to public R&D in pharmaceuticals[144].

Public R&D is a complement to private R&D efforts[145]. Firms use public R&D to provide underpinning knowledge and as a source of new ideas. Industry values the Science, Engineering and Technology Base for the indirect benefits it receives – for example trained staff[146]. The proportion of enterprises that cite the Science, Engineering and Technology Base as an important direct source of knowledge tends to be low in the UK (and across Europe) and a few universities tend to account for most university-industry interaction[147]. In these cases the biggest benefits arise from a more intense relationship – cooperating with universities and Government Research Organisations is more beneficial than using them as a source of information[148]. Furthermore, the importance of university – industry links differs for process and product innovators. Process innovators find universities an important source of information and are more likely to cooperate with them than clients, competitors and consultants. Product innovators are benefit from information closer to the market. However, there may be exceptions, such as biotechnology and other strongly science based industries.

Most would agree that science is an important part of the innovation process, but that the link between the two is not a seamless, single – direction production line between university and firm. Information about science and technology travels through the economy via indirect channels such as from HEIs to users via intermediaries or labour markets. Firms also draw on the knowledge of clients and customers, suppliers and competitors, who in turn also draw on scientific knowledge[149].

137 Evidence, PSA Target Metrics for the UK Research Base, Draft Report to the DTI (2003).

138 In 1999, with only 1% of the world's population, the UK produced 8% of the world's scientific research papers. UK scientific publications are also one of the most heavily cited – attracting 9% of all citations in 1999. The UK leads France and Germany and rivals the US and Canada in terms of papers and citations per head.

139 There is some variation by discipline. In terms of share of citations, the UK is behind the US and France for Mathematics, and behind the US, Germany and Japan for both Physical Sciences and Engineering. In terms of citations per paper the UK remains second behind the US and ahead of an improving Germany. The discipline level performance changes slightly.

140 HMT, DfES, DTI and OST, Cross – Cutting Review of Science and Research (2000)

141 DTI/OST, Science Budget 2003 – 04 to 2005 – 06 (2002)

142 Griliches Z, R&D and Productivity in P Stoneman (ed), Handbook of Industrial Innovation, London, Blackwell Press (1995).

143 Guellec and van Pottelsberghe de la Potterie, R&D and Productivity Growth: Panel data analysis of 16 OECD countries (2001).

144 Cockburn and Henderson, Publicly Funded Science and the Productivity of the Pharmaceutical industry. NBER Conference on Science and Public Policy (2000).

145 David, Hall and Toole, Is Public R&D a Complement or Substitute for Private R&D? A Review of Econometric Evidence. Research Policy (2000).

146 Nelson R.R Institutions Supporting Technical Advance in Industry, American Economic Review, 76, 186-9 (1986).

147 Between 1997 and 1998 the top 10 UK universities accounted for 43% of total industrial research income. OECD 'Benchmarking Industry Science Relationships' OECD, Paris (2002).

148 Swann P, Innovative Business and the Science and Technology Base: An analysis using CIS 3 data, A report for DTI (2002).

149 Swann P (2002) Innovative Businesses and the Science and Technology Base, Report to DTI, October.

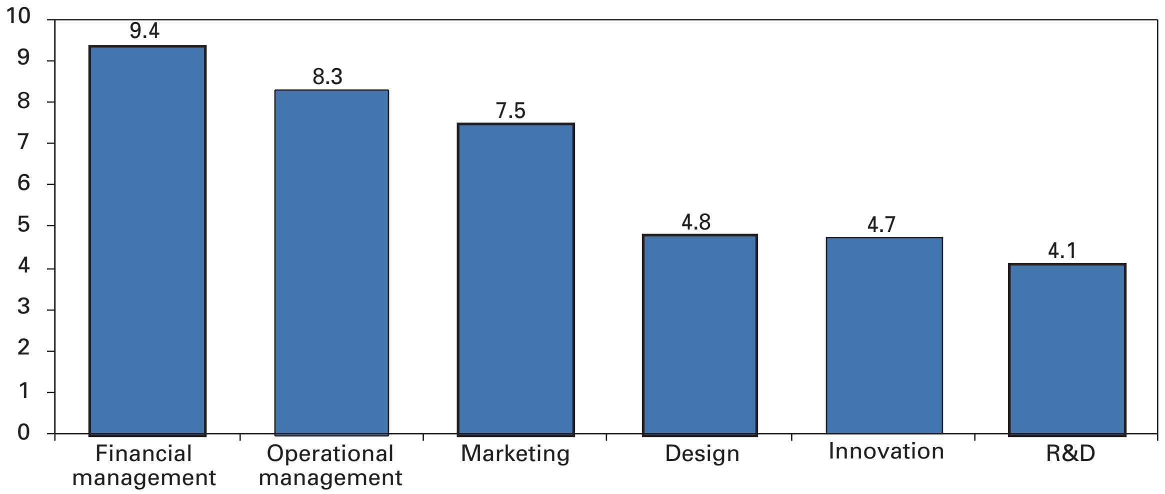
But successful knowledge transfer between the publicly funded science base and firms depends upon firms possessing the relevant competencies. Most studies suggest that the benefits from knowledge transfer are directly proportional to a firm's own investments in innovation.[150] Relatively low levels of innovation investment therefore probably mean that UK businesses are, compared to their major competitors, less well placed to exploit research carried out in the UK Science, Engineering and Technology Base. Weaknesses in skills are another barrier to successful knowledge transfer.

Design

The use of design helps identify problems and develop, test and evaluate solutions. The effective use of design can link emerging technologies to market opportunities and add value to goods and services. The UK has an internationally renowned design consultancy sector[151] with expertise across all design disciplines. Design education in the UK also ranks highly.

In the context of the innovation process design ensures that all thinking within that process is focused around the end user – the customer. It is most valuable at the start of the innovation process, before the decisions have been made and before the costs become prohibitively high. It is this early involvement that reduces the risk of the innovation failing at a later stage. As a result firms tend to rate design as equally important as innovation to their success[152] (Fig 37).

Fig 37. Importance of functions to firm success



Note: Rating 1 – 10 where 1 is not at all important and 10 is crucially important.
Source: Design Council National Survey, PACEC 2002.

150 SPRU (2000) 'Talent not Technology: the impact of publicly funded research on innovation in the UK'.

151 There are 3,700 design consultancies in the UK with a turnover of £5.9 billion and overseas fee income of £1.4 billion.

152 A number of studies indicating a link between design expenditures and economic performance are cited in Design Council (2003) The value of design within innovation, Design Council briefing for the DTI: Innovation Action Plan, April 2003.

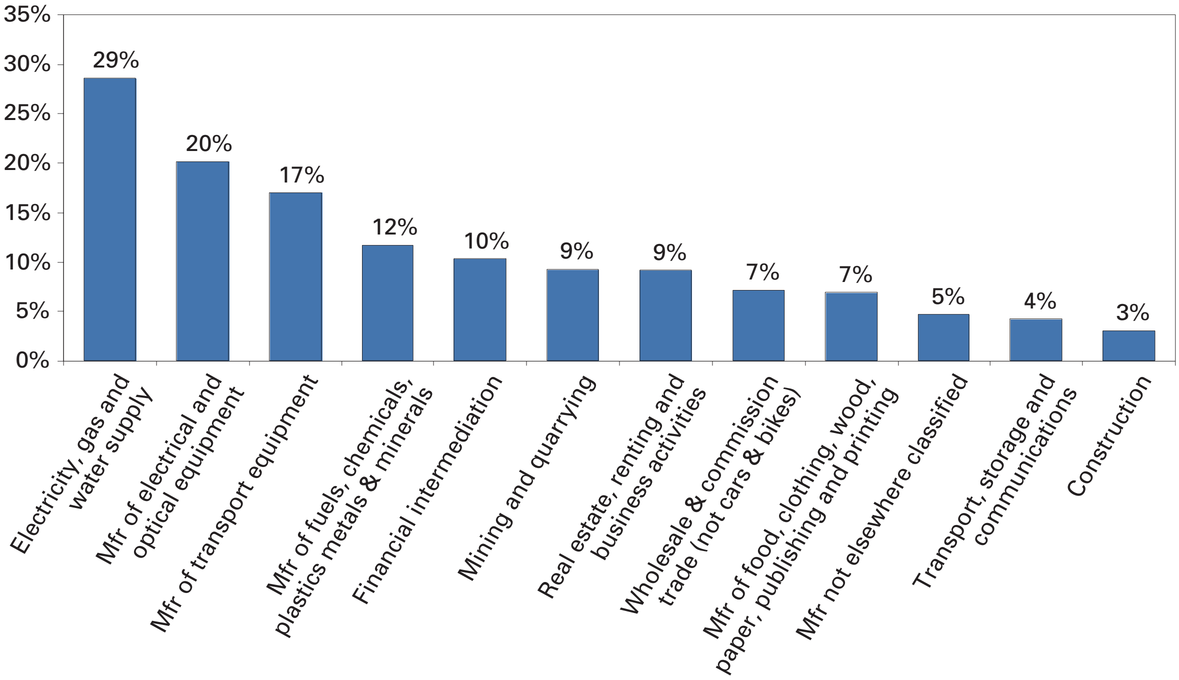
Investments in design can help businesses to compete more on quality and less on price, helping it to be less vulnerable to competition from low cost producers. However, while many firms use design, they are less likely to use it in a strategic way – by incorporating good design across the business in its goods and services, company processes and systems, its working and retail environments and its brand management and marketing[153]. According to the Community Innovation Survey only 17% of enterprises, disproportionately larger ones, report having some expenditure on design which is ultimately directed to a product or process innovation.

Networks and Collaboration

During the course of the innovation review new research[154] was commissioned to assess the evidence base concerning innovation and networking in the UK. This involved a systematic review of the most significant, judged by quality, papers. The researchers considered that the field of existing research had limitations – it covered a large number of subjects, in many disciplines, but lacked critical mass. The study of networking tends to be overly weighted towards high tech industries with only a limited focus on other areas of manufacturing or services. Overall however the evidence suggests that networking plays a pivotal role in innovation, increasingly so as technologies become more complex. But networks are not a panacea (see Annex E for a brief review of how clusters, one form of network, affect business performance).

UK firms appear to have strong network relationships although there is variation between sectors (Fig 38). Innovative UK firms collaborate on innovation projects to a similar extent to firms in other large EU countries (Figs 39&40).

Fig 38. Percentage of UK firms that had some co-operation arrangements on innovation activities

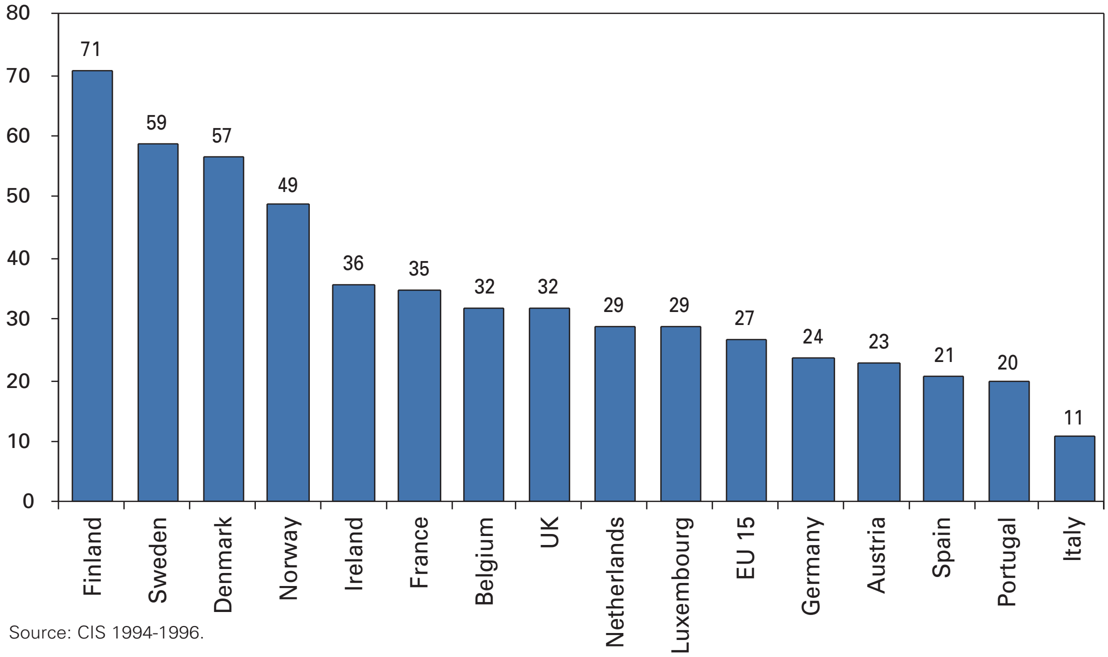


Source: CIS 1998-2000.

153 For example whilst 74% of SMEs believe design is integral or significant to their operations, only 36% used it as a strategic management tool. PACEC National Survey (2002).

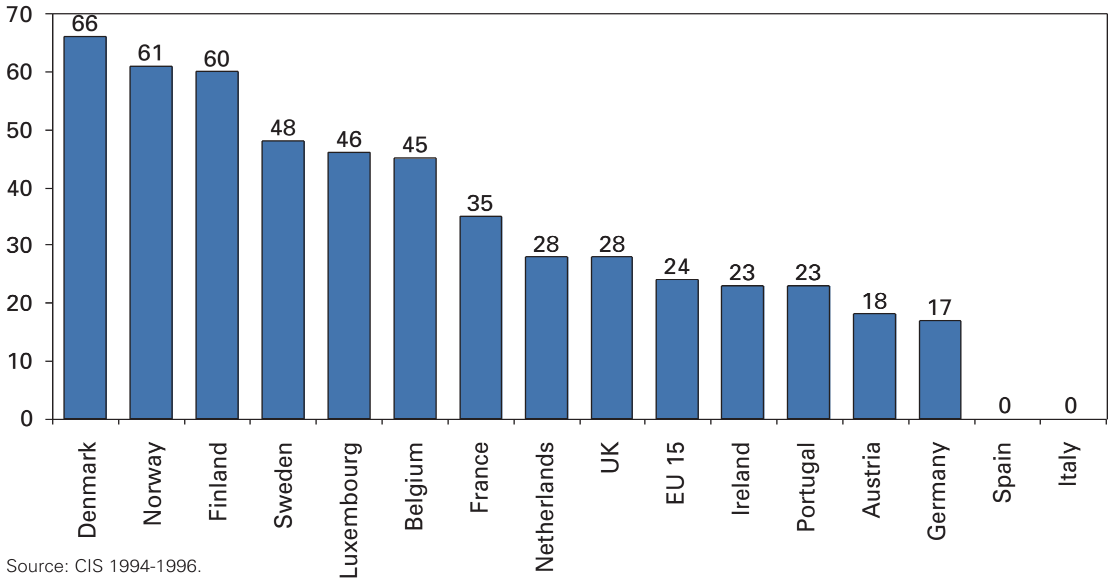
154 Pittaway L, R Robertson and K Munir, Networking and Innovation in the UK, A systematic review of the evidence, AIM management research forum, August (2003).

Fig 39. Percentage of innovators with innovation co-operation agreement on technological innovation activities with other enterprises or institutions, manufacturing, 1996



Source: CIS 1994-1996.

Fig 40. Percentage of innovators with some co-operation agreement on technological innovation activities with other enterprises or institutions, services, 1996



Source: CIS 1994-1996.

In key areas linked to innovation, such as supplier and customer engagement, the UK performs strongly. Data shows, for example, that UK firms appear to place less emphasis on sources of knowledge within their own enterprise and are more likely to collaborate with clients or customers or suppliers compared to their EU counterparts.

Sources of information for innovation, proportion of innovators quoting sources as very important

	Manufacturing		Services	
	UK	EU average	UK	EU average
Sources within the enterprises	43	47	38	52
Other enterprises within the enterprise group	19	25	29	39
Competitors	17	16	20	19
Clients or customers	54	42	65	38
Consultancy enterprises	2	5	10	11
Suppliers of equipment; material; components or software	23	19	27	18
Universities or other higher education institutes	4	4	4	5

Source: Second Community Innovation Survey 1994–1996

According to the AIM review, network relationships can be intermittent and driven by short-term decision making which possibly undermines the stable relationships required for innovation. However, the latest data show that UK enterprises do co-operate with others on innovation projects particularly up and down the supply chain.

