HOUSE OF COMMONS SESSION 1993–94

# SCIENCE AND TECHNOLOGY COMMITTEE

## First Report

# THE ROUTES THROUGH WHICH THE SCIENCE BASE IS TRANSLATED INTO INNOVATIVE AND COMPETITIVE TECHNOLOGY

## Volume I

Report and Appendices, together with the Proceedings of the Committee

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*Ordered by* The House of Commons *to be printed* *13 April 1994*

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The Science and Technology Committee is appointed under Standing Order No 130 to examine the expenditure, administration and policy of the Office of Science and Technology and associated public bodies.

The Committee consists of 11 Members. It has a quorum of three. Unless the House otherwise orders, all Members nominated to the Committee continue to be members of it for the remainder of the Parliament.

The Committee has power:

(a) to send for persons, papers and records, to sit notwithstanding any adjournment of the House, to adjourn from place to place, and to report from time to time;

(b) to appoint specialist advisers either to supply information which is not readily available or to elucidate matters of complexity within the Committee's order of reference;

(c) to communicate to any other such committee and to the Committee of Public Accounts its evidence and any other documents relating to matters of common interest; and

(d) to meet concurrently with any other such committee for the purposes of deliberating, taking evidence, or considering draft reports.

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The following were nominated Members of the Committee on 13 July 1992:

| | |
|---|---|
| Mr Spencer Batiste | Sir Giles Shaw |
| Dr Jeremy Bray | Sir Trevor Skeet |
| Mr Malcolm Bruce | Dr Gavin Strang |
| Mrs Anne Campbell | Sir Gerard Vaughan |
| Cheryl Gillan | Dr Alan W Williams |
| Mr William Powell | |

Sir Giles Shaw was elected Chairman on 15 July 1992.

On 9 November 1992 Mr Malcolm Bruce was discharged and Mr Andrew Miller added to the Committee

On 16 November 1992 Dr Gavin Strang was discharged and Dr Lynne Jones added to the Committee.

The cost of preparing for publication the Shorthand Minutes of Evidence published with this Report was £9,232.37.
The cost of printing and publishing this Volume is estimated by HMSO at £11,930.

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# FIRST REPORT

## THE ROUTES THROUGH WHICH THE SCIENCE BASE IS TRANSLATED INTO INNOVATIVE AND COMPETITIVE TECHNOLOGY

**The Science and Technology Committee has agreed to the following Report:**

### PREFACE

1. As "Realising our Potential" says:

> "The United Kingdom's competitive position rests increasingly on our capacity to trade in goods and services incorporating or produced by the latest science and technology."[1]

The Committee agrees that the successful exploitation of science and technology by industry is a primary factor in achieving growth in a modern economy. We are accordingly concerned that over the last three or four decades the UK has fallen behind comparable sized economies in the amount spent on Research and Development as a percentage of GDP. The situation appears still worse if the UK is compared with industrial leaders such as Japan and Germany. This lack of growth in R&D investment has been accompanied by a poorer average rate of economic growth measured by GDP per capita, and there is now a significant shortfall relative to our principal competitors.

2. The decline in R&D expenditure is doubly disturbing, since we note that there is evidence from recent studies which suggests that there is a significant payback to the economy as a whole from increased levels of investment in innovation, measured by increased investment in Research and Technology, Design and Development, education and training. The payback for such investments cannot be fully captured by those making the original investment and this must be borne in mind when formulating government policies aimed at encouraging increased growth.

3. A determined and sustained effort will be required to reverse the decline in the United Kingdom's standing, and it will not be possible without a widespread understanding of all aspects of the innovation process. Even with a concerted effort, it will take several years to reverse the adverse trends noted above, and decades to close the gap in GDP per capita with comparable nations.

4. There are welcome signs that the Government, through the Office of Science and Technology (OST), is attempting to take the long view and to create a stable climate based upon consensus in which innovation can flourish. However, this task cannot be left to the OST alone. It will not succeed unless all departments, including the Treasury, are seen to share the belief that the UK's future rests on world class innovative industry and that Government policy must be concerned with the long term health of industry.

5. Government policies will only be effective if they are shaped by knowledge of the innovation process; of industry's varying needs; of the interaction between the financial system and industry; and of the wider effects of particular policies. For this reason we welcome the many studies which are currently being undertaken. For this reason, too, we have set out the evidence which lies behind our conclusions in some detail; we hope this Report will contribute to the understanding of innovation and help to identify the barriers to its wider application.

6. In the course of our inquiry we have come to believe that unless reforms are urgently undertaken the United Kingdom will remain less able to exploit science and technology than many of its competitors. There is no one reason for this; rather it is the result of a set of interactions between the education and training system, the organisation of industry and the

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[1] *Realising Our Potential*, Cm 2250, para. 1.14.

operation of the financial system, all of which are strongly affected by government policies and the state of the economy. Within this complex system, however, we can distinguish a number of key problems.

7. The first is in the interaction between the rewards available in industry, and the skills available to industry. Our culture fails to reward adequately those engaged both in industry, in particular manufacturing industry, and in science and engineering. There is evidence that both workforce and management in Britain tend to be under-educated, especially in technical matters. Both the Government and individual educational institutions are attempting to improve this, but their efforts will only succeed if they are backed by industry.

8. There is currently a vicious circle operating in which a shortage of technical skills mean that those with skills are likely to be kept within technical functions. But unless scientists and engineers are offered a route to the top prospective undergraduates will have no reason to study science and engineering rather than other subjects which offer equal chance of reward. Moreover, many of those who do study science and engineering will be attracted to careers other than industry.

9. A second problem is that the lack of technically skilled management interacts with the financial system in a way which makes it more likely that projects are evaluated on short-term financial criteria, rather than on long term strategic grounds. Such financially based evaluation appears less successful in promoting long-term organic growth than other methods.

10. We have concluded that the financial system in the United Kingdom produces a culture which is risk averse and inclined to rely too heavily on short-term financial measures. Behaviour that is rational for those in the financial market place can have destabilising effects for industry. This is beyond the power of any one agency to change but we believe that, if UK industry is to flourish, the financial system will have to adapt positively to seek partnership with innovative industry. At present it has neither the risk acceptance of the United States system nor the patience of the German and Japanese systems.

11. These problems can only be tackled if Government takes the lead. However, Government action alone will not suffice; unless industry and the providers of finance respond only minor improvements can be made.

12. We recognise the importance of the Science Base in the United Kingdom innovation system, and we support the Government's policy to ensure that the resources devoted to research within the Science Base are used to best effect. We are convinced that it is possible to conduct research of the highest quality that will still be applicable to industry, although it should always be remembered that the Science Base has wider responsibilities than industrial research alone.

13. However, we are concerned that Government policy to encourage innovation is focused too much on the Science Base which cannot provide all that industry, especially engineering based industry, needs without abandoning some of its wider responsibilities. Industry provides its own research base, both in-house and through independent research and technology organisations; many government laboratories also provide services quite distinct from those provided by universities. These should be fostered and encouraged, just as such diversity is encouraged in other countries. We are especially concerned that current policy toward sources of technical expertise outside the Science Base may concentrate too much on the immediate needs of government departments, and under-estimate the industrial importance of successful laboratories, whether Government or privately owned.

14. There are many areas, such as purchasing or regulation, in which Government policies may act to encourage or inhibit innovation. There are welcome signs that, on purchasing at least, Government policy is changing in ways that recognise the importance of innovation. In the past this has not been the case. All Government departments should consider they have a responsibility to foster innovative British industry in every way possible. No one department can be responsible for the measures needed to foster innovation and reduce the risk faced by investors in new and high technology industries. If the innovatory capacity of

the United Kingdom is to be safeguarded, long term considerations will have to be weighed against short term cash savings.

15. There must be some central responsibility for considering Government policy for wealth-creating innovation in its entirety. Since changes in other Government policies to support innovation within industry will directly affect the demands placed on the Science Base we believe it would be appropriate for the OST, in conjunction with the DTI, to undertake this role. Without such an overview, guided by a strategic vision, Government understanding of innovation and policies toward it will remain fragmented, and there will be no effective partnership for action to reverse the decline that so concerns us. We hope that our study will contribute to achieving these ends.

## I INTRODUCTION

16. In 1992 the Committee conducted its first inquiry into "The Policy and Organisation of the Office of Science and Technology." This inquiry was purposely narrow in scope, restricted as it was to relationships between the Office of Science and Technology (OST), the Science Base[1] and other government departments. Nonetheless, many witnesses expressed their concern that the United Kingdom did not gain the maximum benefit from the Science and Technology activities conducted here and elsewhere. This evidence was so compelling that we decided that our next inquiry would consider these issues.

17. Since we reported the White Paper "Realising our Potential"[2] has been published. As the White Paper says, "the capacity to put science and technology to commercial use through innovation plays a significant part in modern industry." The White Paper announced that:

"... the Government is engaged in a long-term effort to:

— promote a greater awareness of the importance of innovation throughout all sectors of the economy;

— improve the effectiveness and efficiency with which firms innovate;

— facilitate access to science and technology relevant to business whatever its source;

— ensure that the needs of firms are fully taken into account in decisions on the direction, nature and content of publicly funded science and technology.

These activities form part of the Government's wider policies to improve the competitiveness of industry in the United Kingdom."[3]

We welcome this commitment; this Report will examine the factors which hinder the innovation process and the policies needed to assist it.

18. Like the White Paper, we begin, as the Committee with responsibility for the oversight of the OST, from the Science Base, but, as we shall show, the Science Base cannot be studied in isolation; it is part of a complex system in which industry is intimately involved. The OST is only one of a number of Government departments which have the potential to influence this system, and the Government itself, taken in entirety, funds and organises only parts of it. The innovative and competitive technology of our title is largely developed and deployed by industry. **However committed to partnership between the Science Base and Industry the OST may be, its efforts will be ineffectual if they are not matched by action elsewhere in government and industry.**

[1]The Research Councils and Universities, see Mem. p. 233.

[2]*Realising our Potential*, Cm 2250, para. 2.3.

[3]Cm 2250, pp. 11-12.

19. We have needed to look far more widely than the Science Base itself in order to determine what are the most productive ways to encourage innovation, and what factors act as barriers to its success. We have accordingly divided this Report into three parts. The first looks at Innovation, Research, Technology, Design and Development. We discuss the ways in which the processes directly concerned with innovation operate and might be improved, and assess the importance of innovation at company and macro-economic level. The second part looks at factors such as the availability of finance and of skilled people which critically affect the success of the innovation process. The third draws these strands together to suggest the main thrusts in Government policy which will be needed if we are to succeed in building a strong, innovative and competitive industrial culture.

*Conduct of the Inquiry*

20. The Minutes of Evidence and Memoranda published with this Report[4] represent only part of the work undertaken in the inquiry. We have made a series of visits in the United Kingdom to a variety of research-based institutions, both in the private and public sector. We also undertook visits to Germany and Japan to compare their experience with that of the United Kingdom. We are grateful to all those who took time to brief us, and who acted as our hosts.[5] These less formal parts of the inquiry provided essential background and reinforced the conclusions we drew from the evidence we received.

21. Since we started from the premise that, however closely the Science Base may be involved in the process, the chief agent of innovation is the company, we felt it necessary to look at both industry and the Science Base. The activities included within the definition of innovation and the ways in which they are conducted will vary from sector to sector, and, indeed, from firm to firm. For this reason we chose to focus our inquiry on six sectors: Aerospace, Automotive, Food and Drink, Machine Tools, Office Electronics and Pharmaceuticals. These sectors were chosen since they differed widely in their relative success, the ways in which they conducted Research and Technology, Design and Development (RTDD) and the ways in which they related to external sources of expertise. This method also enabled us to ask a wide range of companies about factors commonly identified as barriers to innovation such as the availability of finance and of skilled personnel.

22. We conducted our investigation in a variety of ways. Our examination of the sectors was conducted by requesting a sample of companies from each sector to respond to a questionnaire. A small number of companies were invited to complete a fuller questionnaire,[6] and some of these were invited to give oral evidence. At an advanced stage in our inquiry we invited some of the companies which had responded to the questionnaires to comment more informally on the information we adduced from those questionnaires. We asked a number of universities about their links with industry and their policies toward interaction between their employees and industry. In addition we formulated a series of general questions and invited both the companies and universities we examined and a range of other interested parties to respond to them. By proceeding in this way we were able to base our observations on sectoral differences in objective responses to the questionnaires, and then to test those observations with those who had experience in the industries concerned. It has, inevitably, meant a great deal of work for many of our witnesses, more than is usual in a Committee inquiry, and we are grateful for their help.

23. The analysis of our questionnaires was carried out by Professor Michael Gibbons, Mr Gerard Fairtlough and Professor Ivan Yates, in consultation with other experts in the field. A summary and analysis of their results is printed as an Appendix to this Report.[7] We are very grateful to all our advisers, Mr Fairtlough, Professor Gibbons, Professor John Kay, Professor Roy Rothwell, Professor Yates and Miss Rosemary Yates (in respect of our visit to Japan), and to the many other experts who freely gave us their help.

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[4]Published as Volumes II and III.

[5]Lists of those we consulted informally and places visited are appended to this Report.

[6]Copies of these have been placed in the Record Office, House of Lords (RO).

[7]See Appendix 1.

*Definitions*

24. There are many definitions of innovation available. In some contexts it is used to mean something akin to "invention"; a new development which has the potential to alter radically a product or process. Some definitions include both new products and processes and incremental improvements in existing ones. The Science Policy Research Unit at Sussex University has assembled a database of innovations which specifically includes commercial success as one of the criteria by which an innovation is defined. This definition has much to commend it, but has the disadvantage that success will only be evident after the event. *We will therefore use the term "innovation" to include both proven and possible successes.*

25. Moreover, the process of innovation differs radically between sectors. We shall discuss this in more detail later, but, broadly speaking, there are two categories of industry, those based on chemistry and the life sciences, and those based on physics. In the former there is a relatively direct relationship between the development in the research laboratory and the larger scale of subsequent quantity production of, for example, a pharmaceutical product, bulk chemical or detergent.[8]

26. In physics based industries the Science Base is used initially to develop technologies, which are then selected by the process of design and interpreted into the definition of a new product, which is then manufactured using another group of technologies; the Science Base may be revisited during the design and development stages, in order to solve problems which have arisen in the development and testing stage prior to the launch of production, and sometimes later when the product has entered service, for instance to solve problems of corrosion or electronic interference. This interaction between product development and scientific expertise can lead to new scientific insight, as well as industrial problem-solving.

27. Design is therefore central to the effective operation of physics based industry; in particular 'design for manufacture' has a profound effect on the cost of production. The Design Council has said "over the development cycle of a product 85 per cent of the eventual costs are determined by the end of the design stage".[9] Design is responsible for defining virtually 100 per cent of the added value which a company can obtain from the product.[10]

28. We have, accordingly, included in our working definition of innovation all the activities included under Research and Technology, Design and Development (RTDD). In some cases our Report will focus more narrowly on pure Research and Development (R&D) for a variety of reasons — for example international comparisons of RTDD may be difficult to draw since much of the reported expenditure is not broken down into these four categories and some of the activities may fall outside the Frascati definitions of research and development drawn up by the OECD on which such comparisons are based.[11]

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[8]Mem. p. 32, 57, 157.

[9]Minutes of Evidence taken before the Trade and Industry Select Committee (hereafter referred to as T&ISC), HC 41—iii, Session 1993-94.

[10]T&ISC Ev. HC (1993-94) 41—iii.

[11]Details of the Frascati Definitions are given in Annual Review of Government Funded Research and Development 1993, Cabinet Office, 1993, pp. 17-18. (Hereafter referred to as R&D '93).

# PART ONE: INNOVATION, RESEARCH, TECHNOLOGY, DESIGN AND DEVELOPMENT

## I R&D SPENDING AND COMPETITIVENESS

### Innovation and Competitiveness

29. The Select Committee on Trade and Industry is currently conducting an inquiry into Manufacturing Competitiveness, which complements our own. We have worked closely with them, and shared evidence. We refer those who wish for detailed arguments about international competitiveness to them; here we will simply remark that Britain must depend for its prosperity on the ability of its companies to trade internationally.

30. There is an increasing recognition of the importance of innovation and technology in international competitiveness. In a study reported by the National Institute of Economic and Social Research (NIESR), J Faberberg concluded:

> "that while competitiveness in relative unit labour costs has some effect on inter-country differences in the growth of export market shares, it appears to be less important than differences in technological competitiveness and 'ability to compete on delivery'"[12]

31. Technological competitiveness, of course, is not simply a matter of developing a new product or process, but of bringing it successfully to market. Innovation alone is not a sufficient factor for company success as research by Professor John Kay has clearly shown.[13] It is a well documented marketing phenomenon that companies which have been first in the field with a particular product often find others reaping the benefits.[14] Moreover, as the House of Lords' Committee noted:

> "The level of innovation necessary for competitiveness varies widely from one industrial sector to another, and ... from company to company and from time to time..."[15]

Nonetheless, as our colleagues in the Lords remarked "In a climate of increasingly sophisticated and individual consumer demands, the successful company is one with the innovative lead."[16] We only would ad 'that can be converted into successful sales'.

32. Yet even though we stress the importance of bringing innovation to the market, successful innovation appears to have long term benefits to companies which go beyond the simple increase in sales or turnover such innovations produce. Paul Geroski and Steve Machin tracked 539 UK quoted manufacturing companies over the period 1972-1983 in order to determine "exactly how innovating firms out-perform non-innovators and why", and found:

> "very noticeable differences in performance between the two types of firm over the trade cycle. In particular, the profits and growth rates of innovative firms hold up much better in recessions than those of non-innovators, and indeed, performance differences between the two types of firm almost disappear in booms."[17]

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[12] *High Level Skills and Industrial Competitiveness: Post-Graduate Engineers and Scientists in Britain and Germany*, National Institute of Economic and Social Research (NIESR) Report (No. 6 of 1994) to SERC, September 1993, p. 20, para 3.4. (Hereafter referred to as NIESR Report No. 6).

[13] See *Foundations of Corporate Success*, Oxford University Press 1993.

[14] There are few sectors which compare with pharmaceuticals for the relative ease with which the intellectual property involved in innovation can be efficiently protected through patenting, and yet even here sales of Zantac were able to out-strip those of the drug first to market, Tagamet, even though both are aimed at the same condition.

[15] HL (1990-91) 18-I, *Innovation in Manufacturing Industry, (1990-91)* para 1.14.

[16] HL (1990-91) 18-I, para 1.12.

[17] Paul Geroski and Steve Machin. *Do Innovating Firms Outperform Non-Innovators?* Business Strategy Review, Summer 1992, pp. 79-90, p. 81.

*R&D Expenditure and Innovatory Success*

33. Geroski and Machin classified companies as 'innovators' and 'non-innovators' according to whether they produced an innovation sometime during the period under consideration.[18] There have been attempts to find a causal relationship between innovative effort and industrial success using indicators such as R&D expenditure instead. There is some debate about the extent to which research and development expenditure is linked to competitive capacity. Some commentators have argued that a high level of expenditure on research and development is a consequence rather than a cause of prosperity.[19] However, as a study released by the Office of Science and Technology (OST) concluded, "the argument for reverse causality is very weak".[20] It is also possible that firms could spend a great deal on R&D and still not be particularly successful innovators. Nonetheless, Dr Muellbauer and Mr Cameron from Nuffield College, Oxford told us that although "researchers often found it difficult to model the long and significant lags that exist before R&D affects productivity... most studies ... found a positive and significant relationship between R&D and residual productivity change."[21]

**Is UK Innovation Competitive?**

34. We asked our witnesses "is innovation by British industry internationally competitive? How should this competitiveness be measured?" Several of our respondents noted the difficulties inherent in equating outputs with inputs such as the amount of R&D expenditure.[22] As a witness from Rolls Royce told us, UK engineering research and development can provide better value for money than that in the US.[23] Cost effective though it may be, there is nonetheless a remarkable degree of consensus that the innovatory capacity of UK industry is not merely lagging behind its competitors, but that its position may be worsening.[24]

35. The OECD publishes regular international comparisons of support for research and development, and we have drawn from these in much of what follows. However, countries differ in their precise interpretation of OECD requirements, or in their definitions of research performing categories, and conclusions drawn from these statistics must necessarily be very broad.[25]

36. In 1990-91 the House of Lords Science and Technology Committee (the Lords' Committee) used the UK's share of OECD patent applications, and its R&D and capital investment, as proxy measures of innovative competitiveness, and noted that each of these measures showed the UK's position in decline.[26]

37. When the Lords reported they used national shares or OECD patent applications in 1979 and 1988 as the basis of comparison. Patents are, however, an imprecise measure of innovation. The significance of patents will vary between sectors in which IPR can be so protected (eg pharmaceuticals) and those in which design (often unpatentable) is more significant. Further, not all developments will be patented and not all patents will be of equal value. Moreover, patent laws vary from country to country and if a country has less rigorous patenting rules than its competitors such a measure will overstate its success. For this reason,

[18]Their source was the SPRU database of innovations between 1945-1983 which included only those innovations which were deemed to be technological breakthroughs and which were commercially successful. Accordingly their sample might have been biased toward successful innovators, rather than taking all those who attempted innovation.

[19]See DEH Edgerton, *Research, Development and Competitiveness, The Future of UK Competitiveness and the Role of Industrial Policy*, Kirsty Hughes, PSI 1994.

[20]*Returns to Research and Development Spending*, A Paper by: The Office of Science and Technology and The Programme for Policy Research in Engineering Science and Technology at Manchester University, May 1993, para. 5.7.

[21]Mem. p. 207.

[22]For example, Mem. P. 1.

[23]QQ. 938-940.

[24]Mem. pp. 4, 7, 56, 120 and 216.

[25]Full discussion of the difficulties will be found in: *International Comparisons of Research & Development Spending*, Cabinet Office (OST) December 1992.

[26]HL Paper 18—I, Innovation in Manufacturing Industry, (1990-91) p. 5, para 1.16.

the level of patenting in a third country is frequently used as a comparator, so avoiding home-country bias in the statistics. Recent figures for the percentage of overseas patents for all technologies granted in the USA show a steady decline in the UK's position since the 1960s and 70s. In contrast Germany and France have seen their rating improve, despite short-term fluctuations, while the Japanese share of US patents has also increased.[27]

38. Our colleagues in the Lords noted that:

> "The United Kingdom was the only country in which Gross Domestic Expenditure on R&D (GERD)[28] declined as a percentage of Gross Domestic Product (GDP) over the period 1981 to 1988."[29]

In 1988 GERD amounted to 2.18 per cent of GDP; since then it has fallen slightly to 2.12 per cent in 1992, in spite of discontinuities caused by an *upward* revision to Government funded R&D in 1991-92.[30]

39. The Lords' Committee was also concerned about the level of Gross Fixed Capital Formation (GFCF), that is, investment in fixed assets such as plant and equipment which enables an economy to absorb technical innovation (ie exploit R&D) more quickly than others.[31] Since the Lords' Committee reported the rate of GFCF has fallen from a high of 20.3 per cent in 1989 to 15.6 per cent in 1992. Only two OECD countries reported a lower rate of GFCF.[32]

BUSINESS ENTERPRISE R&D

40. In 1970, the UK had a stock of domestic business R&D substantially larger than all other countries except the United States.[33] This has since fallen relative to other G7 countries. In terms of Business Enterprise R&D (BERD) as a percentage of GDP, the UK's ranking among G7 countries has changed little since 1981; it remains a mid-ranking spender. However, the gap between the high spenders and the UK has widened considerably; in 1981 BERD was 1.7 per cent of GDP in the highest spenders (USA and Germany), in comparison with the UK's 1.5 per cent; in 1991, Japan, the highest spender, had a BERD of 2.16 per cent of GDP while the UK spend had fallen to slightly under 1.4 per cent.

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[27]T&ISC Ev. HC (1992-93) 702-vi, Chart 22.

[28]GERD is a measure of total civil plus defence R&D. In comparing GERD as a percentage of GDP it is important to take account of the distorting influence that major defence programmes in some OECD countries have on the total figure. Roughly half of UK GERD is defence related. Furthermore much of that defence expenditure is not R&D at all in the sense of the Frascati definitions. See Science and Technology Committee, 3rd Report (1989-90): *Definitions of R&D* (HL Paper 44) and National Audit Office, *Classification of Defence Research and Development Expenditure HC (1991-92) 105*. See also Ev. p.230.

[29]HL (1990-91) 18—I, para 1.17.

[30]CSO *First Release: Gross Domestic Expenditure on Research and Development 1992* CSO (94) 424, March 1994; cf R&D 93, Fig. 3. p. 22..

[31]HL (1990-91) 18—I, para 1.17.

[32]Denmark and the US, Source: OECD.

[33]See David T Coe and Elhanan Helpman, *International R&D Spillovers*, CEPR Discussion Paper No. 840, October 1993, D E H Edgerton, Research, Development and Competitiveness, in *The Future of UK Competitiveness and the Role of Industrial Policy*, ed. Kersty Hughes, PSI, 1994 and paras 176-180 below.