Innovation Partnerships

	Per cent of enterprises with cooperation arrangements				
	Region				
Type of Partner	Local	National	Europe	US	Other
Other enterprises within the enterprise group	14	17	14	12	6
Suppliers	14	37	16	9	5
Clients or customers	14	37	15	10	5
Competitors	7	12	5	10	2
Consultants	11	19	2	3	1
Commercial laboratories/R&D enterprises	5	11	4	4	0
Universities/higher education institutes	15	19	6	2	1
Government research organisations	5	9	3	1	1
Private research institutes	3	8	2	2	0

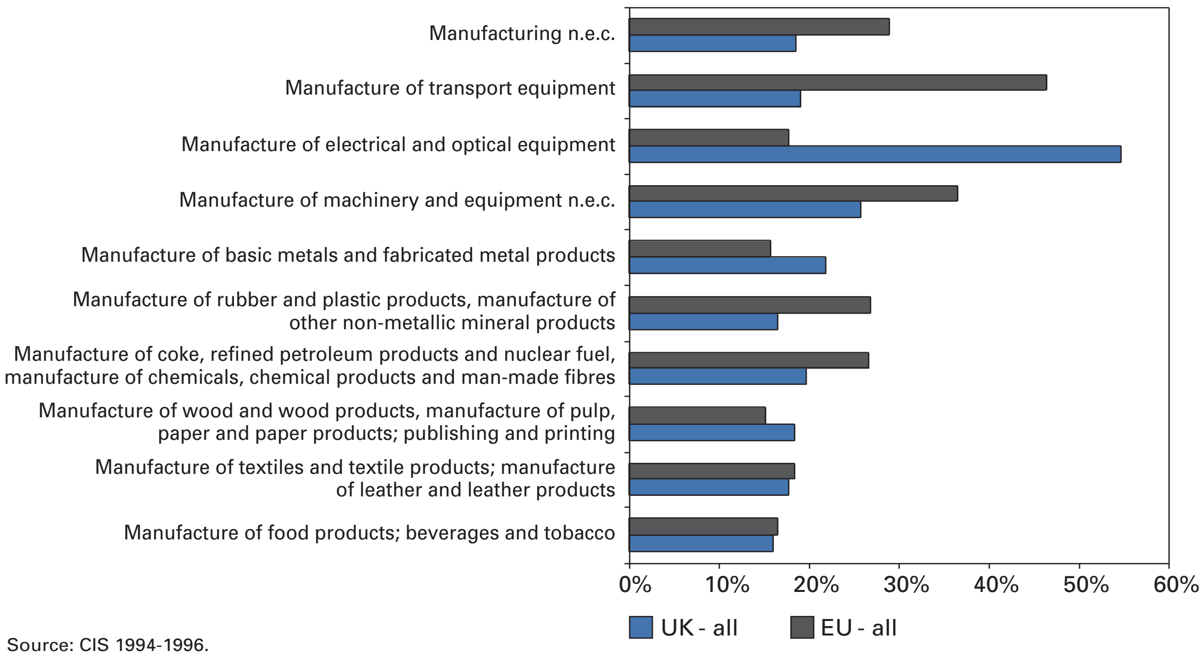
Source: CIS 1998-2000

The AIM review also indicated that the network infrastructure in the UK, whilst it operates adequately, has limited impact in promoting innovation because of insufficient scale. There are also large differences between regions in the scale and effectiveness of their network infrastructure.

Customers and suppliers and the demand for innovative goods and services

A firm's incentive to innovate will depend on the expected demand for a new product or the commercial value it can extract from a new process. It will also depend on the technological opportunities that are open to the firm[155]. Customers take the lead in the innovative process in some sectors[156], in particular when the structure of the market is very competitive and when scale economies in the production and use of the innovation are modest.[157] These factors explain in part why, for example, R&D intensities will vary from sector to sector. For example, R&D intensity is around 50% in Pharmaceuticals and 25% in Aerospace. In contrast the proportion is less than 5% in some parts of manufacturing. Innovation survey data paints a similar picture – significant sectoral variation reflecting differences in the opportunities for innovation across sectors (Fig 41).

Fig 41. Proportion of sales due to new or improved products or processes, by country & industry



Source: CIS 1994-1996.

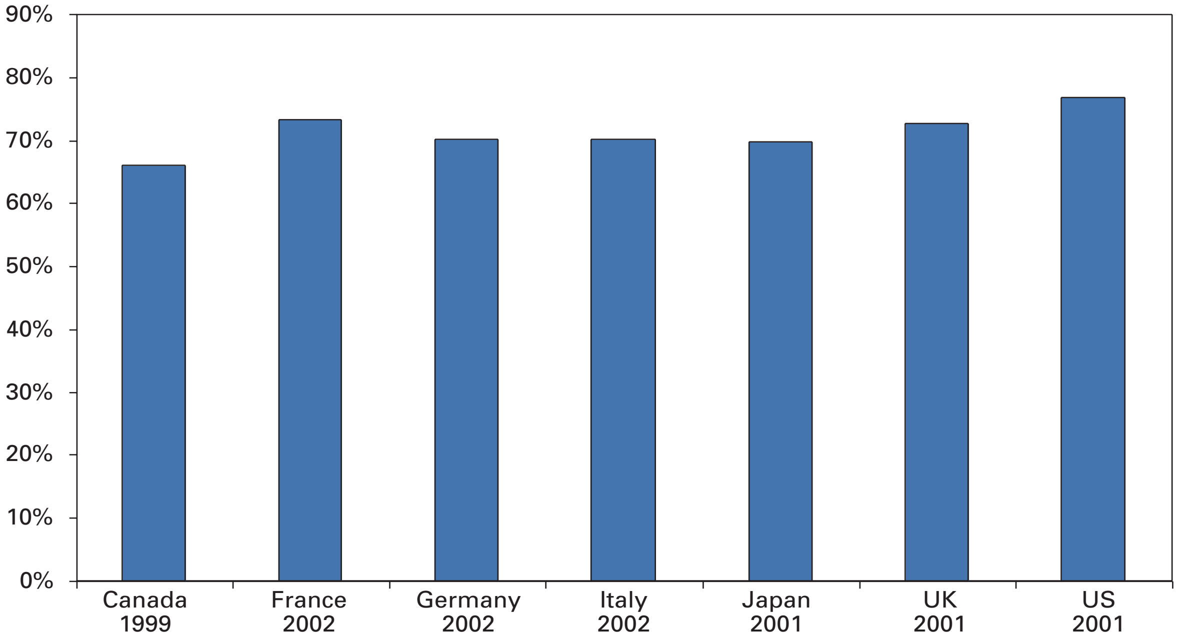
One potential explanation for the UK's less impressive innovation performance is that UK firms produce output in market segments where there are fewer opportunities, or less demand, for innovation.

155 Cohen, W., Empirical studies of Innovative Activity, in P.Stoneman, ed., Handbook of the Economics of Innovation and Technical Change, pp. 409-512, Blackwell, London (1995).

156 Von Hippel E, The sources of innovation. Oxford: Oxford University (1988). For example out of 111 basic, major and minor innovations in four families of scientific instruments users dominated the innovation process in 80% of cases. Users perceived the need for the innovation, invented the new instrument, built and applied the prototype and diffused knowledge about it. Manufacturers only performed product engineering to improve reliability and manufacturability. Users are also important in sectors like electronics and defence.

157 Geroski P, Markets for Technology in P Stoneman (ed), Handbook of the Economics of Innovation and Technological Change (Oxford, 1995), pp 90-131 (1995).

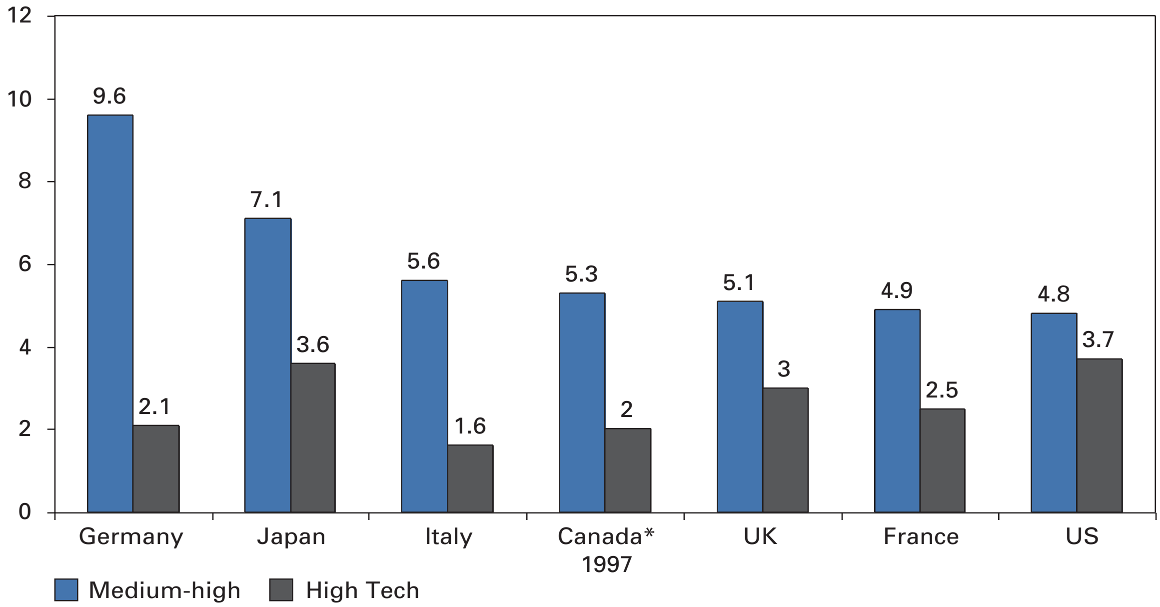
Fig 42. Services value added as % of total gross value added in current prices, G7 latest available year



Source: OECD.

Services tend to do much less innovative activity, as measured by R&D[185], but differences amongst the G7 in the relative size of the service sector are modest (Fig 42). The UK's low R&D investment is not, for example, because it has a large service sector. The UK's weaker R&D performance does not appear to be because UK manufacturing sector is concentrated in sectors which lack innovation opportunities. The UK ranks quite highly in the share of output accounted for by high and medium technology industries (Fig 43).

Fig 43. Value added in high and medium-high technologies as a percentage of total value added, in 1998, except Canada.

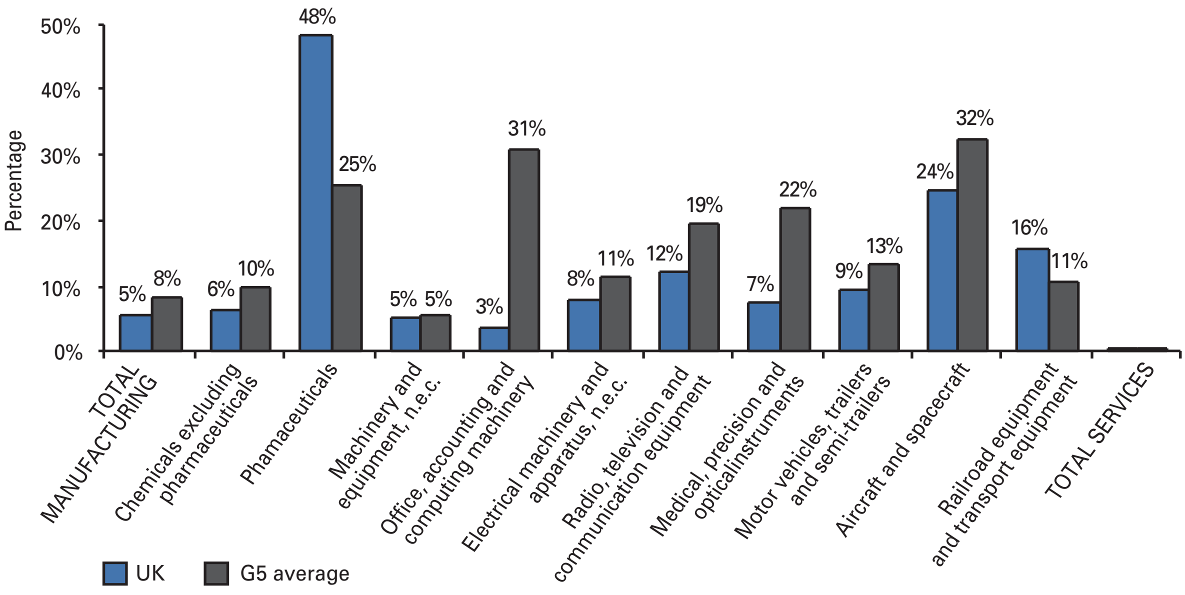


Note: Current basic prices, except Canada, Japan, US, at factor costs.
Source: OECD.

158 Although as shall be discussed later measures such as R&D will underestimate innovation in the service sector.

Within most sectors, except pharmaceuticals and manufacture of railroad equipment, BERD intensity in the UK is below that of the G5[159] economies as a whole (Fig 44). Overall therefore, if sectors are a suitable proxy for technological opportunity, the evidence suggests that UK based firms probably face as many technological opportunities as firms located overseas, but they simply invest less.

Fig 44. R&D Intensity (BERD/Value Added) 1998



Source: OECD.

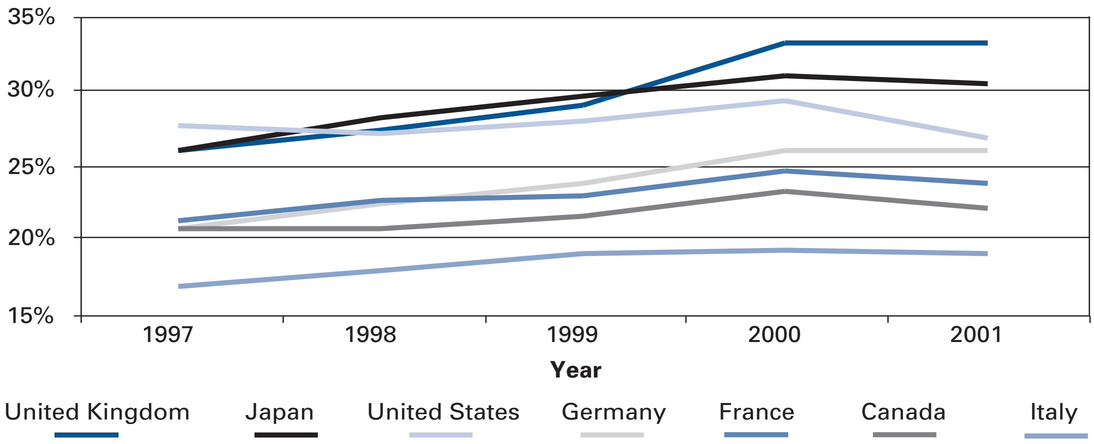
Some commentators have suggested that the UK's innovation performance is held back by a lack of demand for innovative products and services. However evidence that customers for UK produced goods and services are less demanding or sophisticated is hard to find. Part of the problem lies in defining the market and customers for UK goods. UK firms – particularly in manufacturing – are competing in global markets. Exports and imports as a share of GDP are high at around 20% each – more than the OECD average and greater than the US and Japan[160]. The UK is an attractive market for innovative firms based overseas. UK imports of high tech[161] goods account for around a third of all imports (Fig 45).

159 G5 is made up of USA, Japan, Germany, France and UK.

160 DTI (2002) Productivity and Competitiveness Indicators Update.

161 Includes Aerospace, Pharmaceutical, Computers and Office machinery, Electronics and Communications and Scientific Instruments.

Fig 45. Imports of goods in high-tech manufacturing sectors as a percentage of total manufacturing imports



Source: OECD.

Through public procurement the government has a major impact on the demand for innovative goods and services. For example, public sector procurement amounted to £109 billion during 2001/2[162], which is around 10% of GDP. In certain industries, e.g. defence and pharmaceuticals, procurement has a major influence on the UK market. As such a major part of the demand side of the economy there is clearly potential for the government to be a catalyst for innovation. Anecdotal evidence suggests though that Government is a relatively undemanding customer[163]. There is no coherent system for public procurement as responsibility is usually devolved to relevant departments. Management information about the government's suppliers is often poor, which leads to a lack of learning about past procurement projects as well as missing opportunities to take advantage of economies of scale.

The Office of Government Commerce believes that reforms are needed particularly in the areas of commissioning and managing the implementation of major projects and programmes. These improvements would be based around the principles of improving efficiency and rewarding innovation. Improving transparency and predictability of opportunity – so that potential bidders are as aware in advance as possible – can encourage competition in bidding and encourage a longer-term outlook. Streamlining administrative procedures relating to procurement can free up resources, which can be put to more productive use.

Where the procurement of technology intensive goods and services is concerned – such as large IT systems, defence contracts and medical equipment – the public sector should develop the ability to specify intelligently. In such areas, where the goods involved are often non-standardised, the specification of the product should focus on function rather than a detailed prescription of technology. Such 'outcome-based' specification can encourage innovation in the delivery of the specified function. Innovation friendly guidance could be implemented at the evaluation of bids stage. The degree of innovation in a bid could be given greater weight as a criteria for accepting a bid. Solely relying on cost as a criteria for evaluation in technology intensive areas is not good practice.

162 HM Treasury/National statistics, Public Expenditure Statistical Analyses, May (2003)

163 Speech by Peter Gershon, Chief Executive of the Office of Government Commerce, to the Chartered Institute of Purchasing and Supply, 3rd March 2003.

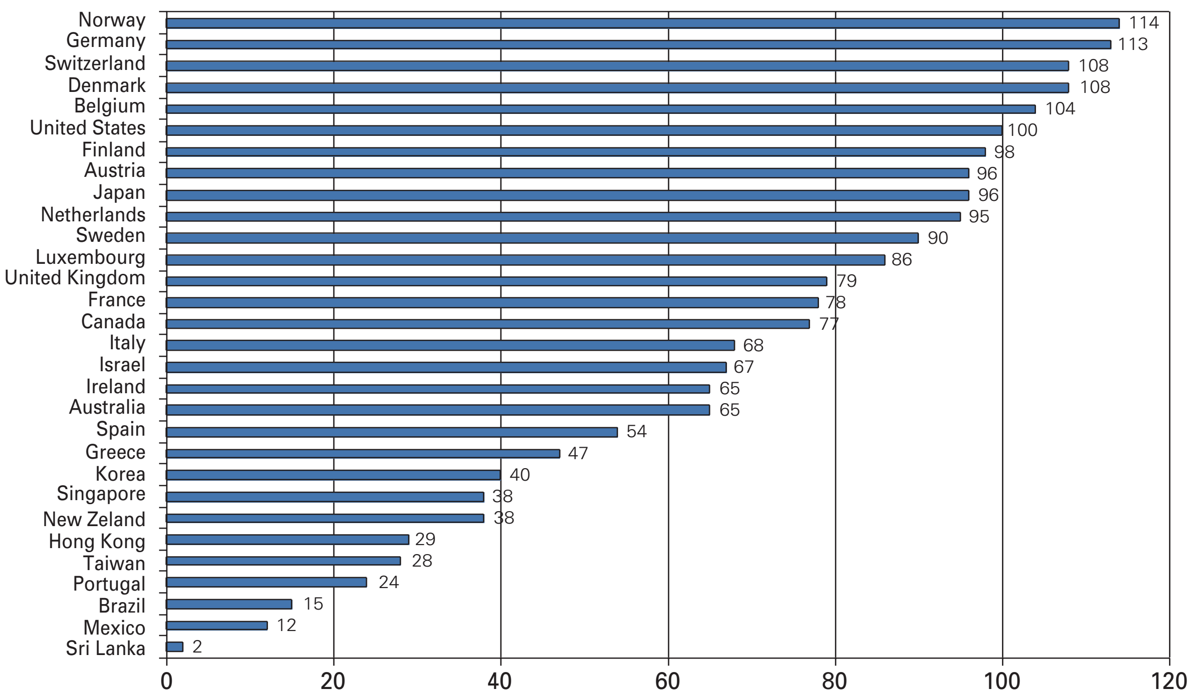
Part IV: Challenges facing the UK

There are a number of key challenges facing the UK innovation system which policy needs to take into account and which UK firms need to adapt to. Many of these are common to other developed countries and have been around for some time. They are best seen as part of a continuous process rather than a discrete change.