## BUSINESS ENTERPRISE R&D AS A PERCENTAGE OF GDP (official OECD estimates)

| | 1981[1] | 1982[1] | 1983[1] | 1984[1] | 1985[1] | 1986[1] | 1987[1] | 1988[1] | 1989[1] | 1990[1] | 1991[2] | 1992[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Japan | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.8 | 1.9 | 1.9 | 2.1 | 2.2 | 2.16 | N/A |
| USA | 1.7 | 1.9 | 1.9 | 2.0 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 1.9 | 1.92 | 1.88 |
| Germany | 1.7 | n/a | 1.8 | n.a | 2 | n.a | 2.1 | 2 | 2.1 | 2.0 | 1.88 | 1.76 |
| France | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 | 1.49 | 1.44 |
| UK | 1.5 | n/a | 1.4 | n/a | 1.4 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.36 | 1.33 |
| Canada | 0.6 | 0.7 | 0.6 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.81 | 0.81 |
| Italy | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.77 | 0.78 |

[1] Figures taken from "International Comparisons of Research and Development spending", Cabinet Office (OST) December 1992. (Official OECD Estimates). P. 45.

[2] Figures taken from "Main Science and Technology Indicators, 1993", OECD.

The recession at the beginning of the 1990s has reduced BERD: as the Annual Review of Government Funded Research and Development says:

> "Between 1990 and 1991 intramural expenditure on R&D for civil purposes was about the same as 1990 in cash terms but declined in real terms by 7 per cent. ... defence R&D declined by 17 per cent in current prices and 22 per cent in real terms."[34]

41. As far as Industry Financed Business Enterprise R&D (IFBERD)[35] is concerned, G7 countries fall into two groups; those like Germany and Japan in which a high proportion of BERD is industry financed, and those like the USA in which a significant proportion is financed by Government. This division roughly correlates with the amount of defence related expenditure financed in each country, presumably because a high proportion of BERD funded by government is spent on defence projects. The UK falls squarely within the second group:

| IFBERD as % of GDP[36] 1991 | |
|---|---|
| Japan | 2.12 |
| Germany | 1.5 |
| USA | 1.37 |
| France | 1.01 |
| UK | 0.94 |
| Italy | 0.6 |
| Canada | 0.57 |

42. Not only is UK IFBERD lower than in any G7 countries other than Canada and Italy, there may be further problems caused by the structure of British industry. While the UK has a surprising number of international companies, it lacks the "mittelstand" of medium-sized companies found in other countries[37] The Institute of Electronic Engineers (IEE) survey of UK manufacturing (May 1992) suggests:

[34] *R&D 93*, para 2.4.8.

[35] That part of BERD financed by industry.

[36] R&D 93, Figure 32 p. 59, figures for France = 1990.

[37] IEE *UK Manufacturing: A Survey of Surveys & a Compendium of Remedies*, Public Affairs Board, May 1992, pp. 27-28.

"an apparently massive difference between the UK and other developed nations. There is a split in UK industry; the top half in terms of per cent of GDP has fast output growth and strong export performance and the remainder tends towards stagnation with mature markets, technologies and structures."[38]

While UK industry is prepared to invest nearly as much in R&D as its overseas competitors in highly R&D intensive sectors, such as pharmaceuticals and aerospace, it invests far less than do those competitors in sectors with medium or low R&D intensities.[39] The lack of a strong "mittelstand", and an unwillingness to invest will surely weaken the UK's innovatory capacity. Indeed National Westminster Bank suggested that the UK lacked the medium sized niche market specialists "who benefit from transferring technology in other countries".[40]

43. Business research and development is important because it leads to new products or processes, rather than as an end in itself, and here there is some more encouraging evidence. A recent Coopers & Lybrand Report 'Made in Britain' suggested that increasing numbers of companies were reducing development lead times and introducing new products more frequently. Similarly over 66 per cent of companies surveyed had introduced new production technology and 58 per cent had developed new technologies over the past 3 years. However, the survey also reported:

"Nearly one third of all companies have introduced no new technology or materials into their products since 1989 and a further quarter plan no such introductions until at least 1995. These trends are representative of all sectors, even in the computer and electronics business 21 per cent have not advanced technically on new products since 1989."[41]

GOVERNMENT FUNDED R&D

44. Just as the UK's spending on BERD and IFBERD has declined relative to other G7 countries, so Government expenditure on R&D (GOVERD) as a percentage of GDP has fallen. In 1984, taking GOVERD as a fraction of GDP, France and the UK were the highest total research funders; in 1990 the UK was overtaken by the USA and Germany. By 1991 only Japan, which has the highest level of industrially financed business expenditure on research and development, had a lower level of Government Expenditure on R&D as a percentage of GDP.[42] These figures include defence expenditure and reflect the sharp cut back in defence spending; when civil expenditure alone is considered, the UK position has declined from third to fifth ranking country.[43]

45. The UK's ranking may be still worse than these figures imply. Following inquiries by the Lords' Committee and the National Audit Office (NAO),[44] which suggested that much product development work had been wrongly classified as R&D, the Defence Analytical Services Agency (DASA) reviewed the statistics for Defence R&D. "The new classification shows that about 15 per cent of the *intramural* expenditure previously attributed to R&D falls outside the agreed Frascati definition."[45] This has had the effect of reducing GOVERD in 1991 and 1992 by .03 per cent. DASA is currently reviewing extramural defence R&D, which in 1991-92 accounted for some two-thirds of Ministry of Defence (MOD) R&D spending. If the anticipated revisions are made here, estimates of GOVERD as a percentage of GDP will fall sharply.[46] As we were told, "R&D data suggest that the UK has tended

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[38]IEE - p. 16.

[39]See Ivan Yates *"Manufacturing and Economic Growth"*, in *Innovation, Investment and Survival of the UK Economy*, ed. Ivan Yates, London 1992, pp 17-18.

[40]Mem. p. 25.

[41]Coopers & Lybrand, *Made in the UK — The Survey of British Manufacturers*, p. 29.

[42]R&D 93, Fig. 33.

[43]In 1984, counting from highest spender on civil R&D to lowest the rank was: Germany, France, UK, Canada, Italy, USA (Japanese figures n/a); in 1990, the rank was Germany, France, Italy, Canada, UK, Japan, USA; Table 6.2, p. 59, *International Comparisons of Research and Development Spending*, Cabinet Office, December 1992.

[44]*Classification of Defence Research and Development Expenditure*, NAO 1991.

[45]Ev. p. 230.

[46]R&D 93, Table 3.25.3, Ev. p 230.

to under-invest in R&D compared with its major competitors, and this problem is even more marked when defence R&D is excluded."[47] Other data on the innovative performance of the UK support this conclusion.[48]

## II THE PROCESS OF INNOVATION

46. **If Government policy is to encourage innovation then the processes by which innovation takes place must be fully explored and widely understood. Policies introduced without understanding will at best be inefficient and at worst counter productive.** While there is widespread agreement that previous models of innovation have been misleading, there has been little consensus as to what should take their place. We consider it so important to understand innovation that we will devote part of this Report to a discussion of how it occurs.

### *Innovation Networks*

47. In our First Report we recognised the difficulties which could arise "from the use of a limiting concept of 'technology-transfer' as a simple linear process, rather than as a complex interactive process."[49] Our current investigation has served to confirm our views and to refine them further.

48. One criticism of the linear model is that it has traditionally made an artificial differentiation between the public sector "Science Base" (ie the science funded through the Research Councils and the Higher Education Funding Councils) and "industry".[50] While "Science Base" may have come to be a term of art it is an unfortunate one, since it ignores the industrial researchers, consultants and independent research and technology organisations who are also engaged in the production of scientific and technological knowledge and expertise. *First of all, it must be understood that the country's community of researchers extends far more widely than the Science Base itself.* Industry spends more on research than does the entire Science Base and in some sectors industry is at the leading edge of research. We shall use the term "*Science and Technology Base*" to refer to the scientific community which encompasses those within both public and private sectors.

49. The second problem with the linear model is its suggestion that advances in basic science may throw up applicable products or processes which industry subsequently develops. Research in this view begins "far from market" and gradually becomes "nearer market". As our witnesses stressed, this can be far from the case.[51] Research is usually a complex, iterative process, in which a need to have some industrial problem solved can throw up questions of fundamental scientific interest. Nor can scientific fields be taken in isolation. As the Royal Academy of Engineering pointed out:

> "For successful innovation, the means and the impetus must be in balance. Provision of the means alone has, in the past, led to pointless innovation ... which fails in the marketplace, while need alone leads to over-ambitious projects which fail technically ... Clearly the chances of a given project succeeding are strongly dependent on both the quality and quantity of the output from the research base; quality for obvious reasons and quantity because innovation puts unpredictable demands on technology in areas quite unrelated to the main thrust. Concorde, for example, required the late abandonment of electromechanical control of the engine intake and a 'crash' development of the first flight safety critical digital system. Fortunately, digital electronics technology had just about reached an adequate state in the mid-60's."[52]

[47] Mem. p. 210.

[48] Ibid.

[49] HC (1992-93) 228—I, para 104.

[50] See Mem. pp. 11, 243.

[51] Mem. pp. 1, 7, 82, 85, 101, 109.

[52] Mem. p. 242.

But if Concorde relied on the fortuitous emergence of a new technology, digital electronics technology itself doubtless advanced as a result of Concorde.

50. Rather than seeing innovation in a linear way, it is helpful to think of each innovation as the product of an "innovation network". These networks will vary immensely. In a very few cases they may be relatively straightforward connections between a public sector research institution and a company which will more or less conform to the linear model. More frequently, they will be complex systems in which information is widely exchanged. 'Innovation networks' rest on a series of other networks; among these are the simple networks within companies, or within individual universities or laboratories; the trans-institutional and international networks of those interested in particular research areas; and the networks between customers and suppliers.[53]

51. The nature of an innovation network will depend crucially on the nature of the innovation itself and the sector in which it applies. A manufacturer of machine tools making a modification of design in-house so that the tool in question better meets the customer's needs (and those of other potential customers) can use a very simple network.[54] Yet even if we take an industry normally considered to have a relatively straightforward relationship to "pure science", such as pharmaceuticals, we find that the innovation network required to produce a new drug may involve several parts of a pharmaceutical company's own laboratories, and collaboration with one or more United Kingdom university departments with appropriate expertise. Small high-technology "start-up" companies may also be involved. The expertise supplied from university departments may, in turn, have been enhanced by information from abroad. Nor is the expertise required necessarily confined to the Life Sciences. On our visit to the Thrombosis Research Institute, we saw how the ability to manipulate computer models of molecules had resulted in significant developments in understanding the mechanisms of disease. At the extremes of complexity, found in some physics based sectors, such as the design of an aero-engine, the network can contain individuals from many different countries, disciplines, companies, universities and other organisations.

52. **To innovate successfully a company or individual must have access to and the ability to utilise a range of expertise or networks, depending on the nature of the project they are undertaking and the stage of that project's development.** Some of these networks can be reached directly through in-house expertise; some will rely on a series of more indirect contacts.

53. An illustration of companies' interest in ensuring that their researchers maintain membership of appropriate networks is given in one of the papers in the ESRC's "Innovation Agenda", which examined the reason why some companies published large numbers of scientific papers. As the researchers said:

> "This appears to run against the grain of commercial logic: you would normally expect companies to keep proprietary knowledge in-house to protect their competitive edge, not disseminate it freely."[55]

For such companies access to the network was clearly more important than the protection of *all* a company's intellectual product.

54. The results of our own survey will attest to the growing importance of innovation, and the increasing use of external expertise. Of the 79 respondents, 74 said technology and innovation were becoming more important to their sector; none felt they were decreasing in importance. 57 respondents had a deliberate policy of using external technological expertise. Of the companies answering our more detailed questionnaire, 9 of 17 saw these external sources of expertise as increasing in importance and only two felt that they were becoming less so.[56]

[53]See Mem. p. 25, 116.

[54]Mem. p. 57.

[55]Economic & Social Research Council, *Innovation update Five - Trends in Corporate R&D in Europe and Japan.*

[56]Appendix 2, Q. 3.11, A 3.16, A 3.17.

55. Networking usually involves a variety of organisations, and the ability to work effectively across organisational boundaries needs a somewhat different set of skills from those needed for working within a single organisation. This means that general professional and systems-integration skills, rather than narrower skills, such as those specific to one company, may be more in demand in the future. This may present an opportunity for the Anglo-Saxon economies with their tradition of movement between firms compared with the tradition of lifetime employment in one firm of Japan and Germany. Systems integration needs to be learnt, and this is where the UK may yet have an advantage.[57]

56. Government, industry and the Science Base are attempting to broaden the understanding of these issues. The ESRC has a major research project in the Innovation Agenda and the Small Firms Initiative; the Department of Trade and Industry (DTI) and the Confederation of British Industry (CBI) are co-operating to identify and encourage best practice, through means such as the Innovation Scoreboard. Individual researchers are devoting attention to the topic. The Committee has been fortunate to be able to draw upon all these sources in this Report. **Successful innovation does not depend on one process or a set number of approaches; it is dynamic and evolutionary. We welcome the efforts currently devoted to the understanding of innovation and recommend that they should continue.**

### The Significance Of Innovation In Different Sectors

57. **It is for industry to identify and carry the innovation it needs through to production, but government policies should assist these processes. Such policies will only be effective if they take account of industry's varying needs.** We structured our inquiry by looking at several different sectors[58] in order to avoid the temptation to consider "industry" as some single entity.

58. When asked to rank a series of seventeen factors according to their importance, respondents from all the sectors surveyed identified innovation as significant; at no point did it drop below mid-point on a scale of competitive advantage from 1 (not important) to 5 (crucially important). However, in no sector was innovation identified as the *single most* important source of advantage, although respondents from the Pharmaceuticals, Automotive and Food and Drink sectors ranked it among the most important factors.

59. There was also no correlation between the timescale from which benefit was derived from innovation and the perceived importance of innovation to a particular sector.[59] The differences between the answers given by respondents from different sectors demonstrated a difficulty in definition; many companies clearly saw innovation as being something other than the simple introduction of a new product.

60. The distinction appears to be between sectors in which the introduction of radically new products is essential, but requires a long timescale, and those in which profit comes from a flow of less radically new products or from steady incremental improvement. This roughly correlates with the division between life science based sectors, with a close relationship to the

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[57]Professor Midwinter of University College London drew our attention to "the key role of systems engineers."

[58]Aerospace, automotive, food and drink, machine tools, office electronics and pharmaceuticals.

[59]For Pharmaceuticals, in which innovation was identified as one of a few key factors, the benefits of innovation were slow to feed through: 8 of a sample of 16 derived over 50% of their turnover from products introduced over seven years previously (mature products); no company derived more than 25% of its turnover from products introduced within the previous three years (recent products). Food and Drink relied on similarly long timescales; only 1 company out of 12 derived more than 25% of its turnover from recent products, while 8 derived more than 25% of their turnover from mature products. In contrast, in the automotive sector seven respondents gained over 25% of their turnover from recent products, while five derived over 25% of turnover from mature ones. For Office Electronics innovation was in the third rank of requirements, even though five of the sample of nine derived one half of their turnover from recent products while only one derived more than 25% (but less than 50%) of turnover from a mature product. Aerospace and Machine Tools both rated only five factors as less important than innovation. For Aerospace, the spread was fairly even; six companies reported that between 25.1% and 50.0% of their turnover derived from mature products. In Machine Tools, three companies derived over 50% of their turnover from recent products although two derived between 25.1% — 50% of turnover from products introduced over seven years earlier and a further one derived over 50% of its turnover from such products.

Science Base, and physics based sectors in which much added value comes from design which we have already noted.[60]

61. One factor which emerged from the analysis of the questionnaires was that, in almost all sectors, the simple innovation process of company research leading to innovation was breaking down. **Innovation links are becoming steadily more complex, and the nature of that complexity varies from sector to sector.[61] This reinforces our belief that an understanding of the innovation networks used by each sector will be vital if Government policy is to be effective.** It is easy to fall into the language, and hence the thinking, of the linear model of innovation, yet to do so means seeing the Science Base as an almost autonomous pool of knowledge, from which industry can draw. As we have seen, this is not the case. **If the model of the innovation network is accepted, then the Office of Science and Technology, as the central department most closely connected with the Science Base, will have a central role in government. Yet the Government will also have to maintain an awareness of all the networks open to industry.** It is important to recognise that "Networks need Nodes", and that the "intelligent node" which can be provided by the multi-disciplinary independent research centre can have a powerful effect, particularly in the development of technology and in problem solving during the development phase, which is one very important aspect of physics based industry. We will discuss the fuller implications of this later in the Report.[62]

62. The question for us then is, given the different types of innovation used by different sectors, and differing importance of innovation for each sector, what are the ways in which government might encourage such innovation, and in which industry can help itself? We start from the Science Base but, as we have seen, even when innovation is considered as the development of new products or processes alone, without any consideration of the factors affecting the chance of those products or processes becoming commercially successful, the innovation process is a complex one. We will also need to consider the wider parts of the Science and Technology Base: government laboratories other than those run by the Research Councils, research and technology organisations, and industry's own research base.

## III FROM RESEARCH TO INNOVATION

### International Comparisons: Innovation Networks

63. We have already looked at the general international comparisons of Government and industry support for R&D. However, the process of innovation in each country will be affected not only by the absolute amounts spent, but by the structure of the Science and Technology Base in each country which will influence the networks available to innovators. It is very hard to draw such comparisons from international statistics, but some indication of the differences is given by the quantity and location of Government funded research.

*Location of Government Funded R&D*

64. When compared with Germany and Japan, Government funded research in the UK is heavily biased to the Science Base, and to the universities in particular. Since the UK's defence expenditure is far higher than that of Germany and Japan we have based our comparisons on UK civil R&D.[63]

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[60]However, in the Food and Drink industry it is routine for a large number of product innovations to be brought to market every year, with the knowledge that a high proportion will fail, while successes tend to become well established. Mem. p. 49. See also Mem. p. 200-201.

[61]See Appendix 1, pp. cxiv-cxv.

[62]See paras. 79-87.

[63]Figures for Government civil R&D expenditure alone are only available for the UK. Figures for Germany and Japan include Government funding for Defence objectives. However, both Germany and Japan's expenditure on defence is small when compared to the UK's. R&D 93, Figure 32 indicates that as a percentage of GDP, expenditure by Government for defence objectives are: UK 0.39, Germany 0.11 and Japan 0.03. Figures derived from'Official Indicators of Science and Technology for Japan', the Report of the Federal Government on Research, Figure II/3 and R&D 93 Figures 21 and 32.

**Location of Government Spending on Civil R&D in 1991**

| | UK (GDP) | Germany (GDP) | Japan (GDP) |
|---|---|---|---|
| | % % | % % | % % |
| Higher Education | 48.9 (0.24) | 37.2 (0.36) | 40.9 (0.18) |
| Private Industry | 11.9 (0.06 | 19.0 (0.19) | 6.2 (0.03) |
| National Research Institutions (including research within Government Departments, Research Council Institutes and Government Laboratories) | 27.2 (0.13) | 37.6 (0.37) | 46.2 (0.21) |
| Others (including overseas and private research associations) | 12.0 (0.05) | 6.2 (0.06) | 6.5 (0.03) |

65. The Japanese figures overstate the significance of the university sector in the country's innovation networks since in comparison with its GDP Japan's public expenditure on R&D is far lower than the United Kingdom's. Expenditure on R&D by Japanese industry amounts to 2.12 per cent of GDP while the *total* of UK R&D spending, from both business and Government, is 2.13 per cent. While the research conducted within Japanese industry is directed toward eventual application, much of it is very far from market. Indeed, on our visit to Japan we were shown several industrial projects which in the UK would have been conducted in Higher Education Institutions (HEIs), possibly in collaboration with industry. For example, the Toyota Central Research and Development Laboratories conduct generic research into semiconductors and advanced information techniques.[64]

66. Japan also puts a great deal of effort into ensuring the dissemination of research results and promoting collaboration. At the national level, the Ministry of International Trade and Industry (MITI) leads industrial projects and, through the Japan Industrial Technology Association (JITA), publicises the Intellectual Property Rights (IPR) available from work done in its laboratories, although its work is not highly developed. The Science and Technology Agency also has an organisation, the Key Technology Centre, which gives loans and grants to encourage companies to collaborate with one another. At the local level, provinces such as Nagoya have centres providing consultancy, training and technical services.

67. In Germany the universities are part of a tri-partite system. Each individual institution within the structure will have its own ethos and its priorities will be affected by the local economy but the main divisions are as follows:

- The Max Planck Gesellschaft (Society), which is a non-profit making body, in which individual scientists are funded, for life, to conduct individual research; the Institute's main emphasis is on basic research, but some projects are undertaken in collaboration with industry;
- Universities, which are funded by the Länder with some central support;
- Institutes of the Fraunhofer Gesellschaft, which concentrate on applied research, and often have links with universities; they perform a great deal of contract research for industry.

In addition the German Government funds large research centres and government institutes, which may be seen as equivalent to Research Council Institutes, and provides support for industry's own sectoral research associations.

[64]See: Toyota Central Research and Development Laboratories Inc. *Research Activities*.

68. While the bulk of support for research comes from national organisations funded by the Federal Government, often in conjunction with the Länder, individual Länder may have their own mechanisms for encouraging technology diffusion, especially between local universities, technical colleges and SMEs. One such is the Steinbeis Stiftung in Baden Wurtemburg in which selected 'Steinbeis Professors' employed at local technical colleges are allowed to spend up to 20 per cent of their time on paid consultancy work for industry. Contacts are arranged by the Steinbeis Stiftung. We were also impressed by the Institute for Micro Electronics in Stuttgart which provided customised "chips" for local Small and Medium sized Enterprises (SMEs). This Institute was funded by the Federal and Land Governments, the European Community (EC) and local industry and co-operated with the State University and with Siemens. A wide range of organisations co-operated to provide hi-tech products which had been identified as vital for local Small and Medium Sized Enterprises.

69. One of the effects of the structural differences in the financing and location of R&D in different countries may be that UK industry will find it more difficult to use the science and technology developed through public funds than do German and Japanese companies. **Industrial spending on R&D in Germany and Japan is far higher than here. This not only means a greater part of these countries' science and technology base is located in industry, but it also gives industry the expertise necessary to absorb science and technology developed elsewhere, including in the UK Science Base.**

70. In addition the 'players' in the German and Japanese systems have relatively clearly defined roles. This can be overstated; Japanese universities conduct research for industry as do some Max Planck Institutes, and many universities in Germany. Nonetheless, by comparison with the UK, each country offers a range of potential collaborators and companies will be able to identify suitable partners relatively easily. In the UK, by contrast, most public sector civil research is conducted in the Science Base, and the bulk of this research is conducted within universities.

71. Universities and industry can form strong, effective links in the UK, and indeed one witness told us that the links between industry and HEIs were stronger in the UK than elsewhere.[65] However, there can be difficulties in identifying suitable partners. As NatWest told us:

> "the technology transfer infrastructure is fragmented and leads to confusion for the innovators"[66]

There are proposals to remedy this, but we are concerned they may not go far enough.

72. We do not pretend that any country has or could have a simple national system for promoting linkages between individual companies and sources of research or development expertise. However, the extensive concentration on the Science Base as the locus for publicly funded expertise may be a disadvantage. It is not that the Science Base fails; rather, too many demands of too many different sorts are made of it. The Government should consider whether a wider range of technology institutions is needed. Furthermore, in comparison with Japan or Germany, the UK appears to give little assistance to those trying to identify potential collaborators within the Science Base.[67] Responsibility for the Science Base is shared between the Department for Education (DfE) and OST itself; responsibility for industry lies with the DTI. Until recently, it has largely been left to individual research councils and Higher Education Institutions (HEIs) to market their own expertise.

*UK Universities: A Diverse System*

73. Even before the abolition of the binary division between universities and polytechnics in 1991, they showed a wide variety in the nature of courses they offered, their research

[65]Mem. p. 258.

[66]Mem. p.28, see also pp.63, 212.

[67]Mem. pp. 63, 212.

expertise and the range of services they offered to industry. This was clearly demonstrated in the answers universities gave to our questions. The "new universities" tended to focus on the ways in which they could aid the local community; indeed, the University of Sunderland saw itself as a principal element in "strong local and regional networks with partners who have a common purpose in securing an enterprising and expanding science base".[68] The "old universities" also provided services to the local community — for example 24 per cent of the companies which had links with the University of Warwick were local[69] — but also sought collaborators from further afield; the epitome of this approach was Cranfield which was actively seeking to attract global companies to its new Technology Park.[70]

74. It would be a great loss if the unification of the system meant that there came to be some notion of the "ideal university" to which all institutions should aspire. It is easy to focus on those universities which provide cutting edge research of interest to national and international companies and to underestimate the contribution made by the universities which concentrate their efforts on providing training and research services to the local industrial community. We recognise that both have an important part to play.