Increasing competition and structural change

The opening up of world markets to trade and increasing industrialisation in developing (and lower cost) countries has led to growing competition in product markets. In price sensitive markets, such as commodities, developing countries can exploit their lower labour costs to gain market share (Fig 46.). Firms in developed countries find it difficult to compete given the higher levels of labour costs, unless they continuously invest in productivity raising measures, which requires investments in innovation and skills. This enables them to develop new products or services with a high knowledge content which firms in low labour cost countries find difficult to replicate.

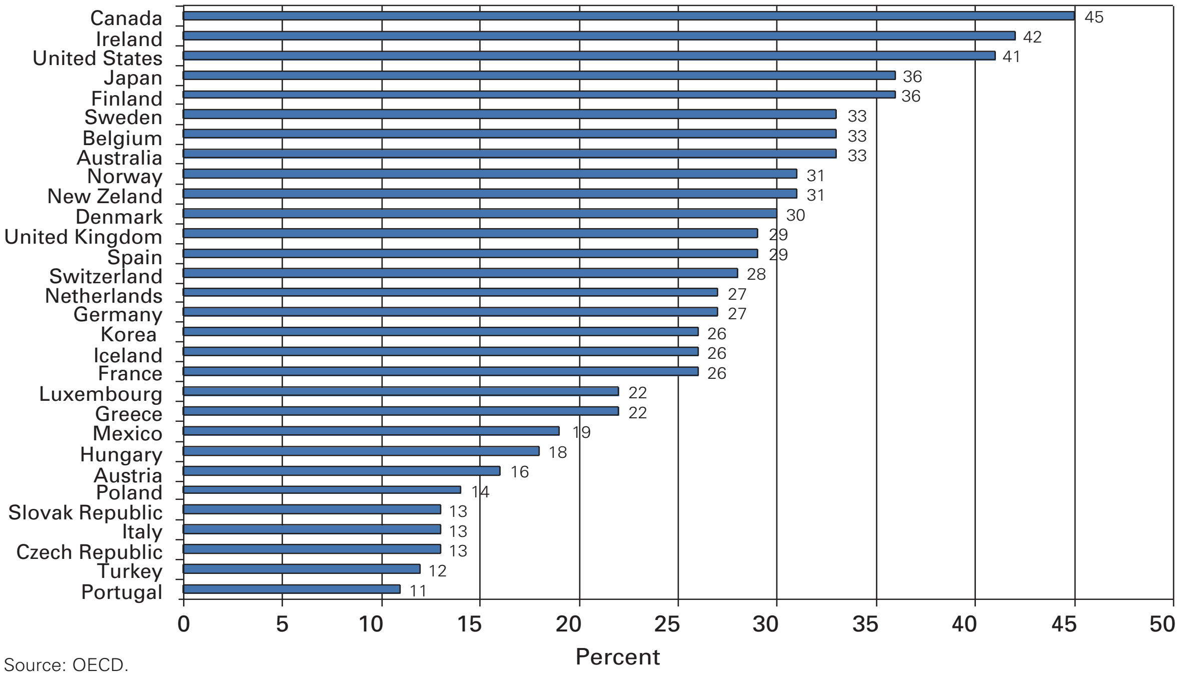
Fig 46. Labour compensation per hour in manufacturing, 2001 (US=100)



Source: US Department of Labor.

But even in so called 'high value added' markets UK firms will still find their positions open to challenge. Some countries with relatively low labour costs have invested heavily in human capital. Korean labour costs, for example, are around half those in the UK, but the share of graduates in the labour force is almost the same (Fig 47).

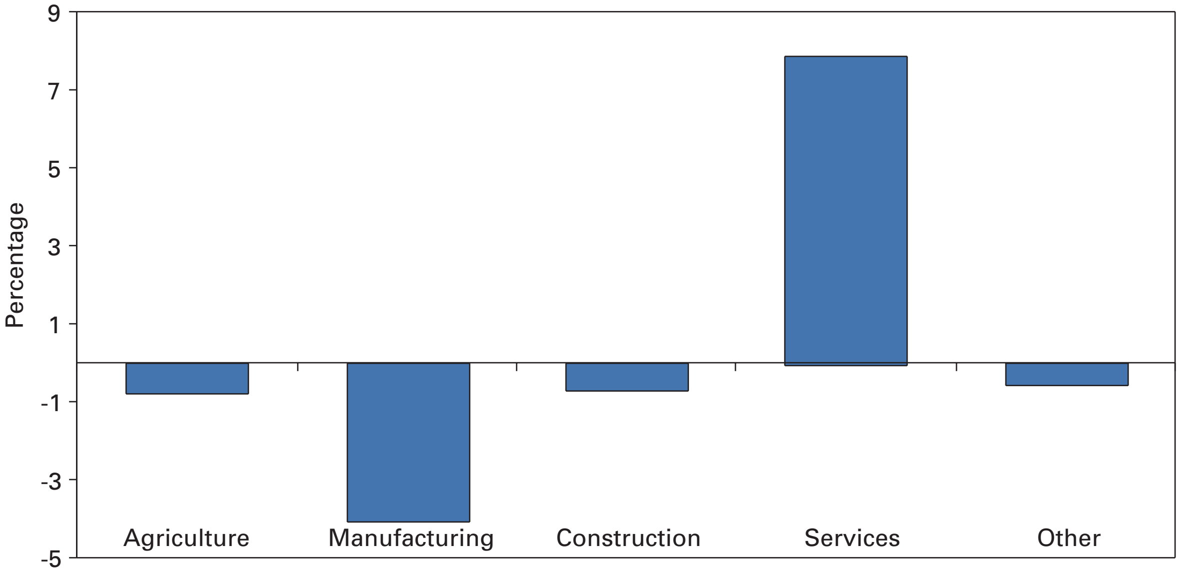
Fig 47. Share of labour force who have participated in tertiary education or advanced research programs



Source: OECD.

Rapid advances in technology and rapid productivity growth in manufacturing have also contributed to significant structural change in developed economies. For example, the share of manufacturing in total output has tended to decline[164] across all the leading economies as technological change has increased efficiency allowing higher levels of output to be produced with fewer workers[165] (Fig 48).

Fig 48. UK sectoral shifts in output (current prices) shown as a percentage of GDP, change in 1991 – 2001

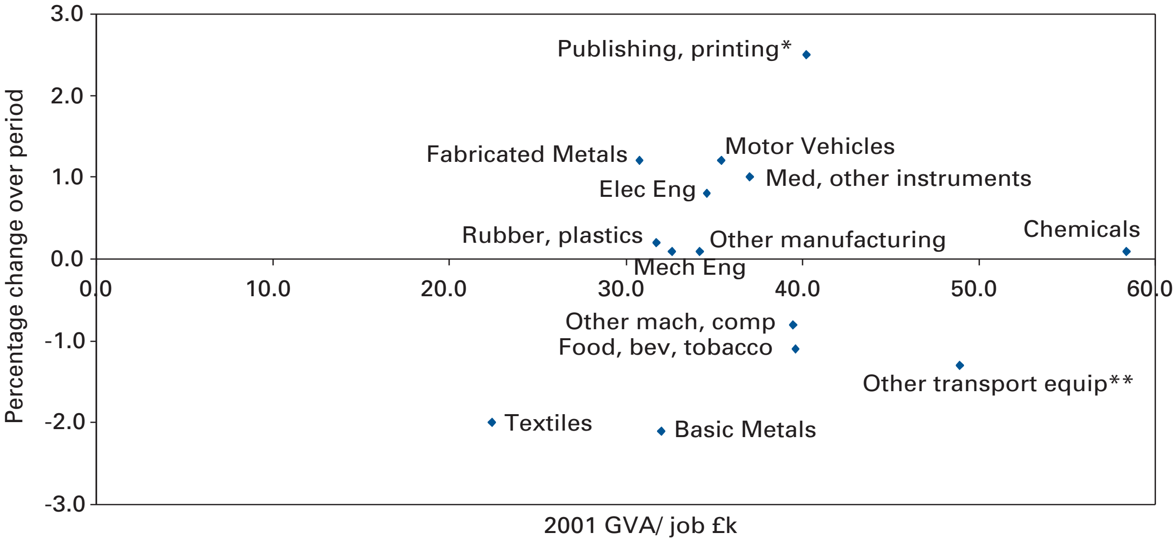


Source: ONS.

164 UK manufacturing output as a proportion of GDP fell from 32 per cent in 1970 to 19 per cent in 1999. In the US, output fell from 25 per cent to 16 per cent in the same period, and 36 to 22 per cent in Germany.

165 For example, in the UK over the past twenty years the proportion of people employed in manufacturing fell from 25 per cent to 14 per cent of the total employed. Yet at the same time, the value in real terms of goods they produce rose 35 per cent.

Fig 49. UK sector shifts in manufacturing output 1991-2001 expressed as a percent of manufacturing GVA



Source: ONS.

But not all areas of manufacturing have been affected to the same degree (Fig 49). Food, beverages and tobacco, textiles, basic metals and other transport equipment have seen significant declines over the last 10 years or so compared to sectors such as Publishing and printing, fabricated metals and motor vehicles which have seen significant growth.

Areas of growth in manufacturing have not been solely restricted to high productivity sectors. This suggests that the potential for improvement in value added is distributed across, and within, sectors. Innovation policies therefore need to be sufficiently generic to encompass firms across this range[166].

New technologies destroy jobs in some industries, especially among the low skilled, whilst creating jobs which are in different industries and require different skills. But over the long term there is no relationship between the employment rate and innovation at the aggregate level. Historically net job creation occurs as new industries replace old ones and the skills of workers adapt to changing and expanding demand[167]. This process is likely to continue. As well as encouraging a shift towards higher value added manufacturing, consumers will spend higher incomes on labour-intensive services like healthcare, entertainment, restaurant meals and holidays. Nevertheless, even if market forces provide the necessary incentives for the pattern of economic activity and employment to adjust, the process of reallocation of resources may involve significant problems of structural adjustment in the short to medium term. Weaknesses in innovation systems could increase the costs and duration of structural adjustment.

166 Lambert R, Value Added, Technology ad Innovation in UK sectors, unpublished DTI discussion paper (2003).

167 OECD, The OECD Jobs Strategy: Technology, Productivity and Job Creation, OECD: Paris, (1998).

Increasing internationalisation

Innovations have the potential to, over time, change patterns of trade within and between countries. Most of the empirical evidence suggests that patterns of comparative advantage in international trade are largely driven by differences in technology which are in turn driven by the processes of innovation and diffusion[168]. It is these changing patterns of trade – for example through liberalisation of markets, increased competition, technical progress and changes in consumer demands – that produce changes in economic structure.

As part of this process, internationally orientated firms, will seek to exploit sources of regional comparative advantage such as cheaper input costs or sources of knowledge. There will continue to be powerful incentives for UK firms to re-locate whole operations or part of the production process abroad. Foreign investors to the UK will bring new practices and knowledge developed elsewhere[169 170]. Evidence for countries such as the US, UK and Germany suggests that outward investment is more likely to occur in industries with a high level of R&D investment in the home country[171]. This suggests that inward investment may lead to new ideas and technologies being utilised in host economies, thereby improving their productivity performance. Several recent studies have suggested that the location of investment by foreign investors is heavily influenced by the location of existing investments.[172]

It is likely that the UK[173] will become increasingly specialised, in the short-term in areas of current scientific or technological strength. In the longer term new industries will emerge although it is likely that they will be based around existing competencies. Indicators of UK relative strength are:

- Patterns of **export specialisation** show that UK manufacturers are relatively specialised in Pharmaceuticals, Chemicals, Office and Computing equipment and Aircraft. These patterns appear to be persistent, reflecting the fact that technological capabilities accumulate over time and that future developments are strongly path dependent.
- Indicators of **technological specialisation** – derived from analysis of US patents – suggest that the UK is becoming increasingly specialised in the health area, agro-food, Chemistry and mechanical engineering. Patterns of specialisation are relatively persistent, although between the periods 1980-89 and 1990-96 the UK saw its relative specialisation in paper and transport disappear.

Growing environmental concerns

There is scientific evidence that climate change is happening and that it is being accelerated by human activity. The earth's temperature rose by 0.6°C during the last century and is forecast to rise by between 1.4 and 5.8°C during this century. Globally the 1990s was the warmest decade and 2002 the second warmest year since records began.

168 Krugman P, Technological change in International Trade, in P.Stoneman, ed., Handbook of the Economics of Innovation and Technical Change, pp. 342-366, Blackwell, London (1995).

169 Inward Investment, Technological Change and Growth. The impact of multinational corporations on the UK economy. Ed N Pain. Palgrave, London (2001).

170 By the end of 1999 the stock of FDI in the UK was equivalent to 27% of GDP compared to around 7% in 1960.

171 Barrell R and N Pain, Domestic institutions, agglomerations and foreign direct investment in Europe, European Economic Review, 43, pp 925-34 (1999).

172 For example, see Deveraux M P and R Griffith, Taxes and the location of production: evidence from a panel of US multinationals, Journal of Public Economics, 68, pp 335-68 (1998).

173 OECD, Managing National Innovation Systems, OECD: Paris (1999).

There is increasing evidence that this is the result of an increase in atmospheric concentrations of greenhouse gases – notably carbon dioxide released by burning fossil fuels such as coal, oil and gas. The rate at which the climate is changing will affect the world in extreme and unpredictable ways. Its impacts could include:

- millions more people being exposed to the risks of hunger, water stress, flooding and diseases like malaria. Poor people in developing countries are likely to be most vulnerable;
- low-lying areas, wetlands and small islands will be at risk from flooding. Globally, an extra 80 million people could be exposed to flood risk by the 2080s, 60% of whom are likely to be in the poorest parts of South East Asia;
- irreversible losses of biodiversity could be accelerated.

A reduction in carbon dioxide emissions requires very significant changes in the way in which we produce and consume energy in the home, in industry and services and in transport. Modelling work[174], suggests that, because of the long timescale involved, changes could be made with only a negligible impact on economic growth over a 50 year period. But this result is, however, critically dependent on innovation delivering low or zero carbon technologies[175] on time and at reasonable cost. Assuming that costs of the new technologies decline until 2010 but do not subsequently decline any further, the costs of meeting a 60% reduction target increased from around 0.5% of GDP in 2050 under the baseline run to around 2%. Continued investments in new technologies are therefore required to reduce the costs of adapting to a low carbon economy.

Studies[176] have concluded, however, that industrial economies exhibit some lock-in to the current carbon intensive, fossil fuel-based energy system. This is considered to create persistent market and policy failures that inhibit the diffusion of carbon-saving technologies, even where these have environmental and economic advantages.

Transport systems and electricity generating systems both have dominant designs based on fossil fuels. Market pull mechanisms for low carbon technologies are weak because carbon emissions are not yet fully internalised. Hence, there is little direct incentive for firms to invest in low carbon technologies. This means that firms generally only search for incremental improvements to existing designs, which would satisfy existing evaluation criteria, and so neglect carbon accounting. This reinforces the wider technological trajectory which the majority of firms are following.

The development of new energy networks could be the most difficult part of the process of moving to a low carbon economy. Networks tend to last considerably longer than new innovative products and are characterised by high investment and low running costs. Incumbents may also have an advantage in their use. In order for the investment to be made network operators will need to be confident that they will be used. Similarly, purchasers of, for example, cars using hydrogen need to be certain that there will be sufficient outlets supplying the fuel in order to justify their investment in a hydrogen vehicle. Distributed or embedded generation involving an enhanced role for renewables and combined heat and power will require innovations in managing the electricity network.

174 DTI, Options for a low carbon future, DTI Economics paper no 4 (2003).

175 There is a wide range of technologies available including renewable electricity sources, such as wind, wave, tidal and biomass, nuclear generation and, in transport, technologies such as hybrid vehicles and hydrogen fuel cells.

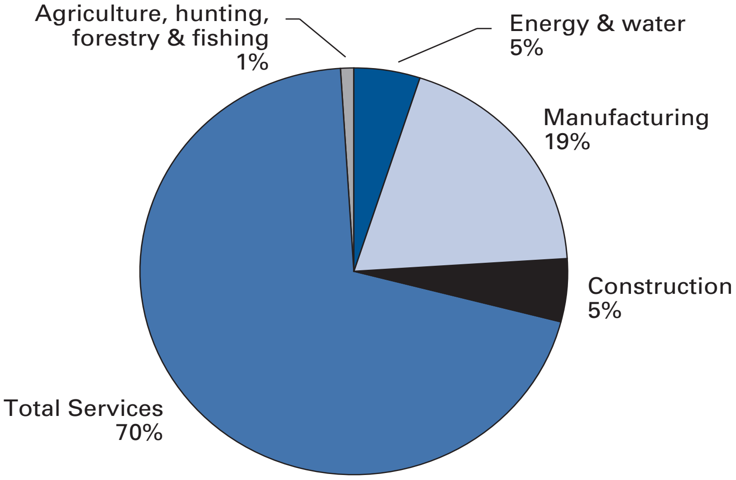
176 Inducing Innovation for a low-carbon future: drivers, barriers and policies: A report for the Carbon Trust (unpublished)

As a result of lock in, and the factors that cause it, a wide range of policy instruments is likely to be necessary to support the development of more environmentally friendly technologies. This is an area where innovation, regulatory and environmental policies can jointly contribute to improving quality of life. Instruments include taxes and subsidies, including support for R&D and demonstration, as well as public procurement and the use of targets and obligations. Regulatory incentives might in addition be required to open existing networks, or establish new networks, to sources of low carbon energy.