75. Such diversity, of course, exists in other countries. However, government support for innovation in those countries is not so heavily biased toward the Science Base. **The problem is not that universities are diverse; it is that, for the uninitiated, it can be difficult to identify the institution most likely to be able to help with a particular problem. The diversity of the university system will be a strength rather than a weakness, as long as there are efficient ways for industry to find the most appropriate source of help.**

### Business Links

76. Dr Robinson, the former Chief Scientific Adviser to the DTI, told us that "the biggest single area of difficulty" in the relationship between industry and the Science Base "is probably still ignorance. There are still large parts of industry where they do not know how and in what way they should best relate to universities".[71] As one remedy for this, the DTI is collaborating with local bodies to set up new Business Links which will provide a range of services to local companies. Each Business Link should have an Innovation and Technology Counsellor to advise on sources of science and technology expertise.[72] Although selection and training of the Counsellors will be the responsibility of the Business Link Management, the DTI has provided guidance on recruitment and will be organising regular meetings of counsellors.[73] The DTI is also:

> "consulting widely on a proposal to support the development of local networks of those able to provide technological assistance or advice to companies (NEARNET) and to network centres of national technological expertise offering help to SMEs (SUPERNET)."[74]

77. The DTI has emphasised the role of Business Links in helping Small and Medium sized Enterprises (SMEs), but even large companies can find problems in locating the expertise they need.[75] Accordingly, even though Business Links are to be established at local level, it is essential that they should form a network for the whole country. **Business Links should be**

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[68]Mem. p. 175. See also Mem. pp. 171-2.

[69]Mem. p. 160. See also Mem. p. 129.

[70]Mem. p. 165.

[71]Q.828.

[72]These were formerly known as "One Stop Shops"; The White Paper (Cm 2250) announced the Government would: "in collaboration with the Training and Enterprise Councils, Local Enterprise Companies, Chambers of Commerce and other business support organisations, establish in England and Scotland a network of One Stop Shops to improve access and delivery of business services, particularly to smaller firms. Access to innovation-related services and to sources of science and technology, including simplified Government schemes, will feature in the portfolios of the One Stop Shops."

[73]Ev. pp. 202-203.

[74]Ev. p. 203, para 3.3

[75]Mem. p. 271.

**able to provide information about national as well as local sources of technological expertise and the databases necessary for this should be developed.**

78. The DTI proposals could go a significant way toward remedying a weakness in the United Kingdom's Science and Technology Base. However, we are concerned there may be problems in their implementation and we will be monitoring their effectiveness in future. In Japan, at least, many technology diffusion organisations are part of central government, and can ensure that their experience is taken into account in forming policy; **the DTI must ensure that Technology Counsellors are seen as a potential source of information about industry's requirements that Government can draw upon, as well as providers of a service for industry. Moreover, if the Technology Counsellors in Business Links are to be fully effective they will require adequate resources and leadership from the DTI.**

## The Science Base

### *The Science Base and Industry*

79. It is vital to get the relationship between the Science Base and industry right. The establishment of the Office of Science and Technology (OST) and the White Paper "Realising our Potential" have brought a new emphasis on partnership between science and industry:

> "The United Kingdom has a strong science and engineering base and some highly innovative and technologically-strong companies. The central thesis of this White Paper is that we could and should improve our performance by making the science and engineering base even more aware of and responsive to the needs of industry and other research users, and by encouraging more firms and other organisations to be more aware of and receptive to the work being done in other laboratories, especially those of the science and engineering base. The Government believes that steps must be taken to encourage greater communication and raise the level of mutual understanding."[76]

80. But it is not the Science Base's only, or main, purpose to generate technology for industry. The Science and Engineering Research Council (SERC) suggested the Science Base was funded to contribute to:

- — industrial/commercial competitiveness;
- — national security;
- — food, resource and energy self-sufficiency;
- — health and public well-being; and
- — culture and national status.[77]

81. When we asked the Chancellor of the Duchy of Lancaster to what extent the universities should have a responsibility for developing the technological capabilities of British industry he replied:

> "I do not believe that it is the primary mission of universities to underpin directly, to be the contract organisations. It is rather easier to say what they should not be. They should not be as their primary mission contract research organisations for industry. They have to be training good people. They have to be laying the base for the next generation of speculative work. They also have to provide, under the dual-funding system, the well-found laboratory into which Sir John [Cadogan][78] can put his more mission orientated research monies. That collection of things is their mission. It is quite important to say to universities that we want them to be part of this overall cultural whole that we are trying to create, but we do not want them to lose the things which only they can do."[79]

[76]Cm 2250, para 2.23.

[77]Mem. p. 83.

[78]Director General of the Research Councils.

[79]Ev. Q. 1017.

82. It is well known that the UK produces only 5 per cent of the world's scientific knowledge;[80] It is clearly important that the UK should be able to tap into the vast amount of information produced elsewhere. One way to ensure the other 95 per cent is accessible, although not the only one, is through a strong Science Base, which produces researchers who are welcomed as part of the international research networks.[81] There is no intrinsic reason why increased interaction with industry should threaten this, *provided a long-term view is taken.*

83. **We welcome the new emphasis on partnership between the Science Base and industry, and we will examine the ways in which it can be made more effective;** however, we recognise the Science Base has wider responsibilities than to this partnership alone. **We agree with the Chancellor that it is important that the universities, and indeed, the Science Base as a whole, should be a partner to industry, but also agree that "we do not want them to lose the things which only they can do".**

*The UK Science Base and Innovation Networks*

84. The Science Base can participate with industry in the innovation networks we previously identified in a variety of ways:

(a) by the provision of trained personnel;
(b) by producing high quality basic and strategic research;
(c) by disseminating its intellectual property;
(d) through consultancy; and
(e) through contract research.[82]

85. The networks and support needed will also depend on company size and type. A small bio-tech spin-out from a university may maintain informal links; a major company like Lucas may use the formal mechanism of the appointment of "Lucas Professors" both to increase the availability of the skills it needs and to gain access to informal networks; Rolls Royce engages in long-term collaborative work, while some companies place formal research contracts with universities.[83]

86. Sectors will also differ in the emphasis they place on each of these roles. Even a factor which is equally important for, say, pharmaceuticals and engineering, such as the provision of trained personnel, may be seen very differently. Engineering firms may wish to develop strong firm-specific competences appropriate to a range of technologies; they will have a role for higher degree graduates, but will also take on many first degree graduates to continue their training in the company. A sector like pharmaceuticals engages many of its research staff in activities which differ only slightly from those they would undertake were they in an academic environment; many of the skills they seek are directly transferable from one environment to another; they will demand a far greater proportion of higher degree graduate students.

87. These differences must not be overstated; many of the engineering based companies we consulted maintained some links with the Science Base.[84] On our visit to Japan, two companies investing in Britain, neither of which was involved in chemicals or life sciences, listed the high quality of the Science Base as among the factors which had decided them to base their European activities in the UK. Nonetheless, while there may be direct links between developments in fundamental research (new materials, say) and aspects of engineering disciplines, the integration of innovation made possible by such developments into a final product will be a most complex process, by comparison with the processes used in industries such as pharmaceuticals.[85]

[80]Mem. p. 231.
[81]See Mem. p. 230.
[82]Mem. pp. 68, 73-74, 78.
[83]Q. 930.
[84]Ev. QQ. 504, 697 and 930.
[85]Mem. p. 56.

### THE APPLICATION GAP

88. Whatever the incentives for academics to collaborate with industry there is frequently an "application gap" in which university results are perceived to fall short of industry needs.[86] Warwick University told us:

"In general the science base is some distance from the market in terms of the research outcome and its relevance to a product or process. This can be a severe problem for some industrial sectors... and very often also for Small and Medium sized Enterprises."[87]

89. The sectors which have least difficulty in relating to the research results are those such as chemicals, pharmaceuticals, electronics and computing; sectors which are close to the Science Base and in which in-house research teams are likely to exist.[88] In contrast, engineering disciplines find single-discipline academic results more difficult to use directly. Moreover, in such sectors high costs are likely to be incurred in moving from initial result to finished prototype.[89] It is not surprising that the managing director of a machine-tool company suggested:

"It is the insistence on approaching innovation from the research and technology end rather than from the market end which is the root cause of much of the failure of British Industry to develop competitive new products".[90]

The German Fraunhofer Institutes have been praised precisely because they provide support for the engineering sectors.[91] The pharmaceutical and chemical industries have, in contrast, been vociferous in calling for the Science Base to focus on so-called 'basic science'.[92]

90. These problems are not insurmountable. Warwick University stated it has a policy of:

"providing research outcomes that are near market and can be fairly easily translated into product or process. This has needed a clear policy decision on the part of the University and in particular strong commitment on the part of those academics involved, to provide a research outcome that the firms can readily use. This has been achieved whilst still maintaining academic excellence and undertaking internationally relevant work.'"[93]

91. However, not all universities have the capability to support research in this way, and while large companies, even in the engineering-based sectors, can help themselves,[94] SMEs may face particular difficulties, since they are likely to lack the human resources to devote to liaison with the Science Base and the financial ones to develop research outcomes.[95]

92. **There must be Government policy to encourage linkages between the Science Base and Industry sensitive to the differing relationships with the Science Base maintained by different sectors and by different sizes of companies.** In some cases, a sector may need technological support which the Science Base as currently structured and resourced, cannot deliver directly.[96] We shall return to this point.[97]

[86] Mem. pp. 25, 55.
[87] Mem. p. 149.
[88] Ibid.
[89] Mem. p. 22.
[90] Mem. p. 277.
[91] Mem. p. 215.
[92] Mem. pp. 73, 81.
[93] Mem. p. 149, see also Mem. pp. 63, 139.
[94] See Mem. pp. 89, 117-118, 174.
[95] See Mem. pp. 29, 49, 55, 95,117-118, 120,140-1, 157, 171, 175, 244.
[96] Mem. pp. 56, 95.
[97] See paras 307-315.

### INDUSTRIAL INFLUENCE ON GOVERNMENT FUNDED RESEARCH

93. Government funding for the Science Base comes through two streams; the research money from the Higher Education Funding Councils (HEFCs) which is allocated to individual institutions, broadly speaking, to use as they see fit, and the more directed funding from the Research Councils, some of which is allocated to particular projects, and some of which is "responsive mode funding" granted in response to "individual" research proposals. Even before the White Paper, the decisions about the research funded by both sources of such money were influenced, to some extent, by industry.

94. While industrial priorities have had little apparent effect upon the undirected funding from the HEFCs, in fact the allocation contained a small amount for "contract research"[98] This was allocated between institutions in proportion to the contract work they attracted, and their success in reclaiming the overheads for it. In addition, each institution decides its own research priorities, and those with strong industrial links are likely to see industrial interest as one of the many factors to be taken into account in deciding those priorities.

95. Research councils have also acted to ensure that some, at least, of the research they sponsored has been industrially relevant. Commercial exploitability was one of the criteria the Advisory Board for the Research Councils (ABRC) developed to guide the Research Councils in making plans and grants.[99] Individual research councils also sponsored a variety of programmes of interest to industry.[100]

96. The White Paper proposals have intensified this process. While the money coming into universities from the HEFCs remains essentially undirected, there are a number of measures to encourage universities to act with industry. The earlier measure of "CR", a measure of contract research, which was designed to encourage institutions to undertake collaborative and contract work on a full cost recovery basis,[101] is being replaced by "GR", a measure of generic research, which is closer to the market than basic or strategic research and which encompasses an area of research leading to direct applications in many different fields, but for which there is no single identifiable customer.[102] Professor Graeme Davies, Chief Executive of the Higher Education Funding Council for England (HEFCE) explained that the change was intended to encourage universities and industry to collaborate in areas where it would be for the common good. Since GR is a measure of research which is of interest to the Higher Education Institutes and several industrial partners, there is no risk that it will subsidise industry. Professor Davies indicated GR might increase in future.[103] Since GR is a measure of research which is of interest to HEIs and has application in a wide variety of different areas, there is no risk that it will replace the specific commercial developments in one particular industry, which that industry should be encouraged to undertake itself.

97. The missions of the research councils have been redefined, and each is to have an industrialist as part time Chairman. As the House of Lords Science and Technology Committee has said: "the White Paper makes explicit what was already substantially the case".[104] The Chancellor of the Duchy made it clear that "we have to have a sensitivity as we introduce industrialists into the system that they really appreciate what the Science Base is all about".[105]

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[98] About 3.3% of the total. See Mem. pp. 110, 113.