Increasing importance of services

Most of the UK economy is in the service sector, which accounts for 70% of value added and 77% of employment (Fig 50). In addition, Over 60% of the UK's productivity gap with the US is accounted for by the service sector.

Fig 50. Share of UK economic activity (GVA at basic prices), 2000

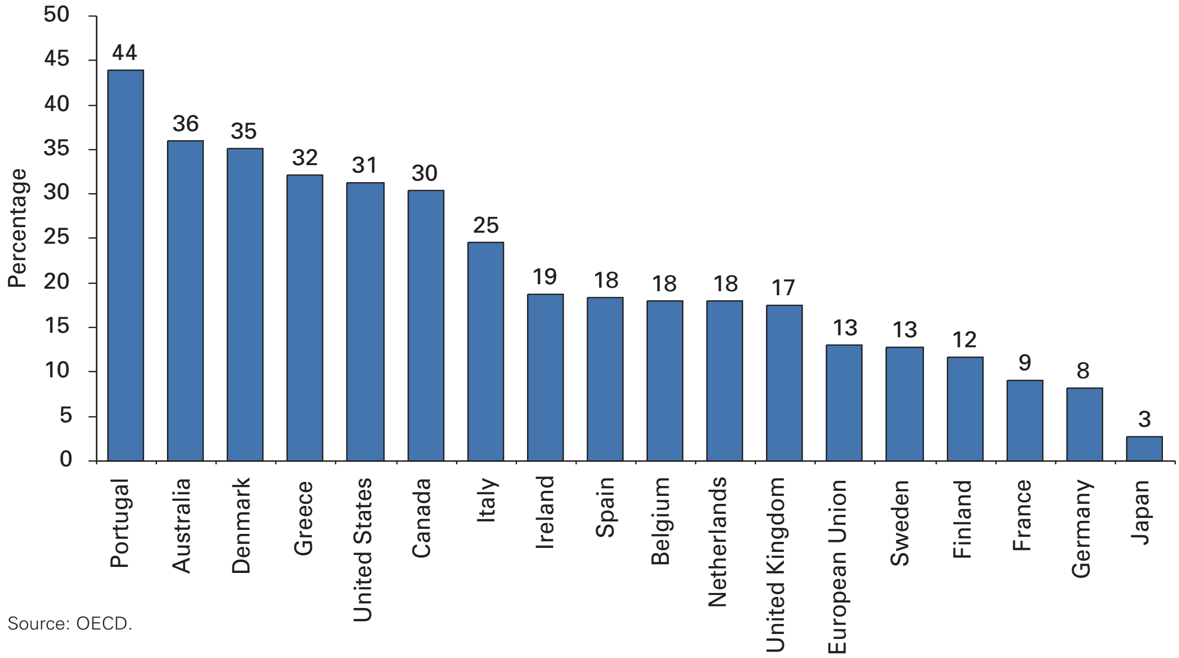


Source: ONS.

Service sector firms differ from their manufacturing counterparts in a number of ways. They are less likely to do R&D. Innovators in the service sector are less likely to use Higher Education Institutes, Government Research laboratories and private research institutes as sources of knowledge. They are more dependent on conferences and consultants. Technology intensive services are heavily dependent on graduates, who constitute a very high share of employment[177]. But the service sector is becoming more research intensive reflecting the outsourcing of R&D to specialised suppliers whose competitive advantage depends on a sound understanding of technology. This is particularly the case in the UK, where the proportion of total R&D coming from the service sector is greater than the European average (Fig 51). It follows, therefore, that any serious analysis of the economic factors influencing innovation performance in the UK should include the service sector.

177 PREST/CRIC, The links between the knowledge intensive services sector and the science base, draft final report to the DTI, June (2003).

Fig 51. Service R&D as a % of total Business Expenditure in R&D, 1999



Source: OECD.

More recently, advances in information and communications technologies (ICT) have enabled a raft of new innovation intensive industries to develop, such as those based on e-commerce and the Internet. Large service sector firms have introduced significant innovations. For example through supply chain management and e-commerce large supermarkets have integrated their supply chains into the core business. Financial services have pioneered technologies such as data warehousing and mining methods enabling sophisticated customer relationship management. But other 'knowledge intensive' business services also play an important role in the innovation processes of their client firms by:

- Providing general information relating to operations and environments;
- Identifying specific problems confronting firms;
- Proposing ways of dealing with problems and delivering solutions.

One classification of services, by capital and technology intensity, is illustrative of the diversity is shown overleaf.

Illustrative classification of service industries

Capital intensity	Technology intensity		
	High-tech services	**Low-tech services**	**no-tech services**
High capital intensive services	Telecom services	Rescue services	Rental services
	Medical services (surgery etc)	Entertainment	Hotels and accommodation services
	Surveillance and security services	Retailing/wholesale	Religious services
	Defence services	Gambling	
	Energy services	Disposal services (sewage, garbage etc)	
	Transportation services	Water supply	
		Financial services etc	
Low capital intensive services	Universities and higher educational services	Entertainment	Social services3)
	Consultancy services (engineering, data etc)	Financial services	Restaurants
	Medical services etc		Consultancy services (management, legal, advertising, accounting etc)
		Police services	Travel agencies Cleaning, house keeping.

Notes:

1) Some services are not in everyday language associated with 'industries' but nevertheless encompass production and transactions of some sort.

2) The Principle classification variables used here are capital intensity and technology intensity referring to the relative degree of hardware and R & D employed, respectively. These variables are continuous but for illustrative purposes here divided simply into high and low. Obviously, this distinction can be disputed, but still be useful for illustration. In several border cases, the technology intensity is rather non-existing than low, that is the corresponding service industry is not technology-based, although possibly based on other professional competencies. Most services categories vary considerably along the variables and thus could be found at several places in the table, which is illustrated in some cases. A third important variable is information intensity, which could have been used as well (cf. the notion of 'information industries'). Technical information is then a special case. Additional variables for the classification services industries are private/public (the public sector contains a variety of services); legal/illegal; location bound/unbound etc.

3) Typically in the public sector.

Source: Bohlin, E and Granstrand O. (eds): "The race to European Eminence – Who are becoming tele-service multinationals". Elsevier Science – North Holland, 1994.

The focus on 'technological innovation' has often missed important innovations in the service sector that are frequently not technology related and are harder to measure. Differences in the nature of services[178] have not helped. As a result, services tend to be less well linked into innovation networks and systems, whose formal and informal structures tend to be directed towards the needs of manufacturing. As a result significant issues have been raised relating to:

178 Service sector outputs are often intangible. Services cover a wide range of activities, working not only with artefacts, but also with people, information and environments. Services are more likely to produce transformations in people, things and data than produce things. Service outputs are interactive – they involve clients very closely in the delivery an even the production of the service. PREST/CRIC, Services and Innovation: Dynamics of Service Innovation in the European Union, University of Manchester/UMIST. (2001) Earlier in the paper we noted that the distinction between services and manufacturing was somewhat blurred by contracting out. It is also true that many manufacturers also sell a service as part of the product (e.g. advice on design, maintenance contracts etc).

- **Lack of Government support.** State funded innovation policies tend to favour manufacturing firms.[179] Government support tends to favour those innovation inputs that can be measured (e.g. R&D) which are more typical of manufacturing.
- **Level of support for trade and internationalisation.** Service sector outputs cannot be exported in traditional ways. Unlike manufacturing, service sector firms have to export them via a physical presence through FDI or through other techniques such as partnerships or franchising. This poses a much higher entry barrier to overseas sales. Trade problems are also associated with differing professional standards and regulations. So often service firms do not bother to supply overseas markets at all and cross border trade in services remains modest. This affects service innovation by restricting the scope for economies of scale reducing the scope for the introduction of successful new services.
- **IPR protection.** Service sector firms complain that IP regimes have traditionally tended to favour manufacturing firms. Patenting is rarely appropriate as a means of protecting service innovations. They perceive that trademarks and copyrights are inadequate and both difficult and expensive to defend[180]. In part this probably reflects generic difficulties in valuing IP. But some argue that the difficulties are amplified for service sector firms.[181]
- **Difficulties in valuing and financing intangible service assets.** It has been argued that service sector firms face particular difficulties in raising finance for innovation since financial institutions are more reluctant to lend unless backed by material security. Also some services – such as software – have very short product cycles but development of the product requires expensive expert input over a prolonged period of time. Financial institutions are less likely to risk extended and high levels of investment in a market that is perceived to be insecure.

The continued blurring of the boundary between services and manufacturing

The provision of services is an important source of comparative advantage for UK firms. Many manufacturing companies are developing service products that are related to their traditional manufacturing business[182]. These activities have become so successful in some cases that they yield higher returns than the manufactured product on which they are based. The following table gives some examples.

179 Thomas M and P Jones, UK Results from the 2nd Community Innovation Survey, Economic Trends (1998). This paper shows that whilst 16% of innovators in manufacturing recorded some involvement in state funded support programmes only 3% of innovating services report similar engagement.

180 PREST/CRIC Services and Innovation: Dynamics of Service Innovation in the European Union, University of Manchester/UMIST (2001).

181 Miles I et al, Service Production and Intellectual property, International Journal of technology management (1999).

182 Howells, J., The Nature of Innovation in Services, in Innovation and Productivity in Services, OECD, Paris (2001).

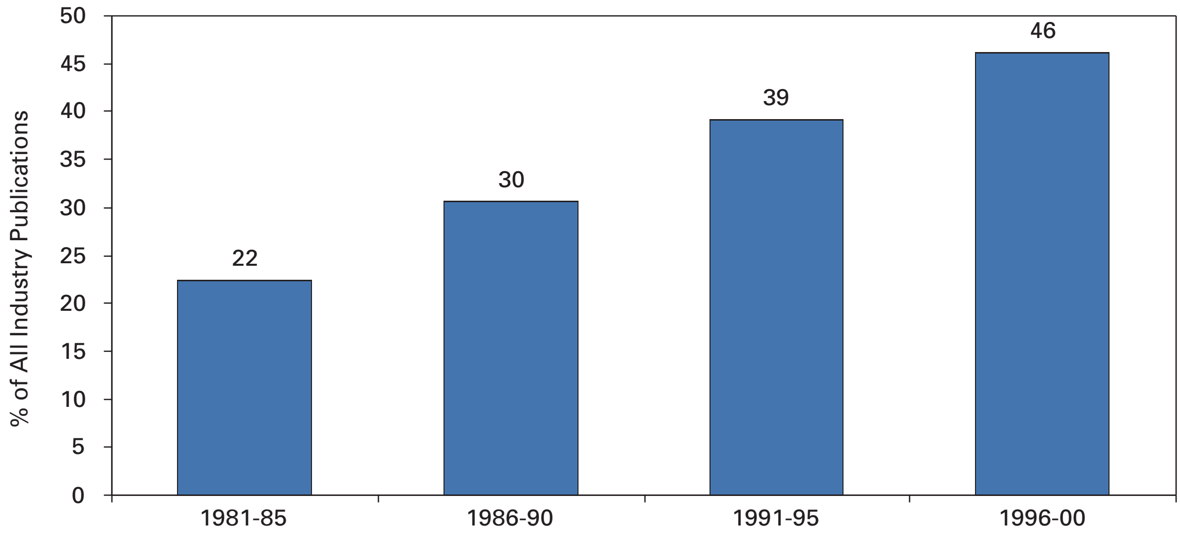
Company	Manufactured product	Service encapsulator	Final offer and consumption
AstraZeneca	Cancer drugs	Cancer Healthcare (Salick Health Care)	Cancer treatment
Fiat	Cars	Financial and insurance services for car customers (Toro Assicurazioni)	Car travel
Ford	Cars	Car travel services: financing and leasing (Ford Finance); maintenance (kwikfit); in-vehicle services	Car travel
General Electric	Aerospace engines	Leasing or selling hours of flight	Air travel
General Electric	Medical diagnostic equipment	Medical analysis and diagnosis	Diagnostics
Liebherr	Cranes	Special software programming to control and run the machines; remote running and testing	Lifting
Pacific Power International/Rio Tinto Energy Resources	Coal	Power plant design and operating expertise and environmental advise	Power/Energy
Rolls Royce	Aerospace engines	Leasing or selling hours of flight (minus) time of ground due to faults)	Air travel
Xerox	Reprographic equipment	Maintenance and leasing	Photocopying

Source: J.Howells (2001)

This blurring of the boundary between manufacturing and services is an indication of a strong relationship between some knowledge intensive (and innovative) service activities and knowledge intensive manufacturing.

Even though services form an increasingly important proportion of our GDP manufactured goods are still (and will remain) an important part of consumption. Many knowledge intensive services activities are, somewhere along the line, linked to manufactured goods and the underpinning technologies. UK firms' ability to break into such service markets will often depend on them mastering the underlying knowledge about the good in question – including its manufacture. For example the sale of an aero engine is an important source of revenue, but not as important as the very lengthy service and maintenance contract that follows. Competitiveness in this 'service' bit of the market is wholly dependent on the knowledge from being involved in design, development and manufacture of the engine in the first place. We should not see all service innovation as 'non-technological' and ineligible for support. And support for technologies should be informed by the potential for new applications in the service sector. Part of the innovation agenda should be to ensure that UK manufacturers are able to see the link between their technological activities and the rest of value chain, i.e. their ability to exploit opportunities in high value added service markets.

Fig 52. Overall Trends in Joint-Industry Publications: 1981-2000



Source: Calvert J and Patel P 2002.

Technological and business trends are changing the way firms invest in innovation[183]. Technological advances have shortened product life cycles. As product lives have shortened, so too have time horizons for research. Businesses are now expected to generate new products faster with an increasingly diverse portfolio of technologies. Many firms are finding themselves in a position where the key to competitive advantage lies in technologies outside their core competence.

Coupled with the desire to achieve greater value from research budgets, this acts as a spur to greater collaboration with knowledge providers such as universities or contract R&D services. Industry-university research collaboration has been increasing over the last two decades in most major countries. The proportion of higher education R&D financed by industry has increased in every G7 country between 1981 and 2001[184]. Analysis of US patent data shows that the number of scientific papers cited in patents has increased for all G5 applicants between 1985 and 1998[185]. The volume of joint university – industry publication has increased significantly in the UK during this time[186] (Fig 52). Throughout the past 20 years Chemical Sciences, Medical Sciences and Biological Sciences have accounted for the majority of joint publishing.

183 Coombs R, R Ford and L Georghiou 'Generation and Selection of Successful Research Projects: A research study for the UK Technology Strategy Forum' (2001).

184 OECD Public Funding of R&D – Trends and Changes (2003).

185 NISTEP S&T indicators (in Japanese) using CHI Research Inc data, as quoted by OECD (2002) Benchmarking Industry – Science Relationships (2000).

186 This trend is already evident. See Calvert J and P Patel (2002) University – Industry Research Collaborations in the UK, paper produced under EPSRC/ESRC Analysis of University – Industry Research Collaborations in the UK (2002).

Industry benefits from access to the outputs of science and basic technology and the opportunity to organise its portfolio of research more efficiently than trying to do everything in house. Those in universities benefit from additional income and industry insight into applied science. Advances in information technology and the increased globalisation of markets have also encouraged companies to internationalise their research activity to exploit overseas sources of knowledge. But most big companies in technology intensive fields recognise that in-house technology generation is vital to long-term growth.

The scientific content of innovation will remain substantial particularly in areas such as chemicals, mathematics and physical sciences. In these areas, leading edge firms will continue to target those universities that have the highest rankings for research quality. But a number of other universities will emerge as important players in some areas reflecting increasing specialisation as well as the influence of regional/geographic factors[187].

187 This trend is already evident. See Calvert J and P Patel, *ibid,* (2002).

Part V: What can Government do to improve performance?

Government can influence innovation performance through two main routes. These are:

- Providing firms with subsidies, such as grants or tax credits, to encourage innovation or knowledge transfer
- Other Government policies which shape innovation systems (e.g. regulation, competition policy).

Taking each in turn.

Subsidies

Government subsidies for any activity can be highly controversial. Government finances activities through taxing existing or future generations of taxpayers reducing the amount they can consume or the amount they can invest in their future consumption. Strictly speaking, the activities Government subsidises should generate a higher return than the value consumers place on their own consumption or saving. If not Government ends up redistributing demand around the economy favouring those activities it believes has merit. Whether or not Government should intervene depends on whether there is proper policy rationale. This has three elements:

- The identification of a problem or opportunity that is being missed which is affecting national economic performance;
- Some barrier or impediment that prevents the normal operation of market forces from achieving the desired outcome[188];
- The design of a cost-effective policy instrument.

Historically the bulk of support for innovation was delivered by the DTI or its predecessors through grants. The introduction of R&D tax credits after 1997 changed this somewhat, with the cost of R&D tax credits expected to significantly exceed the value of DTI innovation support[189]. DTI intervention to improve innovation performance is usually justified on the existence of market failures including:

- **Public goods.** Where consumption of a good or service cannot be restricted it is impossible to establish payment mechanisms and no individual or firm has an incentive to pay for it. The public good rationale is used to justify Government funding of the Science Base and the National Measurement System;
- **Externalities.** Investments in innovation may give rise to externalities or spillovers. The investing firm cannot fully capture all the returns to this knowledge which leaks out to competitors for example by way of movement of workers or by use of

188 A great deal has been written on market and other failures see, for example, chapter 2 of Assessing the Socio-Economic Impact of the Framework Programme (ASIF) – http://www.cordis.lu/fp5/monitoring/studies.htm

189 Estimates suggest that R&D tax credits will cost the exchequer £600 million in 2002/03 compared to around £300 million set aside for DTI innovation schemes. Source: Table 1.5, Tax Expenditures and Structural Reliefs, Inland Revenue Statistics.

technologies developed in new applications. As a result, firms' may under-invest incertain types of R&D because they do not always capture all the returns from the innovation[190]. The degree of under-investment – and the strength of the case for government support – will depend on a range of factors, such as[1891]:

- The level of competition in the market into which products, embodying the technology, will be sold;
- The potential for protecting the technology by using IPR;
- Whether lead times, complementary skills and learning curves provide the innovator with a strong market advantage;
- Whether the technology relevant to many users or if the technology opens up an entirely new line of technological development with associated market opportunities.

- **Uncertainty.** Levels of market and technological uncertainty are usually high when firms invest in innovation and there is the potential for significant information asymmetries. Difficulties in assessing future cash flows mean that the manager will have a much better idea about performance than outside investors. Moreover, the manager of the risky project, having received external financing, may undertake activities that are not in the financier's best interests. Investors therefore find it difficult to identify good managers and good innovation projects. Recognising this, good managers sacrifice longer-term projects to provide higher short-term returns that less able managers cannot match[192]. As a result profitable (over the lifetime of the project) long-term investments (e.g. R&D) might be sacrificed leading to under-investment.

System failures can also occur in the innovation process because innovation takes place within firms which are embedded in set of interconnected knowledge producing organisations (e.g. universities) and institutional arrangements to create, store and transfer knowledge and skills. Increasing specialisation and a growing division of labour in the production of knowledge can lead to differences in culture, use of language and objectives. It becomes increasingly costly to acquire knowledge outside ones immediate domain of competence and experience; and this may result in barriers to communication between, say, small businesses and University Departments since knowledge is difficult to interpret and does not necessarily flow easily between different institutions and disciplines. Networks of commercial relationships provide a degree of co-ordination and access to knowledge sources but government intervention might be required if co-ordination failures prevent the formation of such networks. For example if a firm avoids contributing to paying for a co-ordinating body but it is impossible to exclude that firm from any co-ordination benefits.

The justification for DTI innovation support has traditionally depended on the existence of externalities or high levels of uncertainty. A number of programmes also tackle system failures by encouraging networking and overcoming barriers to communication.

The case for government policy to act as a corrective to market or systemic failures is often taken as given. However, this should not be so. Government intervention can also be subject to failure[193]. There are often good reasons why Governments may not want to intervene even if a problem is identified. Firstly Government may lack the necessary

190 Some economic models produce the opposite result that markets generate too much R&D. The empirical evidence does not support this interpretation.

191 Jaffe A B, Economic Analysis of Research Spillovers: Implications for the Advanced Technology Program, http//:www.atp.nist.gov/eao/gcr708.htm (1996).

192 For a review of the main models incorporating asymmetric information effects see Finance and Technical Change by Alan Goodacre and Ian Tonks, a chapter in the Handbook of the Economics of Innovation and Technological Change, Edited by Paul Stoneman, Blackwell (1995).

193 Krueger AO, Economists Changing Perceptions of Government, Weltwertschaftlichtes Archiv 126, 417-31 (1990).

information to intervene effectively (the problem may not be clear or be amenable to a simple solution). Secondly it is sometimes difficult to discriminate between failures in systems or markets from their normal operation, especially if Government is exposed to vigorous lobby groups. Thirdly the costs of intervention may well exceed any benefits gained[194].

The strength of the case for support to specific interventions will therefore vary depending, in part, on the above factors. Independent and informed expertise is required to ensure that, within its fixed budget constraint, DTI targets its innovation resources on those interventions that offer the potential for the greatest additional economic benefits. This requires learning from previous DTI interventions (Annex F).

Over the years the number of DTI schemes has grown and many have been on such a small scale that they had very little impact. As a result support for innovation has been expensive to administer and has been difficult and costly for companies trying to make use of it. Changes to the delivery of DTI business support should increase the impact, and clarity, of DTI interventions aimed at increasing innovation by concentrating resources on fewer, more cost effective, activities.

Other Government policies

DTI programme spend is not sufficient by itself to address some of the weaknesses in the UK's innovation performance. Some of the areas of weakness lie outside DTI's competence and are influenced by Departments with much larger budgets.

Strength	Weakness
Access to finance although there are some gaps in provision	Capacity to absorb knowledge: particularly management and skills
Networks and Collaboration, although infrastructure could be improved	Demanding customers: Government procurement
Sources of new knowledge	
Regulatory Framework, generally good although more use could be made of output based regulations	

Government has a wide range of influence over the innovation system, it, for example:

- Manages the competition regime;
- Regulates and sets the legal framework;
- Funds education and scientific research;
- Taxes;
- Provides services for example in health, education, defence;

194 In addition in an economy which is probably riven with market failures – in the sense that reality differs from the strict assumptions found in economic text books – the theory of second best probably applies. That is in the presence of more than one market failure there is no guarantee that correcting one will lead to a welfare improvement.

- Procures goods and services worth around 10% of GDP;
- Is the largest single employer.

Other parts of Government can therefore help, and are already helping, to address some of the weaknesses (e.g. the new DFES skills strategy) in the innovation system. The DTI also has a policy role to play too particularly where it is responsible for the delivery of services or acts as a regulator or customer. It is likely that a mix of policies will be required to achieve improved innovation performance. Many of which will lie outside of DTI's responsibilities. No one measure is likely to address all the policy areas and some will be inappropriate in specific cases[195]. Based on the analysis carried out for the Review, the main priorities for a cross Government action to achieve a sustainable increase in innovation performance are:

- Improve the supply and demand for skills;
- More outcome based regulations which encourage innovative compliance;
- Consolidate improvements in the areas of competition policy, macro-economic stability and employment relations;
- Improving policy co-ordination between different levels of Government (national, regional and EU);
- Better public sector procurement.

195 The independent working group of experts, which advised the Commission on steps required to meet the EU 3% R&D target, also suggests that measures are needed across a broad range of policy areas to improve innovation performance.

Annex A: Academic panel membership

Professor Stan Metcalfe	CRIC University of Manchester
Professor John Bessant	School of Management, Cranfield University
Professor Derek Bosworth	Manchester School of Management, UMIST
Dr Gavin Cameron	Department of Economics, University of Oxford
Professor Phillip Cooke	Centre for Advanced Studies, Cardiff University
Professor James Fleck	School of Management and Economics, University of Edinburgh
Dr Christine Greenhalgh	Oxford Intellectual Property Research Centre, University of Oxford
Ken Guy	Managing Director of Wise Guys Ltd
Dr Rebecca Harding	The Work Foundation and London Business School
Professor Michael Hobday	Complex Product Systems Innovation Centre, SPRU, University of Sussex
Professor Anne Huff	Advanced Institute of Management
Professor Alan Hughes	Centre for Business Research, University of Cambridge
Professor Andy Neely	Advanced Institute of Management
Professor Paul Stoneman	Warwick Business School, University of Warwick
Professor Peter Swann	Manchester Business School, University of Manchester
Professor John Van Reenen	London School of Economics and Director Centre for Economic Performance
Professor Toby Wall	Institute of Work Psychology, University of Sheffield

Annex B: Private and Social returns to R&D

A number of techniques have been employed to estimate the economic benefits of R&D[196]. In general these are either based on case studies of particular innovations, studies of either intermediate or final outputs of R&D – largely through the use of patent statistics – and econometric studies of the relationship between R&D expenditure and productivity.

The question of private and social returns to R&D is of particular importance to policy analysis. Investments in innovation may give rise to externalities. They arise because knowledge gained during the process may be applicable to other firms. The investing firm cannot fully capture all the returns to this knowledge which leaks out for example by way of movement of workers or by use of technologies developed in new applications. Since the firm cannot appropriate the full return in some sense under-investment occurs. This is because the social benefits exceed the private benefits and only the latter are taken into account during the investment decision. This line of argument has often been used in support of government intervention[197].

The table below provides a summary of the estimates of private and social rates of returns to R&D that have been published in a number of econometric studies. While the scale of the difference between private and social returns varies across these studies, all the studies predict that social returns are higher than private returns.

Author (Year)	Estimated Rates of Return (%)	
	Private	**Social**
Nadiri (1993)	20-30	50
Mansfield (1977)	25	56
Terleckyj (1974)	29	48-78
Sveikauskas (1981)	10-25	50
Goto-Suzuki (1989)	26	80
Bernstein & Nadiri (1988)	9-27	10-160
Scherer (1984)	29-43	64-147
Bernstein & Nadiri (1991)	14-28	20-110

Source: Table adapted from Griliches (1992) and Nadiri (1993)

196 For a survey, see Griliches, Z, R&D and Productivity: Econometric Results and Measurement Issues in Stoneman, P (ed) "The Handbook of the Economics of Innovation and Technological Change", pub. Blackwell (1995)

197 Katz and Ordover, R&D Co-operation and Competition, Brookings Papers on Economics (1990).

Annex C: Impact of innovation on economic performance: measurement issues

Standard economic theory suggests that the benchmark for assessing the value of an innovation depends on whether it increases some measure of social welfare. Such measures however do not exist. It is for this reason that policy makers tend to focus on the impact of innovation on productivity. Unfortunately, published productivity statistics are generally poor measures of the output of innovation. There are four main reasons for this[198]:

- Missing markets mean that some things cannot be valued – for example the development of coal-fired power plants led to greater economic efficiency but produced pollution that had an adverse effect on people's welfare. The absence of any form of market for pollution rights meant that only the economic benefits (e.g. profit, wages) were recorded in statistics and not the social and environmental costs[199].
- Nor is it easy to value benefits from an improved quality of goods and services in general. The well-known examples of lighting and computers indicate how a failure to allow adequately for quality improvement can result in serious underestimates of the real value of the producing industries output[200]. The problems of valuing quality improvements in service sector outputs are particularly acute[201].
- Furthermore output prices may not exist for some markets. By convention their contribution to productivity is shown by how much it costs to produce a good or service. Public services in the UK (such as Health and Education), provided by the state free at the point of delivery, operate under this convention. So it is likely that any productivity improvements in these sectors do not fully appear in the final statistics.
- Some outputs, improved longevity from better healthcare for example, also do not appear in the national accounts since to a first approximation longer life will raise both output and hours worked. It is very difficult[202] in practice to quantify the benefits from medical innovations such as the intra ocular lens and the consequential shorter time required to perform cataract operations, or the improved survival chances after heart operations and so on.

198 Grilliches, Z, *ibid*, (1995).

199 Markets for pollution rights are now being developed. An EU emissions trading scheme for carbon will be in operation from 2005. This will mean that carbon emissions will be priced into industry's costs.

200 Although firms in other industries may see an increase in productivity from using the improved product.

201 PREST/CRIC Services and Innovation: Dynamics of Service Innovation in the European Union, University of Manchester/UMIST (2001).

202 Difficult, but not impossible. For example, the use of quality adjusted life years in health option appraisal.

On balance it is likely that national accounts under-estimate the effects of innovation on economic output[203]. Despite these difficulties researchers have tried successfully to estimate the impact of innovation on economic performance. The empirical literature for example has consistently shown a positive relationship between innovation indicators and measures of economic output[204]. But the discussion above suggests the link between innovation and productivity is complex. It is possible to have a strong innovation performance – as measured by innovation indicators – and an average or worse productivity performance. For example, Sweden[205] leads Europe on innovation indicators but has slipped from being one of the richest countries in the world to below the OECD average. This is because innovation expenditures are a necessary, but not sufficient, condition for improved economic performance. Sufficient conditions include well functioning Innovation Systems which can translate innovation into growth.

203 Crafts N, DTI Economics seminar.

204 Griliches, Z., *ibid*, (1995).

205 Elg L 'The Swedish Paradox', unpublished discussion paper circulated at the OECD Committee of Science and Technology policy 25th – 26th March (2003).

Annex D: Innovation performance by region

Employment and expenditure on research and development by business in the UK is heavily concentrated in the South East and Eastern Regions which account for nearly half the UK total (Fig 53). Studies have shown the tendency of business R&D to cluster in specific areas highlighting the importance R&D business units attach to exploiting local spillovers and access to a local research infrastructure. For example, knowledge transfer is affected by spatial distance: research collaboration is strongly influenced by geographical proximity; as distance increases, collaboration decreases[206]. There are also substantial regional differences in skills with more productive regions having higher levels of skill[207].

A major factor driving the innovation propensity of business is the market for products and services, including its geographical range. According to the third Community Innovation Survey[208] innovation active enterprises[209] mostly perceive themselves as operating in national or international markets. Although the relative importance of local markets tends to be higher in the north. In Northern Ireland firms are very concentrated on their local market while most English regions rely more on the national market.

Largest Market	Share of Innovation Active Enterprises %
Local	37
Regional	43
National	53
International	64

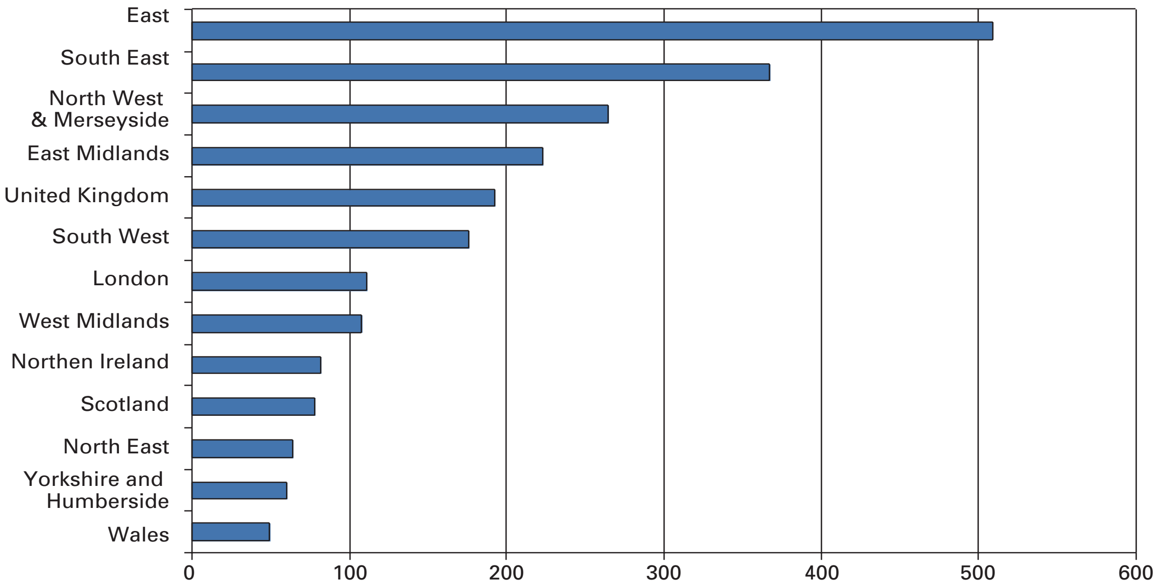
204 See Katz J S, Geographical Proximity and Scientific Collaboration, Scientometrics, Vol 31 no 1, pp31-43 (1994). For similar findings concerning corporate research see Hicks D, P A Isard and B R Martin, A Morphology of Japanese and European Corporate Research Networks, Research Policy, Vol 25, no 3, pp 359-378 (1996).

205 HMT, Productivity in the UK: 3 – The Regional Dimension (2001).

206 The third CIS collected the views of enterprises on their innovation activities between 1998-2000.

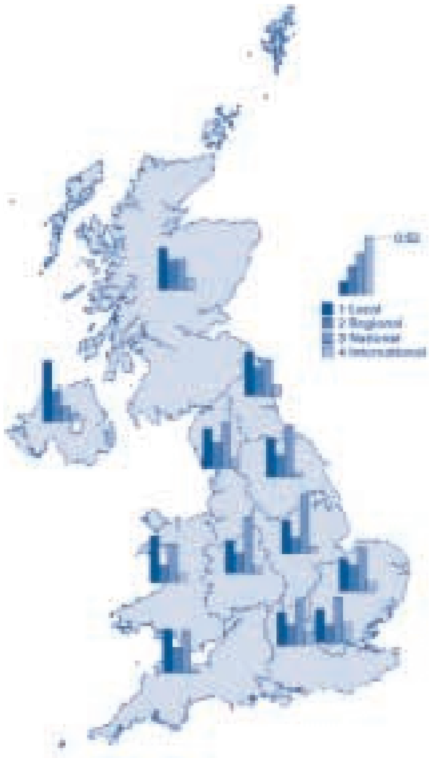
207 We define an enterprise as "innovation active" here if they:
- have introduced a new or significantly improved good, service or process;
- were engaged in innovation projects not yet complete or abandoned;
- engaged in longer-term innovation activity such as basic R&D or technology watch;
- made innovation directed expenditures in internal or extra-hural research and development, training, acquisition of external knowledge or machinery and equipment, design or market preparation;
- formally co-operated on innovation activities with other enterprises or institutions.