[99] HL (1993-94) 12-1, para 2.12, see also Mem. p. 109.

[100] See Mem. pp. 86, 90, 92, 94, 100, 106-7.

[101] Ev.p.232.

[102] Ev.p.232. Ev. QQ. 1051-1053.

[103] QQ. 1059-1061.

[104] HL(1993-94)12-I, para 2.15.

[105] Q. 993.

98. **The Chancellor of the Duchy's sensitivity to the wider responsibilities of the Science Base is welcome. It is not appropriate for publicly funded research in the Science Base to be driven by the short-term needs of industry. However, we believe it is possible to conduct research which is both of the highest international quality and, where relevant, applicable to industry.**[106]

*Direct Science Base/Industry Interaction*

99. Measures to increase interaction between the Science Base and industry tend to focus on the Science Base itself. However, industry is a vital part of this relationship, and however great the technology push may be it will not succeed without demand pull. The Natural Environment Research Council (NERC) told us:

> "There is already a high investment of research staff time in seeking to develop interactions with industry but the cultural inertia in many of the potential recipient organisations is such that returns are unlikely to be immediate."[107]

For academe and industry to work together, industry must be prepared to invest in the relationship. Rolls Royce felt the limited contribution academics made to the solution of industrial technology problems was "partly the fault of the industry in not devoting the resources necessary to harness the academic contribution."[108]

100. Industry must also be prepared to use the Science Base in appropriate ways; small scale research and consultancy are among the services which Higher Education Institutions (HEIs) offer to industry, and we support this. However, it is not appropriate for these activities to dominate the Science Base. As Professor Midwinter of University College London said:

> "striving to increase Industry-HEI collaboration will only destroy the HEIs if it succeeds in forcing them to become short-term Research Job-Shops whilst at the same time, it will do nothing to help companies preoccupied with short-term survival."[109]

101. **In the exchange between the Science Base and industry both parties must work at successful communication; failures are not the fault of the Science Base alone.**

102. We will suggest ways in which industry could become more alert to the possibilities offered through co-operation with the Science Base. But first we consider the mechanisms through which the Science Base may relate to industry.

103. The Science Base and its institutions are already very successful at attracting industrial research. The Research Councils have increasingly attracted income from industry for contract and collaborative research.[110] Most of the old universities we surveyed had established Science Parks as a means of increasing their own revenue and making their expertise more widely available.[111] A large majority of our respondents already placed some external Research and Technology, Design and Development (RTDD) with universities and polytechnics making them the most favoured sources of external R&D: only eight of 49 placed no research at UK universities or polytechnics, and 25 companies placed more than 10 per cent of external RTDD in UK institutions; in contrast, only 13 companies conducted any external RTDD in overseas universities and only 2 of those conducted over 10 per cent

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[106]See Mem. p. 107.

[107]Mem. p. 95, see also pp. 101, 106, 133, 138, 179.

[108]Letter from Rolls-Royce plc, 29 November 1993, (not printed: deposited in the RO.) See also Mem. pp. 62, 137.

[109]Mem. p. 259, see also Mem. p. 234.

[110]See Mem. pp. 88, 91, 97, 99.

[111]Mem. pp. 128, 132, 152, 156, 160, 173, 179.

of their research there.[112] Although research networks are becoming more international, one should not underestimate the importance of the UK's Science Base for UK industry.

104. Interaction can bring considerable benefits to both parties. We were most impressed by the way in which Warwick University managed interaction with industry through the Warwick Manufacturing Group, which offered both contract research and courses tailored to meet particular industrial needs. The Group derives only 10 per cent of its funding through the Higher Education Funding Council for England (HEFCE), and produces a considerable profit which benefits the entire university. It is also able to pay its teaching staff a higher salary than would otherwise be the case.

105. However, there are a number of difficulties in the relationship between industry and the Science Base, both at an organisational and at an institutional level. These are:

— liaison with industry;
— the recovery of overheads;
— protection of intellectual property; and
— academic career paths.

### Liaison With Industry

106. Each of the Research Councils devotes considerable effort to industrial liaison, although, because of the differences in their missions and structures, the arrangements for such liaison vary considerably.[113] The responses from universities revealed a wide variation in the way in which liaison with industry was structured, and the resources devoted to such liaison. The chief difference might be said to be between those institutions which expected all interactions between academics and industry to be dealt with at some point by the university's Industrial Liaison Office (ILO) or some equivalent body, and those where the ILO was provided simply as an optional additional resource for academics or industry. *However, it should not be assumed that a university's commitment to interaction with industry can be judged by the formality of its procedures.* The only organisation which did not mention some separate industrial liaison function was Cranfield, which received most support from industry, and where "every member of the academic staff acts as an Industrial Liaison Officer".[114]

107. Many organisations were unable to give an assessment of the resources devoted to interaction with industry, claiming that much of it was devolved to individual departments or academics. In addition, in some universities while ILOs themselves were small, significant resources were clearly devoted to university companies and similar organisations.[115] There is clearly a wide divergence between different universities. Cambridge University takes no share in IPR, leaving its staff free to exploit their own research, has a small Industrial Liaison and Technology Transfer Office and has a single company for exploiting IPR. In Cambridge the Science Parks are independent of the university.[116] Imperial College has an Industrial Liaison Office run at a cost of £800,000 pa, two University Companies and two science parks.[117] At Salford, there are University companies, the Development Unit and CAMPUS, a liaison service for industry, employing together a total of 115 staff.[118]

108. Dr Lyndon Davies suggested that the limited funds and staff resource many universities devoted to technology marketing and the protection and licensing of intellectual

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[112]See Appendix 2 Q. 3.14a. These figures may be used to determine the extent to which our sample was more likely to source R&D from universities than elsewhere; however, the companies responding to our questionnaire appeared likely to be above average in their RTDD effort; a different sample, more biased to SMEs, would probably show a far higher proportion of companies with no contact with the Science Base.

[113]See Mem. pp. 87, 89, 94, 98.

[114]Mem. p. 165.

[115]For example, Manchester allocates only £50,000 to its Industrial Liaison Office, but has a budget of £400,000 pa for the protection and exploitation of intellectual property. See also Mem. p. 155.

[116]Mem. p. 168.

[117]Mem. pp. 159-160.

[118]Mem. p. 128.

property[119] was "a limiting factor in the effective exploitation of university science."[120] There seems little reason to doubt him. However, as the Medical Research Council (MRC) says:

"many Universities are required to work in a broad range of science and technology, often without significant scale in any area. Consequently, it is difficult, or even impossible, to create a body of expertise for technology transfer in the defined areas of University expertise. There is also a lack of funds to support the technology transfer activities of the universities. Successful exploitation requires heavy investment in staff and in patenting and legal costs, and most academic institutions will be unable to finance a successful technology transfer *ab initio* from royalty income alone."[121]

109. The Department of Trade and Industry has sponsored two schemes to overcome these problems. The first, the Technology Audits Scheme, provided grants of up to £50,000 for HEIs to carry out an audit of their technology base in order to identify and assess research strengths with commercial relevance. The second, the Industrial Units Scheme:

"is helping academics to manage and market their research more effectively. DTI is providing grant assistance over three years, of up to £100,000 per HEI, to strengthen an existing industrial unit, mainly by supporting the recruitment of professional staff with expertise in marketing, management, patenting and other disciplines."[122]

**These schemes are very welcome. We trust that they will be repeated if necessary.**

110. Some universities can fund highly sophisticated Industrial Liaison Offices (ILOs) from the funds generated by the Industrial Liaison Officers themselves. We hope more will be enabled to do so by the schemes described above. We have already remarked on the need for clear "sign posts" in the system, and ILOs provide such sign posts. However, it should be accepted some universities will find it impossible to establish large scale, self-financing ILOs. It is important that, even where the university can only afford a small scale ILO, that the ILO is professionally managed, not overloaded with other responsibilities, and that senior officers of the university are seen to be committed to its activities. This can, for example, be achieved by giving the person responsible for industrial liaison direct access to the Vice-Chancellor.

111. While ILOs provide a useful starting point for industry, not all university interaction with industry should be formally structured. Networking requires informal links, and the availability of such links is particularly important for Small and Medium sized Enterprises (SMEs). The Director of the Oxford Trust told us:

"Formal mechanisms ... tend to prevent small company technology transfer; they are regarded suspiciously as regulating and policing and create a perception of disproportionately high cost. Informal methods on the other hand appear to have positive effect... Culture, human relations and communications are key issues for successful technology transfer."[123]

However, it is not only SMEs that object to over formal mechanisms. A company as large as Glaxo complained:

"The tendency of some Industrial Liaison Departments to attempt to operate blanket rules, or develop doctrinaire policies, has created barriers between the academic and industrial sectors."[124]

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[119]We consider intellectual property in detail in paras 116-123 below.

[120]Mem. p. 23.

[121]Mem. p. 102.

[122]Ev. p. 202.

[123]Mem. p. 255, see also Mem. p. 30.

[124]Mem. p. 265. See also Mem. p. 188.

Many of our academic witnesses stressed that much interaction with industry arose from already established links, and effective personal interaction between particular researchers and their industrial counterparts. Over insistence on formal contracts at too early a stage could reduce the effectiveness of such contacts between academics and industrialists.[125]

112. **Universities should not be compelled to see every interaction with industry as a source of immediate profit. While informal relationships between industry and academia may lead to difficulties in strict accounting terms, they serve to strengthen the country's industrial and academic base. Moreover, such links may lead on to more formal contracts.**

### Recovery Of Overheads

113. Many of our Science Base witnesses complained about industry's unwillingness to pay the full cost of the research it commissioned. Cambridge University considered that although there had been some improvements in the recovery of indirect costs "there is still an element of subsidy of industrially-sponsored research from our general funds".[126] This was seen as a problem most likely to occur with United Kingdom industry.[127] While some SMEs may need help in identifying and funding the research they need, large companies should have no such problems. **Industry must be prepared to pay the full costs of the near market research it contracts to universities.**

114. However, Glaxo attributed problems to:

> "the failure on the part of some university Industrial Liaison or Technology Transfer Departments to understand, or accept, the differences between collaborative, or inquiry, research projects and 'contract' research and also the needs of different industrial sectors. This becomes particularly acute when attempting to set terms relating to contributions by the industrial partner to the indirect costs ('overheads') of the project, and also ownership and exploitation of intellectual property rights (IPR)."[128]

The introduction of "GR" funding to encourage universities to support such research should go some way to meeting this point.

115. Nevertheless, UK industry should be aware that overseas companies may be prepared to give more generous support for such research or, indeed, provide support in return for indirect benefits. Professor Colin Andrew noted "Hitachi have 'bought' space at the Cavendish Laboratories in Cambridge and their staff live there. Why Hitachi?"[129] It is disturbing that only 12 of 33 contracts at the MRC collaborative centre in Mill Hill have come from British companies.[130] Edinburgh University told us "British industry appears to prefer to relate to universities on a project by project basis, projects normally being short-term and low risk in terms of finance"; US and Japanese companies which entered into long-term arrangements gained far wider benefits, including access to the University's pool of intellectual property. It may be that the higher level of in-house research in overseas companies is one of the factors enabling them to engage with the Science Base in this way.[131] The House of Lords Science and Technology Committee is conducting an inquiry into International Investment in UK Science; we hope they will consider the extent to which overseas companies may be more willing to foster long-term relationships with the Science Base than United Kingdom ones.

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[125]Mem. pp. 92-98, 130, 135, 136, 161.

[126]Mem. p. 167. See also Mem. p. 220.

[127]Mem. p. 179.

[128]Mem. p. 265. See also Mem. p. 149.

[129]Mem. p. 236.

[130]Mem. p. 99. See also Q. 1054 and Mem. p. 183.

[131]Mem. p. 183.