Fig 53. Business R&D spend per head of population (2000)



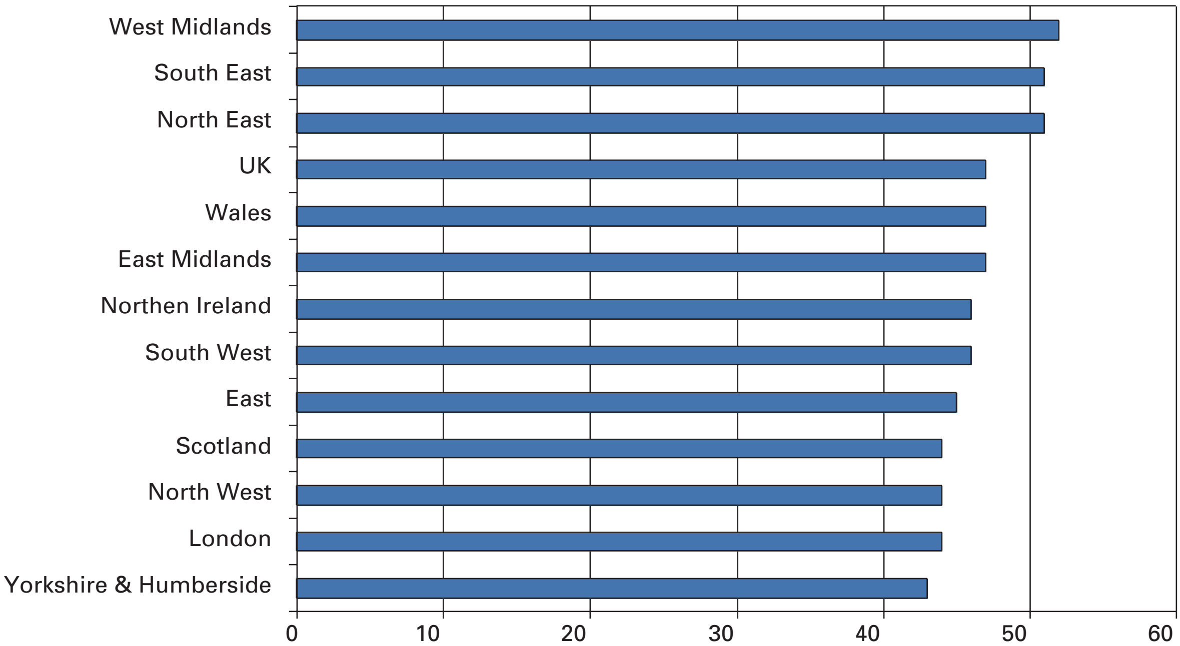
Source: ONS.

Largest market by region – innovation active enterprises



In contrast to differences in R&D investment across regions there is little evidence of difference in innovation activities against more broadly defined innovation measures (Fig 54).

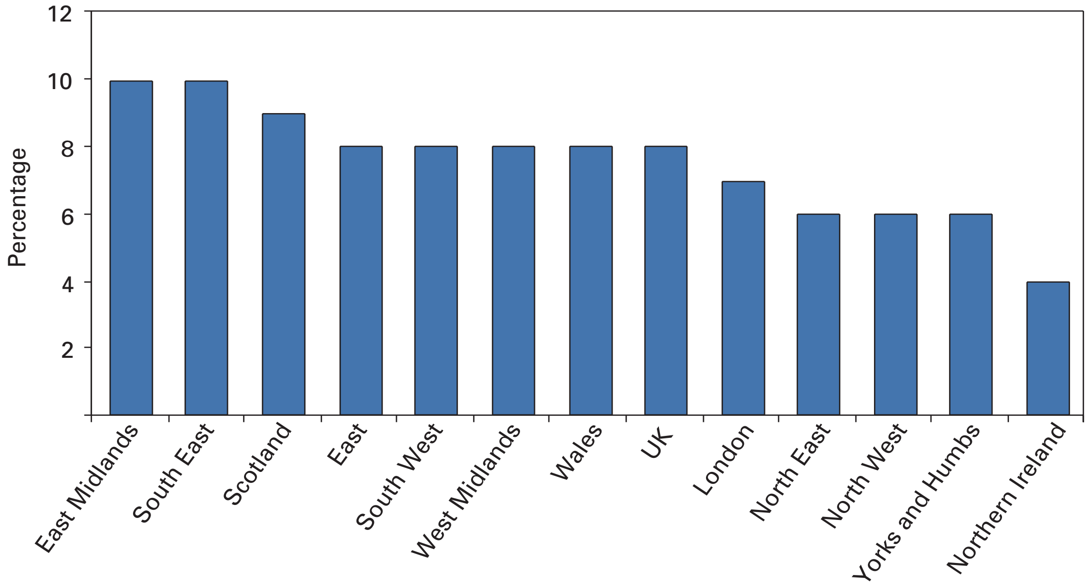
Fig 54. Innovation activity – % of innovation active firms by region



Source: CIS 1998-2000.

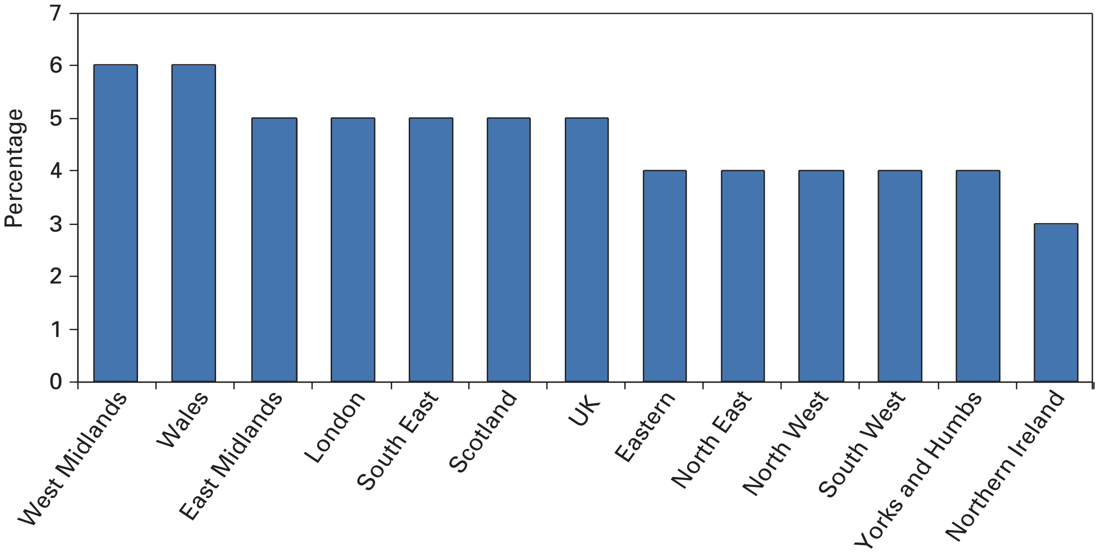
One indicator of the nature of innovation rather than just its existence is in the degree of newness. This is shown here by the share of enterprises with products and processes which are not only new to the firm in question, but also new to the firm's market or industry, dubbed novel innovation (Fig 55).

Fig 55. Novel product innovation by region, percentage of all enterprises



Source: CIS 1998-2000.

Fig 56. Novel process innovation by region, percentage of all enterprises

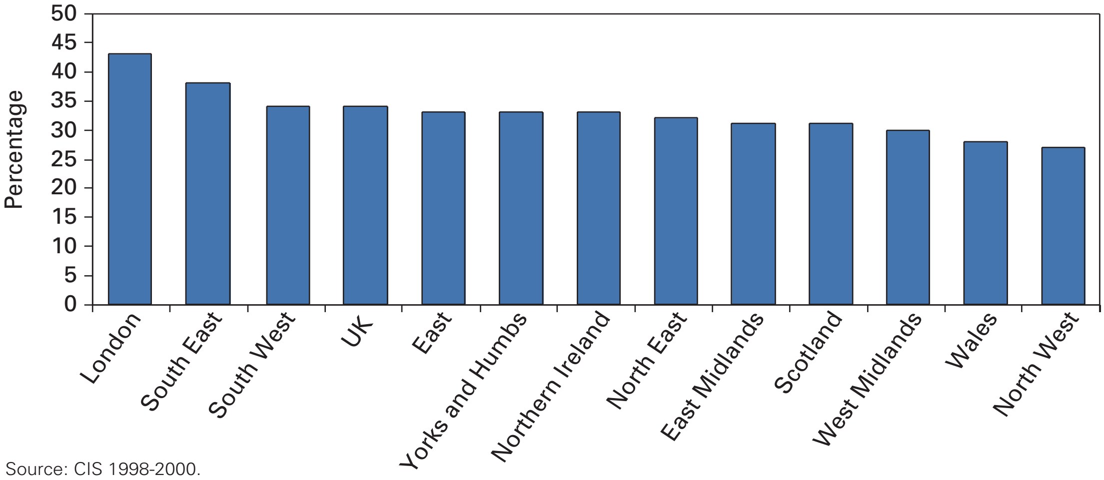


Source: CIS 1998-2000.

The South East leads the way in novel product innovation along with the East Midlands, both at 10 per cent of enterprises. Wales and the West Midlands results reflect their relatively strong process innovation with 6 per cent of their enterprises introducing novel processes (Fig 56). Northern Ireland has the least novel innovation with only 4 per cent of firms introducing a novel product and 3 per cent introducing a novel process.

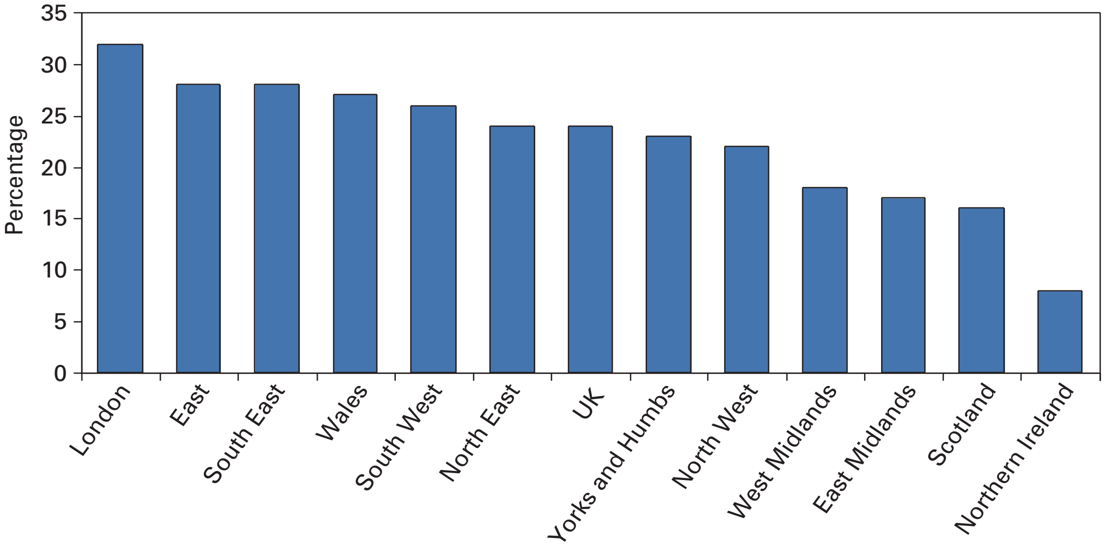
There are also regional differences in the extent firms generated revenue from new and novel products between 1998 and 2000 (Figs 57&58).

Fig 57. Percentage of turnover from products new to the firm or significantly improved for product innovators



Source: CIS 1998-2000.

Fig 58. Percentage of turnover from novel products for product innovators



Large businesses are always more likely to engage in innovation activity than small, although they have a lower share of their turnover from new products than SMEs. This probably reflects size effects (larger firms have a wider product range). The greater market reach of larger firms means that innovations have much greater economic impact. Product innovating firms in London generate 43 per cent of their turnover from new or improved products, well over the UK average of 34 per cent.

The position is similar for novel products. Of those firms that introduced novel products SME's generated a much higher percentage of their turnover from these products than large firms. The only region where this was not true, Northern Ireland relied by far the least on novel products for its turnover (three times less than the UK average). Also novel innovators in London made the greatest percentage of turnover from novel products at 32 per cent.

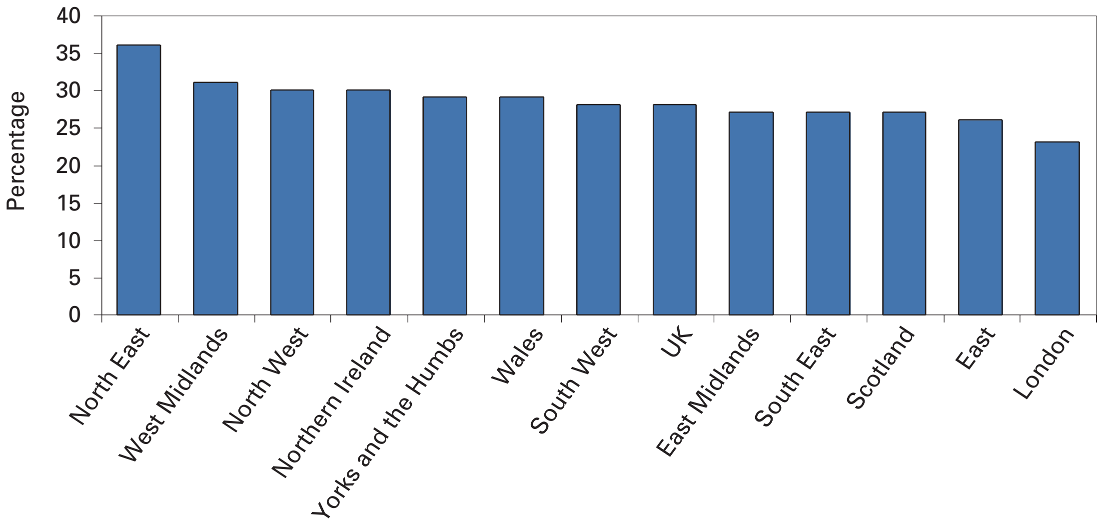
Further analysis shows that variations in the propensity to innovate and the degree of innovation intensity are larger between industries than between regions, suggesting that regional innovation levels are substantially the result of industry location effects.

The Community Innovation Survey[210] covered in some detail the networks of communication through knowledge transfer or co-operation between business and the science and engineering base. A higher share of businesses in the North East report the science and engineering base as an important source of information while the lowest share was in London (Fig 59).

The next level of engagement with the range of external sources of innovation capability or knowledge is more formal co-operative research projects. Eight percent of firms surveyed in the UK said that they had one or more formal cooperation agreements on innovation projects with a variety of other businesses and institutions

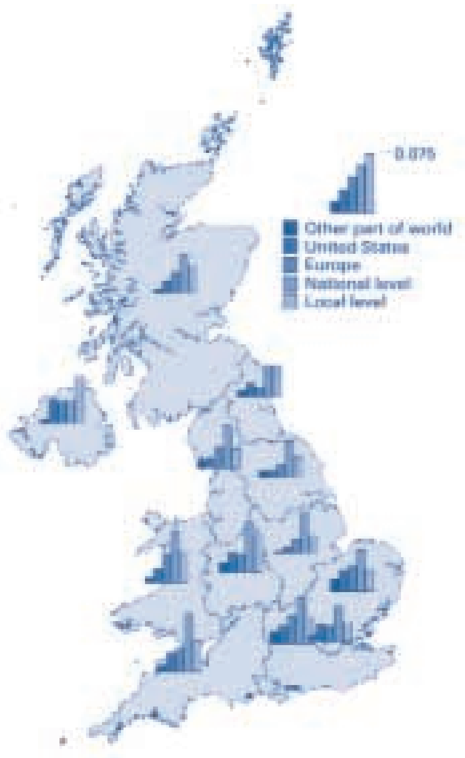
210 In this extract from the results of the community innovation survey respondents were asked to rank the importance of several potential sources of information for innovation as being not used, low, medium or high. Science, Engineering and Technology Base sources include:
- Universities or other higher education institutes
- Government research organisations
- Other public sector such as business links and government offices
- Private research institutes

Fig 59. Region of enterprises finding SEB sources of information of some importance, percentage of all respondents



around the UK and the world. Most collaborations were with national rather than local or regional partners in all regions of the UK except Northern Ireland where local partnerships were more prevalent.

Overall the data shows that firms throughout the UK look beyond their immediate location when they describe their customer base or when they look for specialised sources of knowledge or collaboration opportunities (e.g. links to the Science Base). Although many firms will of course rely on access to skilled labour on local or regional labour markets. This suggests that policy delivery needs to reflect a division of labour between regional and national government. National government has a greater role to play where there are clear economies of scale or scope – for example developing technology programmes relevant to firms across more than one region.



Annex E: Clusters

Clusters – geographically proximate groups of companies, suppliers, services and institutions – are a form of network which has received significant attention in analytical and policy circles in recent years. But the observation that industries concentrate in particular locations goes back to 19th Century[211]. Recent studies[212] argue that clusters of firms within related industries stimulates the demand for innovative goods and services. And that clusters help increase productivity by reducing transaction costs, allow economies through more efficient stock control and build up stocks of specialised and mobile labour and managers. The active and tacit sharing of knowledge facilitates problem solving and mutual technical progress. It is also argued that clusters increase the capacity for innovation by making opportunities more obvious. Some even go as far to argue[213] that national competitive advantage is generated at the regional level, via clustering effects, rather than the national level.

This is however a rather static view. History shows how some clusters have declined over time. Some have argued that the forces that initially drive firm into clusters eventually erode[214]. It is argued that firms within clusters develop blind spots since they define their field of competition as the cluster to which they belong rather than the wider industry. Non clustered firms would, by extension, be less constrained and more adaptable to industry wide shocks. Others argue that the reliance on local face to face and tacit knowledge make local networks especially vulnerable to lock in[215]. Clustered firms, whilst capable of incremental improvement, are unable to adapt to radical shifts in technology and product[216].

One difficulty for policy is the lack of any definition, either industrial or geographic, for a cluster[217]. Cluster boundaries – if identifiable – are unlikely to conform to industrial or regional classifications used for data collection. Nor is it easy to justify why some firms should be included within a cluster and why others should not. Distinctions based on the strength of linkages or spillovers between firms have to be able to define the relative strength of those connections. Something which is difficult to do in practice. The lack of precision has led to a multitude of cluster types. Indeed critics argue that virtually every firm could be considered as part of a potential cluster.

As a result it is often difficult to identify consistent estimates of numbers of clusters in any given economy. Estimates of the number of US clusters range from 60 to 380 (accounting for 60% of US output). For the UK estimates range from a handful to several dozen. Mapping exercises[218] typically identify the UK as having important clusters in financial services in the City of London, Ceramics in Staffordshire and Chemicals in the North East, while there are also local/regional agglomerations such as high technology industry in Cambridge and Oxford.

211 Marshall A, Principles of Economics, London: Macmillan (1890).

212 Porter M E and C H M Ketels, *ibid*, (2003).

213 Harding R, Venturing forward – the Role of Venture Capital Policy in Stimulating Entrepreneurship, London, IPPR (2000).