INTELLECTUAL PROPERTY

116. Intellectual property rights (IPR) offer a potential way for universities and Research Councils to profit by their research.[132] Here, too, we must acknowledge that much is already being done. The British Technology Group (BTG) told us:

> "the UK has been more successful in patenting and licensing academic technology than almost any other country, including the USA... we in the UK generate five times more licence revenues per $ of spend in universities than in the US. We believe the comparison is similar in most European countries and in Japan."[133]

117. Most of the universities we surveyed maintain their right to the IPR developed by any employee, or even any student.[134] All have arrangements for sharing revenue with the inventor, although the amount assigned to the inventor varies considerably. The great exception is Cambridge, which assigns IPR to the inventor, on condition that satisfactory arrangements for its exploitation are made through the organisation sponsoring the research or through Lynxvale Ltd, the University company.[135] While it is good practice for universities to protect their IPR vigorously, there are arguments for flexibility in its exploitation. The Cambridge memorandum suggests that the "Cambridge phenomenon" has been brought about by the University's IPR policy. The NERC also warns against an over zealous application of an IPR protection policy.[136] A number of companies have commented unfavourably on what they see as universities' unrealistically high valuation of their IPR, which could prevent useful developments from being introduced.[137]

118. The responses to our questions showed a wide variety of approaches to patenting, and variation in the income from patents and royalties. Edinburgh received over £3,500,000 on royalties in 1992-3, mostly from one licence.[138] Warwick received only £183,226 in 1992-93 and Heriot-Watt only £20,000,[139] even though both these universities receive an income from industry that is roughly comparable with Edinburgh's. Hertfordshire used its patents to encourage industry to collaborate with the University, rather than simply licensing them.

119. These figures might suggest that not enough is being done to protect and exploit IPR and that universities needed to manage their IPR more professionally. However, a university's ability to produce saleable IPR will depend on the research fields in which it is strong.[140] Moreover, some might feel protecting IPR takes valuable resources and the chances of significant reward from any individual development are so small that it is only worthwhile to protect the most promising developments. Warwick University suggested that the British Technology Group (BTG) could be invited to arrange for the protection and exploitation of innovation[141] but since BTG has decided to concentrate on pursuit of licences for technology already entrusted to it, rather than seeking "yet more technology"[142], universities are increasingly dependent on their own resources. The cost of obtaining an international patent is at least £10,000 for an initial filing; renewal fees will also have to be found to keep the patent in force.[143] If this view is taken, it seems there is an argument for the University of Edinburgh's approach, which is, broadly speaking, to re-assign ownership of IPR to its inventor in cases where no licensee can be found within a year or two. In this

[132]Most Research Councils only lay claim to the IPR they generate 'in-house'; they do not claim IPR generated as a result of the university research they sponsor. Mem. p. 88.

[133]Mem. p. 49.

[134]See Mem. p. 133 for example. See also Mem. p. 232.

[135]Mem. p. 168.

[136]Mem. pp. 95, 97.

[137]Mem. p. 265.

[138]Mem. p. 182.

[139]Received for one transfer of patent rights, Mem. pp 151, 152.

[140]Mem. pp. 165, 172.

[141]Mem. p. 150.

[142]Mem. p. 50, see also Mem. p. 119.

[143]The MRC also aims to license its IPR, except in exceptional cases. Mem. p. 99.

way the University does not have to bear the full costs of patenting, but promising developments are not simply lost.[144]

120. Dr Robinson, the former Chief Scientist of the DTI, told us he had asked:

"is it right for universities to try to protect their intellectual property because, in that way, they might build a barrier between themselves and industry? Their response was that they are fully aware of that and do whatever makes sense in the circumstances and have managed to find the right relationships with industry for the project they are involved in. Wherever I look I see that encouraging sign of a mature relationship between both partners."[145]

**It is important that universities should protect their Intellectual Property Rights (IPR) appropriately. Nonetheless, we agree with Dr Robinson, the former Chief Scientist of the DTI, that the current diversity of arrangements for exploitation is a strength rather than a weakness.**

IDENTIFICATION OF IPR

121. If IPR is to be protected it must be first identified and patents filed.[146] In its Report into "The Policy and Organisation of the Office of Science and Technology" the Committee noted the difficulties that the requirement that developments filed for patents should not have been published caused for academics, who depend on publication and the speedy dissemination of research results.[147] The MRC told us:

"The demand of most patent offices... that patents be filed prior to any publication inevitably leads to hurried decisions on patenting, and consequently exposes inventing organisations to errors. This is a particular danger in basic research; the importance of basic research findings usually takes some time to become apparent."[148]

122. The current IPR system can result in a conflict between academic and industrial priorities. A company sponsoring research may wish to keep the results of that research confidential, while for academic institutions publication is, as Cambridge University pointed out, "important not only for our academic standing, which is now being subjected to a more searching and quantitative analysis by Government, but also for our tax status as a research and educational institution."[149]

123. We previously recommended that Europe should adopt the US system of a grace period in which a patent could be filed up to one year after publication. We were encouraged by the Government reply to our Report which said:

"It seems likely that the rest of the world will come into line with the US system. It is expected that a diplomatic conference will be organised in the first half of 1994 at which this question will be resolved."[150]

Since then, it appears the negotiations have run into difficulties.[151] **We reiterate our concern at the difficulties this causes our researchers, and urge the Government to do**

[144]Mem. p. 181.

[145]Ev. Q. 826, see also Mem. p. 79.

[146]See Mem. p. 92.

[147]HC (1992-93) 228-I, para 85.

[148]Mem. p. 101.

[149]Mem. p. 167, see also Mem. pp. 136, 160, 179, 194, 235.

[150]First Special Report, (1992-93) The Government's response to the Science and Technology Committee's Report on the Policy and Organisation of the Office of Science and Technology, para 2.

[151]According to reports on International Patents the Treaty is unlikely to be signed this year because the US is clinging to its distinctive system, which awards patents to the person who proves they had the idea first, as opposed to a 'first-to-file' system which most other countries operate. (eg New Scientist 12.2.94.)

**whatever it can to ensure the harmonisation of IPR in a way which allows a "grace period" between publication and patent application.**[152]

ACADEMIC REWARDS

124. Many witnesses stressed that personal interaction was the most efficient form of "technology transfer".[153] Such interaction is likely to be encouraged if it is well rewarded and is seen to contribute positively to career progression.[154] However, Glasgow Caledonian University told us:

> "At present most academics advance their careers by research, teaching and administration. There is not a defined career path for the academic who links up extensively with industry to develop a product from research. Promotion is generally viewed on the basis of a good teaching record and a publication record."[155]

Some universities suggested the increase in student numbers and the increasingly performance related funding of research had exacerbated this conflict.[156]

125. The increased teaching load can be managed in various ways; Professor Davies told us that institutions were increasingly dividing staff into those whose main function was research, and those who concentrated upon teaching.[157] However, there may be advantages to students in being taught by active researchers. In particular, exposure to researchers engaged in fruitful collaboration with industry might increase interest in industrial research and break down some students' preconceptions about industry. **It would be a great loss if the increase in student numbers and the way in which the research selectivity assessment was organised combined to make an unbridgeable division between teaching and research, especially industrially relevant research.**

126. The Warwick Manufacturing Group makes sufficiently high profits to enable it to pay its Teaching Fellows, who are responsible for courses directed at industry, a higher stipend than would normally be the case. The fact that it is necessary to do this highlights the gap between university salary scales and the pay levels that can be commanded in the private sector. Salford University encourages its staff to work with industry by including success in technology transfer and entrepreneurial activity among the criteria for promotion.[158] Not all universities will be able to use such methods, but they are a good example of encouraging interaction with industry through increased rewards.

127. The Higher Education Funding Council for England (HEFCE) is addressing the criticisms of the Research Assessment exercise by reducing the work required for assessment to four publications or other pieces of public output.

> "...we would see perhaps the important research contracts held with industry or Government, perhaps patents and other pieces of intellectual property so that we try to redress the balance away from what many would judge to have been a fixation with the numbers of publications rather than with the quality of the generality of activity."[159]

128. We are also very much encouraged by the OST's new "Realising our Potential Awards" (ROPAs) which will give funds to:

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[152]See Mem. p. 101.
[153]Mem. pp. 3, 74, 86, 236, 244.
[154]Mem. p. 236.
[155]Mem. p. 139, see also Mem. pp. 149, 244.
[156]See Mem. pp. 155, 179.
[157]Q. 1069.
[158]Mem. p. 129.
[159]Q. 1064.

"people selected by industry to do other work of their own choosing. It may be very basic, it may be generic or it may be anything else."[160]

These seem an ingenious means by which to ensure that success in industrial collaboration will give academics the opportunity to consolidate their reputation in whatever way they wish.

129. **Academic success and the quality of academic research should be linked. However, the measures of research quality used in the past have discriminated against research undertaken with industry.[161] We support the initiatives to widen the criteria used in assessing performance and to increase the status of industrial research.**

## Industrial Research

130. In our consideration of the routes through which the Science Base can interact with industry to produce innovative and competitive products, we must not lose sight of industry's own research base. Industry is the major funder of R&D in the UK. In 1991, industry financed business R&D totalled £6,633m — 1.16 per cent of GDP.[162] This may not be an impressive percentage of GDP by international standards. Nonetheless, it is higher than the *total* Government funded research and development spend of £5,047.9m.

131. The nature of industry financed R&D varies according to the size of company and its sector. Much of the innovative work in the machine tools sector, for example, would be carried out in the context of meeting a particular customer's requirements, and so would not be classed as research.[163] Many small companies, in particular, must rely on external networks to provide expertise. In-house research is essential for the majority of companies in sectors such as pharmaceuticals, aerospace and automotive and is conducted by all the large companies in food and drink. However, here we remark on general trends rather than being sector specific.

### *In-House Research*

132. Industrial research has a wider function than simply ensuring that a company can use its own scientific and technological resources effectively. It also provides people able to transcend the culture gap, between industry and academe, and to interact with networks elsewhere in the science and technology bases. As SmithKline Beecham told us:

"There is a vast out-pouring of the fruits of academic research into the public domain... However, although knowledge is a public good, it cannot be absorbed costlessly — in-house R&D is needed in order to create an absorptive capacity."[164]

133. However, the interface between corporate research and externally generated research can be more than 'absorptive'. As we have seen, companies with well developed corporate research bases link into scientific networks through publishing some of the results of their research.[165] The reasons given for this were:

"Companies believe that they have to publish to gain credibility in the eyes of the academics they want to work with. It is a form of advertising. It also helps the business to highlight their scientific prowess, which makes it easier to recruit new research."

and

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[160] Q. 993.

[161] See Mem. p. 96.

[162] R&D 93, p.2, Fig. 3.

[163] Q. 689.

[164] Ev. p. 135, see also Mem. pp. 3, 210.

[165] See para. 53.

"... by subjecting their research to peer review, publishing motivates the companies' researchers and raises standards."[166]

Such research networks allow access to a range of expertise far greater than any one company could, and they provide the company with a supply of trained personnel and potential collaborators. In-house research provides people capable of bringing technology into the company and people who are well placed to ensure successful collaboration by conveying the company's needs to partners who may have different perspectives.[167]

134. There has been a growth of R&D at division or business level in large firms and a corresponding reduction in the scale of central laboratories. As Dr Rod Coombs of Manchester School of Management has said:

"This de-centralisation of R&D has permitted new and more intimate arrangements to develop which bring technical, commercial and operations staff together at business unit level in effective teams for product and process innovation. *This is a major historical gain for UK firms, and should not be under-estimated.*"[168]

135. However, while this decentralisation ensures the needs of the end-user are properly considered, it may have the effect of 'consolidating strength within the existing technological regime.'[169] Small devolved units may find it hard to deal with major shifts in competence, and central corporate research or strong external networks may be needed to compensate. As Dr Coombs noted, the reduction in central R&D may mean "that the overall technology and skill portfolio of a diversified corporate structure can often simply become **invisible** to the company" and it "has led to a relative under performance of UK firms in identifying, adapting to, and commercialising newer technologies which fall outside the established competences of individual businesses."[170]

136. There are ways of keeping an overview while maintaining the business-orientation of R&D. We were most impressed by the corporate structures in place in Sharp in Japan, where business unit and central R&D are balanced, and each business unit has to make a contribution to the central research laboratories, which conduct long-term research. Within the UK, Lucas has a policy of trying to get synergy between its aerospace and automotive businesses and uses a Group Technology Council to discuss problems and solutions. It also uses the Lucas professors the company sponsors at various universities. The company maintains its emphasis on synergy by restricting its bids for defence contracts to those that have technology shared with a civil application.[171]

137. The analysis of our questionnaire suggested that many sectors are experiencing, to varying extents, a shift from an industrial structure in which research, innovation and manufacturing were all conducted by the same company to ones in which increasingly operations were bought in or contracted out. The London Business School has pointed to the dangers of buying in technologies as a package to bolt on to the existing organisations.[172] A decline in a company's central research capacity can increase the dangers of such procedures.

138. Lucas and Sharp do not provide the only models possible, but they demonstrate ways in which companies can ensure that while business units can ensure they have the technology they need in the short term, long-term objectives and opportunities to apply technology widely are not neglected. **A high degree of both management and technological or scientific**

[166]Economic & Social Research Council, *Innovation Update Five - Trends in Corporate R&D in Europe and Japan.*

[167]Mem. p. 55.