214 Prouder R and CH St John, Hot Spots and Blind Spots: Geographical Clusters of Firms and Innovation, Academy of Management Review, 21, 4 pp 1192-1225 (1996).

215 Amin A and P Cohendet, Learning and Adaptation in Decentralised Business Networks, Environment and Planning D: Society and Space 17, pp 87-104 (1999).

216 Loasby B, Industrial Districts as Knowledge Communities in M Bellet and C L'Harmet (eds) Industry, Space and Competition: The contribution of economists in the past. Cheltenham: Edward Elgar, pp 70-85 (1998).

217 Martin R and P Sunley, Deconstructing Clusters Chaotic Concept or Policy Panacea? CEBR Working Paper 212, University of Cambridge, September (2001).

218 The Sainsbury Report (1998)

Some authors have lamented the relative absence of research on the nature and scope of clusters, or the measurement of their influence on wider economic performance[219]. Some studies have suggested that clusters may increase innovation in regions, although the difficulties in obtaining good data and identifying clusters makes the evidence far from conclusive. Other studies have generated contrary or ambiguous results[220]. This has led one author to conclude that the case for clusters boosting business performance and local economic development is not conclusively proven[221].

What is clear is that while being in a cluster has its advantages, it cannot compensate for poor awareness of market conditions, failure to adapt to technological shifts, or weaknesses in management. Nor are clusters likely to be a panacea for regional or industrial development. It is likely that there is a natural limit to the size of a particular cluster. The growth of industrial concentrations tends to increase costs as local labour and housing markets tighten and congestion increases[222]. At some point firms are likely to be discouraged from joining a cluster because the costs exceed the benefits. Increasing costs are likely to force less productive firms out of business or out of the locality. So it cannot be assumed that the promotion of clusters within regions leads to balanced economic development, or greater competitiveness, or greater well being across a region.

There is a consensus in the literature that Government policies to create clusters from scratch are unlikely to succeed[223]. And attempts to force the development of regional "embryo" clusters through location subsidies (including rent and rates holidays etc) could potentially damage the growth and performance of market generated clusters elsewhere in the UK. It is likely therefore that Government and DTI's role in encouraging cluster formation and networking is primarily:

- To act as a sign post to other firms, institutions and networks;
- To provide information about who is active in what field;
- To promote the strengths of UK science and business abroad so that we are included in international networks;
- To act as a catalyst in areas of strategic interest.

219 Harding R and M Cowling, How Important are Regional Clusters as Hubs for Entrepreneurial Activity? London Business School Working paper, (2003).

220 See Martin R and P Sunley, *ibid*, (2001).

221 Best M, The New Competitive Advantage: The Renewal of American Industry. Oxford: OUP (2001).

222 DETR , Planning for clusters, London: HMSO (2000).

223 Schmitz H and K Nadvi, Clustering and Industrialisation: Introduction, World Development Vol 27, No 9 pp 1503-1514 (1999).

Annex F: Design of cost effective policies: lessons learnt

As part of the Review DTI officials looked at existing evaluation evidence for a number of major innovation programmes. Some new research was also commissioned to come up with an early assessment of the effectiveness of the Faraday programme[224]. The programmes either belonged to the Department's innovation portfolio or contributed to the Department's knowledge transfer objective. The programmes were chosen because they were significant in terms of size. They accounted for over £190 million, 56%, of innovation related expenditure.

Officials looked at the following programmes:

Scheme	**Budget (TFR 2003/4)**	**Purpose**	**New Business Support product**
Smart	£27m	Funding towards the costs of R&D projects in small and medium sized firms (< 250 employees)	R&D grant
TCS	£18m	Support for graduates to work on innovative projects in firms	Knowledge transfer through people
LINK	£19.3m	Programme supporting research collaborations between firms and universities	Collaborative R&D
NMS	£75m	National Measurement System responsible for funding measurement research and its dissemination to users	NMS
Faraday Partnerships	£9.4m	Funding of networks to promote flows of people, technology and innovative business concepts between the science and engineering base and industry.	Knowledge Transfer Networks
Biotechnology	£10.2m	Public funding of a range of activities from LINK research programmes, support for exploitation (e.g. advice on IP) and support for manufacturing.	Product depends on business case and type of activity supported
Space technologies	£32.9m	Funds technology projects in support of ESA and UK space missions.	Product depends on business case and type of activity supported

224 PACEC, Evaluation of the Impact of Faraday Partnerships: Interim Report, a Report Prepared for the DTI (2003).

A number of schemes, in particular the smallest, have been excluded from the analysis. But in some cases we have lacked available evaluation evidence to make a judgement. HEIF – support for knowledge transfer from universities – (£64m) is relatively new and there has not yet been time to carry out a full evaluation. CARAD (£21m) – support for aerospace technologies – is an older scheme but no full evaluation is available, although one is due to start later this year.

Estimates of total impact of many of these schemes are hard to come by. Most are in part justified by the wider benefits that accrue to others. These include benefits such as better health outcomes from new medical technologies as well as commercial benefits as a wide range of firms can potentially use the technologies funded. In many cases these wider benefits will exceed the directly measurable benefits that accrue to the supported firm.

General lessons

A range of evidence was reviewed covering individual evaluation reports (where available) as well as analysis of a wide range of innovation and other programmes carried out as part of the Department's Business Support Review. A number of general lessons emerged:[225]

- The strength of a schemes rationale is an important determinant of programme success. Schemes that tackle an identifiable market or systemic failure achieve better results than those that do not. A good rationale is a necessary, but not sufficient condition to justify intervention. Other conditions need to be met, such as, whether the likely benefits of intervention exceed costs.
- Schemes that support the sharing of knowledge through the brokerage of partnerships or collaboration tend to achieve widespread economic benefits.
- Schemes that involve SMEs tend to achieve greater additionality.
- Other success factors include well-specified target group of beneficiaries, clarity about the innovation activities supported and well defined conditions that have to be met to justify support.
- Successful programmes support activities that are long term and innovative in nature and engage strategic commitment because they are seen as core to the future of the business.

Specific programmes

A review of the evaluation evidence for specific programmes produced the following points. These are summarised below.

- **Smart** has a good rationale which is based on the grounds that SMEs would otherwise find it difficult to raise relatively small sums due to the high costs of due diligence. Almost all beneficiaries (94%) state that they could not pursue their objectives without Smart support. The majority of Smart firms also report an improvement in the skills base and R&D capability. There is a degree of similarity between Smart and the refundable element of the R&D tax credit although there are important differences between the schemes in the timing of payments, the scope of eligibility (individuals or partnerships cannot qualify for tax credits) and the range of eligibility amongst other things. Further research to identify how firms use both schemes is probably needed. Smart has achieved significant economic impact[226]

225 General lessons were set out in SQW Ltd, DTI Industrial Support Policies, Mapping and Assessing the Patterns of DTI Industry Support and its Impacts, Report to DTI, (2001).

226 For example the latest evaluation estimated that £1 million of public expenditure on SMART increased turnover in the economy by £2.4 million and exports by £1.3 million.

although successes are inevitably concentrated in a minority of projects. Seven out of ten projects reach the market and of these 20% account for 80% of the sales arising. This in itself suggests that Smart is operating at the uncertain end of the spectrum of technology projects where financing constraints are likely to be more significant. Spillover benefits also accrue to Smart firm customers and suppliers.

- **TCS** has a good rationale based on the difficulty firms face exploiting technological developments outside their area and that barriers to communication exist between firms and HEIs. TCS, running since 1975, is an early example of a scheme that addresses a systemic failure. Both large and small businesses participate, although the majority of projects are with small firms. The rationale is not small firm specific- and the scheme was originally designed for medium enterprises, that have greater market impact to spread innovations through the economy. There is a case for rebalancing the target market to include more of this group. TCS is a successful knowledge transfer instrument, but with some of the knowledge at the leading edge with 12% of knowledge base partners attaining 5 or 5* rankings in the Research Assessment Exercise. Over 80% of companies believe that knowledge transferred during the course of the placement is either new to the firm or represented a considerable advance on their existing base. Academics also believe that involvement in TCS makes a significant contribution to their research. The scheme generates economic benefits[227], and while not all HEI Departments give involvement high priority, there is evidence of unsatisfied demand for projects.

- **LINK** has a strong rationale based on both systemic and market failures. The scheme aims to overcome barriers to communication between business and HEIs by fostering collaborative research and also helps to address the market failure caused by the divergence between private and social returns to R&D. The scheme generates research which is broadly comparable to OST funded research in terms of quality. It has also led to substantial economic benefits[228] including quality of life benefits such as improvements to the environment and advances in medical care. There is no evidence that the scheme is generating diminishing returns and there is a good case for expansion. LINK programmes are over-subscribed and approximately 1 in 6 applicants are successful in the LINK competitions. Furthermore since LINK funds research in specific technological areas there is scope to launch programmes in new fields. The recent strategic review has recommended broader, longer lasting themes as the basis for support, building on the strengths of LINK in high quality research with exploitation potential.

- **National Measurement System (NMS)** has a particularly strong rationale based on the fact that measurement standards are public goods. Firms have little incentive to supply these since they cannot exclude other firms from the benefits. It would therefore be difficult to recoup a return from their investment so the private sector would tend to under-invest. Furthermore there are efficiency gains from the use of standard measurements. Although the benefits of the NMS are largely taken for granted, they are substantial and widespread[2239]. One indicative estimate[230] suggests that metrology underpins around £5 billion of GDP. NMS also secures quality of life benefits – such as better control of therapeutic radiation dosages for cancer patients. Current levels of funding meet existing demands, although cuts in budgets would put at risk the economic activity it supports.

227 Allowing for non-additional outputs and displacement, TCS grants of £84.5m generated between £70 million and £73.5 million.

228 Estimates suggest that since its inception LINK was responsible for an increase in turnover of between £700m and £2400m – a benefit to cost ratio of between 1.1 and 3.8 to 1.

229 Swann G M P, Case studies, Mechanisms and a Micro Model of Measurement Impact, Report to DTI, 27 August (2003).

230 PA Consulting, Review of the Rationale for and Economic Benefit of the UK National Measurement System, Report for DTI, 8 November (1999).

- **Faraday partnerships** aim to address the systemic barriers to collaboration and knowledge transfer that exist between HEIs and business. Although the scheme is relatively new (some Faradays were only set up in 2000) participants in the programme generally felt that it was effective in promoting knowledge transfer. Faradays appear to have stimulated some increased innovation activity, particularly amongst smaller firms. But most thought that the volume of innovation activity had not increased. Instead the main impacts were found on the effectiveness and nature of innovation activity. Firms said that effectiveness increased, although a minority believed it was due to Faraday involvement.

In addition to the generic instruments which can be applied to any technological area, the DTI currently funds a number of sector specific schemes.

- Biotechnology support is encompassed within a range of programmes, some specific to Biotech others drawing on existing products to provide support – e.g. LINK. Support for **Biotechnology** is justified on the grounds that it potentially offers major economic benefits but industry needs support in order to draw upon and exploit the strengths of the UK science base. The biotech industry is characterised by SMEs many of which are spin-outs or at a very early stage of development. Venture Capitalists are reluctant to invest in early stage companies which do not have a substantial pipeline of products. A number of measures – such as assistance to public sector research institutions (HEIs, NHS, etc) in identifying and exploiting intellectual property, and the provision of business advice to spin-outs and early stage companies – generated significant benefits to participants. Both these measures probably accelerated a process that would have been undertaken anyway – universities and business owners would have developed the competencies in time – although IP within the Science Base may have gone unexploited or companies may have failed. A scheme aimed at raising awareness of biopharmaceutical manufacturing issues has been successful in the provision of relevant training to scientific staff but, importantly, less successful in engaging interest from senior managers, despite the fact that exploitation of products is vitally dependant on manufacturing processes that can overcome the inherent difficulties of scaling up from laboratory to pre-clinical and early stage trials. This programme has not been able to utilise its full budget.
- The evaluation of DTI's civil space activity concluded that the rationale for a measure of DTI support for the development of **space technologies** was supported by sound economic arguments. High technical and financial risks and the potential for spillovers, particularly in the form of markets for space based services, meant that benefits might not accrue fully to those taking the risks and as a result incentives for private sector involvement were small. Furthermore the public sector is a major consumer of some space-based services (e.g. imagery from earth observation). As a result of an earlier evaluation DTI's funding of space has been subject to some changes. Responsibility for science aspects have been passed to the Research Councils for example. The DTI has commissioned a study to look at the evidence for spillovers of technology from space to non-space sectors, as well as wider impacts, such as the development of services, from UK civil space activity.

A number of points emerged during the exercise which are applicable to the development new interventions. These are:

- The importance of basing interventions on a wide analytical base, including contributions from those with an independent, but informed, perspective.
- Ensuring that individual projects funded under programmes are scrutinised for their contribution to productivity. In practice this means that projects need to address a market or systemic failure, which has been identified through detailed analysis.

This should ensure that intervention provides widespread economic benefits rather than supernormal returns to a narrow range of firms.

- Making greater use of piloting for projects where there is uncertainty concerning the strength of the rationale. For example because the problem or opportunity identified is novel. The period of the pilot should be used to gather more evidence on the strength of the rationale. Piloting could be used more extensively for policy experiments.
- Effective monitoring procedures which allow programme managers to assess the impact of interventions and which can be used to make mid-course corrections to the design, or funding, of specific projects.
- An evaluation strategy is needed for each project or programme, which should be developed before the scheme begins. This should set out the data requirements for the final evaluation, the method of, and responsibility for, collection and the main hypotheses which the evaluation should test.
- Ensuring that projects or programmes are routinely evaluated at least every five years or so. Evaluations should address whether the rationale is still valid and whether objectives have been met. Schemes that achieve time-limited objectives or, where the rationale proves no longer valid, should be stopped.

Many of these points have been taken on board in the design of the DTIs new business support products.

References

Aghion, P. and Howitt, P., Endogenous Growth Theory, MIT Press, Cambridge, Massachusetts (1998).

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P., Competition and Innovation: an inverted U relationship, NBER working paper 9269 (2002).

Aghion, P., Dewatripont, M. and Rey, P., 'Corporate Governance, Competition Policy and Industrial Policy', European Economic Review, 41, pp 797-805 (1997).

Amin, A. and Cohendet, P., Learning and Adaptation in Decentralised Business Networks, Environment and Planning D: Society and Space 17, pp 87-104 (1999).

Andersen, B., Howells, J., Miles, I. and Boden M., Service Production and Intellectual Property, International Journal of Technology Management (1999).

Arrow, K.J., Economic Welfare and the Allocation of Resources for Invention in RR Nelson (ed) The Rate and Direction of Inventive Activity: Economic and Social factors. Princeton: Princeton University Press (1962).

Bank of England, Financing of Technology Based Firms, Bank of England (2001).

Barnett, C., The Lost Victory, Pan Publishing (1995).

Barrell, R. and Pain, N., Domestic Institutions, Agglomerations and Foreign Direct Investment in Europe, European Economic Review, 43, pp 925-34 (1999).

Becker, B. and Pain, N., What Determines Industrial R&D Expenditure in the UK?, National Institute of Economic and Social Research (2002).

Bessant, J., Caffyn, S. and Gilbert, J., Learning to Manage Innovation, Technology Analysis and Strategic Management 8, 59-70 (1996).

Best, M., The New Competitive Advantage: The Renewal of American Industry. Oxford: OUP (2001).

Birdi, K., Denyer, D., Munir, K., Neely, A. and Prabhu, J., Post Porter: Where Does the UK Go From Here? Summary Report from the AIM Management Research Forum, June (2003).

Kitching, J. and Blackburn, R.A. (1998) 'Managing Intellectual Property in the Small and Medium Enterprise (SME), 21st ISBA National Small Firms Policy and Research Conference, Durham, November.

Bloom, N. and Van Reenan, J., Real Options, Patents, Productivity and Market Value: Evidence from a Panel of British Firms, IFS Working Paper 00/21 (2002).

Blundell, R., Griffith, R., and Van Reenen, J., (1999) Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms, Review of Economic Studies, vol 66, pp529-54 (1999).

Bond, S., Meghir, C. and Windmeijer, F., Productivity, Investment and the Threat of Takeover. Mimeo, Institute for Fiscal Studies, London (1998).

Bosworth, D., Wharton, A. and Greenhalgh, C., Intangible Assets and the Market Valuation of UK Companies: Evidence from Fixed Effects Models, Oxford Institute of Intellectual Property Working Paper (2000).

Broadberry, S. N. and Crafts, N. F. R., British Economic Policy and Industrial Performance, Business History, Vol 38 No 4, pp 65-91 (1996)

Broadberry, S. N. and Crafts, N. F. R., Competition and Innovation in 1950s Britain, working paper in Economic History no 57, London School of Economics (2000)

British Venture Capital Association, The Economic Impact of VCTs (2003).

Bureau of Industry Economics (Australia), The Economics of Patents, Occasional Paper 14, (1994).

Calvert, J. and Patel, P., University - Industry Research Collaborations in the UK, paper produced under EPSRC/ESRC Analysis of University - Industry research Collaborations in the UK (2002).

CBI/TUC, Productivity Report (2001).

Chandy, R. and Tellis, G., “The Incumbent’s Curse? Incumbency, Size and Radical Product Innovation,” Journal of Marketing, 64 (3), 1-17 (2000).

Charan, R. and Colvin, G., Why CEOs Fail, Fortune magazine, 21st June (1999).

Charles Rivers Associates, Innovation and Competition Policy, Report presented to the Office for Fair Trading, March (2002).

Ciborra, C., Alliances as Learning Experiments: Co-operation, Competition and Change in High-tech Industries, in L. Mytelka “Strategic Partnerships and the World Economy, London, Pinter (1991).

Clegg, C. W., Wall, T. D., Pepper, K., Stride, C., Woods, D., Morrison, D., Cordery, J. L., Couchman, P., Badham, R., Kuenzler, C., Grote, G., Ide, W., Takahashi, M. and Kogi, K.., An International Study of the Use and Effectiveness of Modern Manufacturing Practices, Human Factors and Ergonomics in Manufacturing, 12, 171-91 (2002).

Cockburn, I. and Griliches, Z., Industry Effects and Appropriability Measures in the Stock Market’s Valuation of R&D Investment, American Economic Review (1988).

Cockburn, I.M. and Henderson, R.M., Publicly Funded Science and the Productivity of the Pharmaceutical industry. NBER Conference on Science and Public Policy (2000).

Cohen, W., Empirical Studies of Innovative Activity in P Stoneman (ed), Handbook of the Economics of Innovation and Technological Change, Oxford, pp 182-264 (1995).

Cohen, W. and Levinthal, D., Innovation and Learning: Two Faces of R&D, Economic Journal, 107,139-49 (1989).

Coombs, R., Ford, R. and Georghiou, L., Generation and Selection of Successful Research Projects: A research study for the UK Technology Strategy Forum (2001).

Coopers and Lybrand, Final report for the Study of International Differences in Cost of Capital for the European Commission, April, Brussels, European Commission (1993).

Cosh, A. and Hughes, A., Enterprise Challenged: Policy and Performance in the British SME Sector 1999-2002, ESRC Centre for Business Research, University of Cambridge (2003).

Council for Excellence in Management and Leadership, Managers and Leaders, Raising Our Game (2002).

Crafts, N. and O'Mahoney, M., A Perspective on UK Productivity Performance, Fiscal Studies vol 22 no 3 pp271-306 (2001).

Crafts, N. and Mills, T.C., TFP Growth in British and German Manufacturing. ESRC programme Business Cycle Volatility and Economic Growth, Research Paper no 01/3 (2001)

David, P.A., Hall, B.H. and Toole, A.A., Is Public R&D a Complement or Substitute for Private R&D? A Review of Econometric Evidence. Research Policy (2000).

Dearden, L., McIntosh, S., Myck, M. and Vignoles, A., The Returns to Academic, Vocational and Basic Skills in Britain, Skills Task Force Research paper 20 (2000).

Design Council, The Value of Design within Innovation, Design Council briefing for the DTI: Innovation Action Plan, April (2003).

DETR , Planning for Clusters, London: HMSO (2000).

Deveraux, M. P. and Griffith, R., Taxes and the Location of Production: Evidence from a Panel of US Multinationals, Journal of Public Economics, 68, pp 335-68 (1998).

DfES, Learning and Training at Work Survey (2002).

Dixon, P. and Greenhalgh, C., The Economics of Intellectual Property: A Review to Identify Future Research Themes (2002).

DTI, Productivity and Competitiveness indicators: Update, (2002).

DTI, The 2003 R&D Scoreboard, Commentary and Analysis (2003).

DTI, The Value Added Scoreboard (2003).

DTI, Options for a Low Carbon Future, DTI Economics paper no 4 (2003).

DTI, HMT and DFES, Investing in Innovation: a Strategy for Science, Engineering and Technology, July (2002).

Elg, L., 'The Swedish Paradox', unpublished discussion paper circulated at the OECD Committee of Science and Technology policy 25th - 26th March (2003).

Engineering Employers Federation, Catching up with Uncle Sam - the Final Report on US and UK Manufacturing Productivity (2001).

Eraut, M., The Role and Use of Vocational Qualifications, National Institute Economic Review No 178 (2001).

Evidence Ltd, PSA Target Metrics for the UK Research Base, Draft Report to the DTI (2003).

Frenz, M., A Comparison of the Second and Third UK Community Innovation Survey, Unpublished paper available on dti.gov.uk\tese (2002).

Geroski, P., Markets for Technology in P Stoneman (ed), Handbook of the Economics of Innovation and Technological Change (Oxford, 1995), pp 90-131 (1995).

Godden, G., Investment Appraisal in UK manufacturing: has it changed since the mid 1990s? CBI discussion paper (2001).

Goodacre, A. and Tonks, I., Finance and Technical Change, in the Handbook of the Economics of Innovation and Technological Change, Ed Paul Stoneman, Blackwell (1995).

Gourlay, Hargreaves, McCraken, Seaton and Weyman - Jones, Comparative Study of Systems for IP Management in HEIs in the UK, USA and Germany (1998).

Grandstrand, O., Patel, P. and Pavitt, K., Multi-technology Corporations: why they have 'distributed' rather than 'distinctive core' competences, California Management Review, Vol. 39 (1997).

Greenhalgh, C. and Longland, M., Intellectual Property Scoreboards for the UK in 2000, part C of the research project titled 'The Extent and Value of Intellectual Property in UK firms (2003).

Greenhalgh, C. and Longland, M., Running to Stand Still? - Intellectual Property and Value Added in Innovating Firms, Oxford Institute of Intellectual Property Working Paper (2002)

Griffith, R. and Harrison, R., Understanding the UK's poor technological performance, IFS Briefing paper no 37 (2003).

Griliches, Z., Patent Statistics as Economic Indicators: a Survey, Journal of Economic Literature 28 (1990).

Griliches, Z., R&D and Productivity: Econometric Results and Measurement Issues in Stoneman, P., (ed) The Handbook of the Economics of Innovation and Technological Change, pub. Blackwell (1995)

Guellec, D. and van Pottelsberghe de la Potterie, B., R&D and Productivity Growth: Panel data analysis of 16 OECD countries, OECD working paper, (2001).

Hall, M., Oppenheim, C. and Sheen, M., Barriers to the use of Patent Information in SMEs, Final Report to ESRC (1998)

Hall, B.H., Jaffe, A. and Trajtenberg, M., Market Value and Patent Citations: A First Look, Conference in commeration of Zvi Griliches (2001).

Harding, R. and Cowling, M., How Important are Regional Clusters as Hubs for Entrepreneurial Activity? London Business School working paper, (2003).

Harris, R. and Robinson, C., A Critical Review of Empirical Research on Hindrances to Business Development and Productivity Growth and the Relative Importance of Different Constraints on UK business, Report to DTI, April 2001.

Haskel, J. and Martin, R., The UK Manufacturing Productivity Spread, CERIBA discussion paper (2002).

Harding, R., Venturing forward - the Role of Venture Capital Policy in Stimulating Entrepreneurship, London, IPPR (2000).

Hicks, D., Isard, P.A. and Martin, B.R., A Morphology of Japanese and European Corporate Research Networks, Research Policy, Vol 25, no 3, pp 359-378 (1996).

HM Treasury, Productivity in the UK: The Evidence and the Government's Approach, HM Treasury, November (2000).

HM Treasury, Lambert Review of Business University Collaboration: Summary of consultation responses and emerging issues (2003).

HM Treasury, Small Business Service, Bridging the Finance Gap: a Consultation on Improving Access to Growth Capital for Small Business (2003).

HM Treasury, Productivity in the UK: 3 - The Regional Dimension (2001).

HM Treasury/National statistics (2003) Public Expenditure Statistical Analyses, May 2003

HMT, DfES, DTI and OST, Cross - Cutting Review of Science and Research (2000)

Hogarth, T. and Wilson, R., Tackling the Low Skills Equilibrium: A Review of Issues and Some New Evidence, Draft Report to DTI, October (2003).

Horne, M. and Stedman Jones, D., Leadership: The Challenge for All, Institute for Management, (2001).

US Department of Labor , International Comparisons of Hourly Compensation Costs for Production Workers in Manufacturing 1975-2001, Bureau of Labor Statistics (2002).

Jaffe, A. B., Economic Analysis of Research Spillovers: Implications for the Advanced Technology Program, http//:www.atp.nist.gov/eao/gcr708.htm (1996).

Katz, J. S., Geographical Proximity and Scientific Collaboration, Scientometrics, Vol 31 no 1, pp31-43 (1994).

Katz, M. and Ordover, J.A., R&D Co-operation and Competition, Brookings Papers on Economics (1990).

Keep, E., Mayhew, K. and Corney, M., Review of the Evidence on the Rate of Return to Employers of Investment in Training and Employer Training Measures, Report to the DTI, (2003).

Kitson, M., Michie, J. and Quinn, M., Markets, Co-operation and Innovation, University of Cambridge working paper No212 (2001)

Krueger, A.,, Economists Changing Perceptions of Government, Weltwertschaftlichtes Archiv 126, 417-31 (1990).

Krugman, P., Technological change in International Trade, in P.Stoneman, ed., Handbook of the Economics of Innovation and Technical Change, pp. 342-366, Blackwell, London (1995).

Lalonde, R. and Lecavalier, D., The US Miracle, mimeo (2001).

Lambert, R., Value Added, Technology ad Innovation in UK sectors, unpublished DTI discussion paper (2003).

Leach, D., Totterdell, P., Birdi, K., Clegg, C., Wood, S. and Wall, T., Innovation at Work: Findings from a Survey of Innovation in UK Organisations, Sheffield: University of Sheffield (2001).

Leseure MJ, J Bauer and K Birdi, Adoption of Promising Practice, a Review of the Evidence, a Systematic Review, AIM Management Research Forum, August (2003).

Licht et al, Results of the German Service Sector Innovation, Manheim, ZEW (1997).

Loasby, B., Industrial Districts as Knowledge Communities in M Bellet and C L'Harmet (eds) Industry, Space and Competition: The contribution of economists in the past. Cheltenham: Edward Elgar, pp 70-85 (1998).

Lundvall, B-A., National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, Pinter, London (1992).

MacDonald, S. and Lefang, B., Protection or Dissemination? The contribution of the Patent System to SMEs, Final Report to ESRC (1998).

Mansfield, E., Patents and Innovation: an Empirical Study, Management Science, 32, 173-81 (1986).

Marshall, A., Principles of Economics, London: Macmillan (1890).

Martin, R. and Sunley, P., Deconstructing Clusters Chaotic Concept or Policy Panacea? CEBR Working Paper 212, University of Cambridge, September (2001).

Mason, G., Graduate Utilisation and the Quality of Higher Education in the UK, National Institute of Economic Research Discussion paper 158, October (1999).

McCauley, Robert N. and Zimmer, Steven A., Explaining International Differences in the Cost of Capital Federal Research bank of New York Quarterly Review Summer: 7-28 (1989).

Metcalfe, J.S., Knowledge of Growth and the Growth of Knowledge in Change, Transformation and Development, ed JS Metcalfe and U Cantner, Physica Verlag (2002)

Metcalfe, S., The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives, in P.Stoneman, ed., Handbook of the Economics of Innovation and Technical Change, pp. 409-512, Blackwell, London (1995).

Miles, I., Andersen, B., Boden, M., Howells, J., Service Production and Intellectual property, International Journal of Technology Management (2000).

Moser, C., Improving Literacy and Numeracy for Adults: A Fresh Start, An independent review for HM Government (1999).

Myners Report, Institutional Investment in the United Kingdom: A Review, Report prepared for the Chancellor of the Exchequer, (2001).

Nelson, R.R and Winter, S., An Evolutionary Theory of Economic Change, Cambridge, MA, Harvard University Press (1982).

Nelson R.R., Institutions supporting technical advance in industry, American Economic Review, 76, 186-9 (1986).

Nickell, S. and Beath, J., The Economic Record of the Labour Government, Oxford Review of Economic Policy (2002).

Nicoletti, G. and Scarpetta, S., Regulation, Productivity and Growth: OECD Evidence, Economics Department Working papers no 347.

North, D., Institutions and Economic Development, Paper presented at the OECD workshop on 'Institutional Framework and Economic Development, Paris, November (1995).

OECD, Computer Price Indices and International Growth and Productivity, Statistics Directorate, April (2001).

OECD, Science, Technology and Industry Outlook (2002).

OECD, Managing Innovation Systems (1999).

OECD, Technology, Productivity and Job Creation: Best Policy Practices (1998).

OECD, Venture Capital Country Note: United Kingdom, (2002).

OECD, Competition, Innovation and Productivity Growth: A Review of Theory and Evidence (2002).

OECD, Benchmarking Industry Science Relationships (2002).

OECD, Public Funding of R&D - Trends and Changes, (2003).

O'Mahony, M. and W de Boer, Britain's Relative Productivity Performance: Updates to 1999, Final Report to DTI/HMT/ONS, National Institute of Economic and Social Research (2002).

PA Consulting, Review of the Rationale for and Economic Benefit of the UK National Measurement System, Report for DTI, 8 November (1999).

PACEC, Evaluation of the Impact of Faraday Partnerships: Interim Report, a Report Prepared for the DTI (2003).

Pain, N. (ed), Inward Investment, Technological Change and Growth. The impact of multinational corporations on the UK economy, Palgrave, London (2001).

Pakes, A. and Schankerman, M., The Rate of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources (1986).

Pavitt K, 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory' Research Policy 13 (6) pp 343-373 (1984).

Pickering, J., Matthews, D., Wilson, C. and Kirkland, J., The Strategic Management of Intellectual Property: Review of the Interview Programme, NIESR Discussion Paper 129 (1998).

Pittaway, L., Robertson, R. and Munir, K., Networking and Innovation in the UK, A systematic review of the evidence, AIM management research forum, August (2003).

Porter, M.E. and Ketels, C.H.M., UK Competitiveness: Moving to the Next Stage, DTI Economics Paper No.3 (2003).

PREST/CRIC, Services and Innovation: Dynamics of Service Innovation in the European Union, University of Manchester/UMIST (2001).

PREST/CRIC (2003) The links between the knowledge intensive services sector and the science base, draft final report to the DTI, June 2003.

PriceWaterhouseCoopers, Peer Review of the UK Competition Regime, Report to the DTI (2001).

Prouder, R. and St John, C.H., Hot Spots and Blind Spots: Geographical Clusters of Firms and Innovation, Academy of Management Review, 21, 4 pp 1192-1225 (1996).

Proudfoot Consulting ,Untapped potential: Global productivity study, October (2002).

Rolfe, H., University Strategy in an Age of Uncertainty: the Effect of Higher Education Funding on Old and New Universities, National Institute for Economic and Social Research Discussion paper 171, December (2001).

Rosenberg, N., Why do Firms do Basic Research (With Their Own Money)? Research Policy 19, 2, pp 165-174 (1990).

Ryan, P. and Unwin, L., Apprenticeship in the British Training Market, National Institute Economic Review No 178 October (2001).

Savery, L., Mazzarol, T. and Dawkins, P., How Others See Us Competitively, Perth: Institute for International Competitiveness, Curtin University (1994).

Scarpetta, S. and Tressel, T., Productivity and Convergence in a Panel of OECD industries: Do Regulations and Institutions Matter? OECD Economics Department Working Papers (2002).

Schankerman, M., How valuable is patent protection? Estimates by Technology Field, The Rand Journal of Economics (1998).

Scherer, F.M. and Harhoff, D., Technology Policy for a World of Skew-distributed Outcomes, Research Policy 29, 559-566 (2000).

Schlie, E., Prabhu, J. and Chandy, R., Legacy Effects in Radical Innovation: A Study of European Banking, Judge Institute of Management working paper (2003).

Schmitz, H. and Nadvi, K., Clustering and Industrialisation: Introduction, World Development Vol 27, No 9 pp 1503-1514 (1999).

Shipton, H., West, M. A., Dawson, J., Patterson, J. & Birdi, K., Organisational learning as a predictor of innovation, submitted to Human Resource Management Journal (2003).

Smith, K., The Systems Challenge to Innovation Policy, in W.Polt and B.Weber, eds., Industrie und Glueck. Paradigmenwechsel in der Industrie-und Technologiepolitik, Vienna (1996).

Sorescu, A., Chandy, R. and Prabhu, J., Sources and Financial Consequences of Radical Innovation: Insights from Pharmaceuticals, Journal of Marketing, (2003).

SPRU, Talent not Technology: the Impact of Publicly Funded Research on Innovation in the UK, Report to HMT, (2000).

SPRU, University - Industry Research Collaborations in the UK (2002).

Swann, P., Innovative Business and the Science and Technology Base: An analysis using CIS 3 data, A report for DTI (2002).

SQW Ltd, DTI Industrial Support Policies, Mapping and Assessing the Patterns of DTI Industrial Support and its Impacts, Report to DTI, (2001).

Steil, B., Victor, D.G. and Nelson, R.R. (eds) Technological Innovation and Economic Performance, Princeton (2002).

Swann, P., Innovative Businesses and the Science and Technology Base, Report to DTI, October (2002).

Swann, P., Case studies, Mechanisms and a Micro Model of Measurement Impact, Report to DTI, 27 August (2003).

Symeonidis, G., Price Competition, Non Price Competition and the Market Structure. Theory and evidence form the UK, Economica, 67 (267), August pp 437-456 (2000).

Symeonidis, G., The Effects of Competition, Cartel Policy and the Evolution of Strategy and Structure in British Industry, MIT press (2002).

Tamkin, P., Hillage, J. and Willison, R., Indicators of Management Capability, The Institute for Employment Studies (2002).

Taylor, C. and Silbertson, A., The Economic Impact of the Patent system, Cambridge, Cambridge University press (1973).

Tether, B. and Swann, P., Sourcing Science: The Use by Industry of the Science Base for Innovation; Evidence from the UK's Innovation Survey, Paper Presented at the CIS user group in June, (2003).

Thomas, M. and Jones, P., UK Results from the Second Community Innovation Survey, Economic Trends (1998).

Thomson, A.W., Storey, J., Mabey, C.L. and Gray, C.W.J.A., Management Development: The Views of the Association of MBAs, The Association of MBAs, London (1998).

Thompson, S., Robbie, K., Wong, P. and Wright, M., Management Buy Outs in the Short and Long Term, Journal of Business Finance and Accounting (1995).

Von Hippel, E., The Sources of Innovation. Oxford: Oxford University (1988).

Webster, A., University Spin - offs, SMEs and the Science Base: The Effective Use of IP, Final report to ESRC, (1998).

Workplace Employee Relations Survey, DTI, ESRC, Policy Studies Institute (1998).

Printed in the UK on recycled paper with a minimum HMSO score of 75
November 2003 Department of Trade and Industry. http://www.dti.gov.uk