[168]Submission, from Dr Rod Coombs, Manchester School of Management to the Chancellor of the Duchy of Lancaster, as part of the consultation process which led to the White Paper, CM 2250. This has been placed in the Record Office.

[169]Ibid para. 4.

[170]Ibid p. 4. See also mem. pp. 52, 57, 212-3.

[171]QQ. 9, 504, 506—507.

[172]See Mem. pp. 1, 8.

**expertise will be needed to ensure the effectiveness of new ways of operating, and, in those companies large enough to sustain such a department, the corporate research function will be vital.**

*Collaborative Research*

139. Collaborative research may involve a range of partners from within the same sector, other sectors or the Science Base. It may be fully funded by the companies involved, or attract government or European Union (EU) support. Increasingly, government and EU support has been directed at encouraging companies to collaborate with the Science Base either in the UK or elsewhere in the EU.

140. Collaboration between companies enables them to pool their financial and technical resources to reduce the risks inherent to conduct long-term research. It also produces a faster diffusion of new ideas within the manufacturing base which may well enhance the competitiveness of entire sectors.

141. Certainly, in Japan industrial collaboration is regarded as worthy of support. The Japan Key Tech Centre provides up to 70 per cent of the funds needed for collaborative research in particular subjects[173] for up to seven years (10 years in exceptional circumstances). Aggregate funding of such programmes since 1985 had been ¥137.3bn (c. £858m). The budget for 1992 was ¥22,000m (c. £135m).[174]

DTI SUPPORT FOR COLLABORATIVE RESEARCH

142. In contrast to the Japanese support for industrial collaboration, the DTI announced, on the day "Realising our Potential" was published, that it was to withdraw resources from industrial collaborative research to focus on technology transfer activities. We asked for figures on previous support for such collaboration; in 1992-93 £55,864,000 was spent on the Advanced Technology Programmes (ATP) and the General Industrial Collaborative Projects.[175]

143. The DTI told us it was withdrawing support from such projects since industry/industry collaboration was becoming the norm and no artificial pump-priming was needed for such activities.[176] However, Professor Mellett of the CBI told our colleagues in the Lords that reducing support for the ATP was "throwing the baby out with the bathwater".[177] Mr Slater of Ford pointed out that support for industrial collaboration tended to be directed to things where "there may have been benefits long-term — but it is still a longshot from our point of view."[178]

144. **We understand the Government's unwillingness to provide funding for research that would have taken place without such support. However, government does have a role in encouraging and, where necessary, supporting industry's attempts to take a long-term view.** It is too early to say with confidence what the effects of the shift in resources will be: the current Advanced Technology Programmes will not show their economic worth for many years. **The DTI should monitor the effects of its change in support of industrial research, and be prepared to adjust its policy if it appears the amount of long-term research is being reduced. In addition the effectiveness of the Advanced Technology Programmes should be examined and an evaluation published.**

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[173]New materials, biotechnology, machinery, electronics, communication processing, network, radio communication, message transmission.

[174]Booklet on the Japan Key Technology Centre (deposited in the RO).

[175]Ev. p.203.

[176]Q. 871 but see also Mem.p.27.

[177]HL (1993-94) 12-II, Q. 1031.

[178]Q. 582.

145. Industrial collaboration may make sense for strong companies: it makes even more for SMEs.[179] There are some small or medium companies which make a living from performing contract or collaborative research for larger organisations. We were most impressed by what we saw at Ricardo Engineering, for example, and the evidence we received from Lotus. However, many smaller companies are not sources of technology, but rather need to bring technology into the company. One of the most effective ways of doing this is through the supply chain (although we would stress that not all suppliers are SMEs). All respondents bar one were making deliberate efforts to forge closer relationships with suppliers. Most of our sample had reduced the number of suppliers they used over the previous five years; and of the three companies which had increased the number of their suppliers, two were growing, at least in their UK operations. However, over half of all companies said their main equipment suppliers were based overseas. Our evidence indicates that a bare majority (24) of companies placed some external R&D with UK suppliers, while 13 placed external R&D with overseas suppliers. Similarly, while nine companies placed external R&D with UK customers only three did so with overseas customers.[180]

146. It appears from this that collaboration with home-based suppliers and customers is easier than with those based overseas. Nonetheless, the supply base in the UK appears weak, and if the trend to devolve research and technology development to suppliers continues, this weakness will have increasing implications for the Science and Technology Base. It is encouraging that inward investing companies seem to have improved the performance of UK companies in their supply chain.[181]

*Research and Technology Organisations and Government Laboratories*

147. Broadly speaking, companies have two main types of external sources of expertise: research and technology organisations, (RTOs) whether government or privately owned, which are mainly orientated to providing services or information for fees, and Science Base institutions, such as universities or research council laboratories, which have primary purposes other than selling their expertise to industry.

148. Both types of institution, but especially the former, have been seen as potential substitutes for Fraunhofer institutes, allowing:

> "intellectuals and academics within institutes... to communicate on equal terms with the people in universities but also having enough understanding of likely market applications so that they can say, 'Here is technology which we now know has potential for exploitation in a particular field' and say to industry, 'Now you take it from here'."[182]

149. The process of innovation is rarely as linear as this description, rather it requires continuing interaction between the parties involved. This need means that the intermediate institutions, with their ability to communicate with both academe and industry, are well placed to play a vital role.

150. **We consider that both independent Research and Technology Organisations and Government Research Laboratories are valuable and cost-effective parts of the Science and Technology Base.** They provide effective nodes in the complex network of interactions which brings together the resources necessary for innovation, and they are likely to be particularly effective in supporting the physics based industries and SMEs which, as we have seen, find direct interaction with the Science Base most difficult. Moreover, the reduction in corporate research centres may well mean that "the role of intermediate organisations sitting between HEIs and industry becomes even more important."[183]

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[179] Mem. p. 55.

[180] Appendix pp. /

[181] *UK Technological Competitiveness: The Influence of Inward and Outward Investment*, POST 1993, p.45, 49-50.

[182] Q. 925. See also Mem. pp. 78, 117, 118.

[183] Mem. p.54.

## Independent Research And Technology Organisations

151. Independent Research and Technology Organisations (RTOs), at least, appear very successful. Only 12 out of the 49 respondents to our questionnaire did not place at least some of their external research with independent RTOs in the UK. The advantages of such organisations are that they develop specific areas of expertise, often based on particular sectors; since they rely on selling their services to industry they are likely to be both aware of current industrial needs and attitudes, and, since their future relies on having expertise to sell in the long term as well as the short, they are inclined to take a long term view of research.[184] They are well placed to act as an interface between industry and the Science Base and they do so with limited Government support[185]; the Welding Institute receives less than 20 per cent of its support from the DTI, while Fraunhofers may receive more than 70 per cent of their support from Government (Federal or Land) sources.[186] The Association of Independent Research Organisations, which represents 36 RTOs, told us that 80 per cent of the income of its members came from industry.[187]

152. RTOs have great potential as a way of reaching small businesses.[188] About 650 (400 of whom are UK based), businesses are members of Campden Food and Drink Research Association (Campden FDRA)[189] and AEA Technology undertakes contract and consultancy work for several hundred SMEs.[190] AEA suggests that SMEs have difficulties in interacting with the Science Base and are best helped by:

> "awareness activities, training programmes, establishment of best practice, movement of people, services and consultancy, joint ventures and industrial Clubs."[191]

Many of these activities are conducted by RTOs.

153. We were told on our visit to Campden FDRA that they had great difficulties reaching all SMEs who might benefit from their activities, since there appeared to be no database of firms in the food and drink sector for them to draw upon.[192] *There is a role for government and industrial organisations in ensuring that all SMEs who can benefit should at least have their attention drawn to the appropriate RTO.*

154. All organisations need to be able to plan for the medium to long term. We heard from Dr Robinson of the DTI that the Welding Institute was "looking ahead of most other people" in its attempts to find what implications the DTI's change of policy would have for future funding after its programmes ended in 1994-95.[193] We fully understand their need to plan ahead.

155. Some successful RTOs, such as the Campden Food and Drink Research Association, have grown from government organisations, and we do not believe their work, with its industrial focus, could be bettered by a government laboratory. But Campden still attracts reasonable funding for contract research from the Ministry of Agriculture, Fisheries and Food (MAFF) and it is not wholly dependent on the commercial sector. Furthermore, the Director-General stressed Campden's dependence on fundamental research conducted in the public sector, through contacts with the Agricultural and Food Research Council (AFRC) Institutes and a formal arrangement with Birmingham University which spanned all science departments and was not confined to those directly related to food.

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[184] Mem. pp. 42, 43, 54.

[185] Mem. pp. 42, 43-45, 51, 54.

[186] Mem. p. 52.

[187] Mem. p. 56.

[188] See Mem. pp. 29, 51, 55, 77.

[189] 1993 Annual Report of the Campden Food and Drink Research Association.

[190] Mem. p. 54.

[191] Mem. p. 54.

[192] Mem. p. 46.

[193] Q. 875.

156. Government has a responsibility to maintain an overview of the Science and Technology Base, and to ensure that it meets the country's needs. Where there are gaps in that base, it is for government to identify and remedy them, either directly or through supporting private initiatives. **There is no fixed pattern for Government support for RTOs. There should be awareness of the ways in which changes in policy may affect them and may affect the Science and Technology Base.**

GOVERNMENT RESEARCH LABORATORIES

157. While fewer of our respondents placed research in Government Research Laboratories than did in RTOs and universities, they were seen as one possible source for information about new technologies by those in the aerospace, automotive, food and drink and pharmaceuticals industries. They are clearly not a negligible resource.

158. The DTI has announced that the future of its laboratories is under review.[194] When we asked whether the DTI planned to ensure the continued existence of the expertise and information built up within government research centres, the starting point for the reply was that "the Department is concerned to ensure that it will continue to have available to it the expertise and information necessary for it to fulfil its own functions."[195] *In our view, the value of government research establishments goes wider than this comment implies.*

159. Government laboratories provide a resource for industry as well as for the Departments to which they are attached. They also enable national standards to be set. We note that the CBI has written to the Minister for Trade and Technology to urge that the National Measurement System should be restructured in a way that would not "diminish the UK's reputation or performance" since:

> "It enjoys a high international reputation which helps to give the UK influence in international negotiations on measurement-related matters and has enabled many mutual recognition agreements for calibration and test results to be achieved. It also has a strong influence on attracting inward investment. Companies from Japan, USA and other countries, expect the UK to maintain a national measurement system as part of the industrial infrastructure."[196]

The CBI is clear that the national measurement system should be independent of commercial influences.[197]

160. As we have seen, recent reductions in the scale of central laboratories in UK firms may have weakened industry's ability to take the long term view, even though they have had compensating advantages. The "near market" principles which have been operated with a vigour that was widely criticised,[198] ensure government laboratories have had a long-term focus and have been able to support industry in longer-term projects. **For this reason we do not believe that the value of a government laboratory, even one operating in areas of direct relevance to industry, can be judged by its ability to meet departmental needs or to attract contract research alone. There may be cases where a Government Research Laboratory is a valuable part of the Science and Technology Base and its expertise should be maintained.**

161. It may be that this can be accomplished by careful use of research contracts. The intention of the Rothschild customer-contractor principle was admirable in many ways but proved impracticable. As the Lords' Committee noted, it depended on departments' ability to act as "intelligent customers" and ensure the long-term future of the facilities they

[194] Official Report, 4th May, Col. 4w.

[195] Ev. p. 203.

[196] Letter from Director-General, CBI, to Mr Patrick McLoughlin MP, dated 8 October 1993.

[197] See also mem. pp. 69, 78.

[198] See Mem. pp. 80, 117-8.

need.[199] If the knowledge base is to be safeguarded through purchasing, factors other than the best price obtainable will have to be taken into account. Government will need to enter into the long-term arrangements with its "suppliers" that are increasingly becoming normal in industry.[200]

162. Privatisation of government facilities need not be ruled out. As we have seen, independent research and technology organisations have an admirable responsiveness to the needs of industry. Nor will the knowledge base needed remain static: it is reasonable to judge that some research functions are no longer needed. **However, the DTI's role in monitoring the expertise available in government laboratories or former government laboratories should be wider than simply ensuring that its own research needs can be met. Industry should be widely and publicly consulted on matters such as these.** Moreover, as Government Department most clearly suited to maintaining an overview of the nation's Science and Technology Base, the OST should always be consulted on the closure or privatisation of government laboratories.

### THE EFFICIENCY UNIT SCRUTINY

163. The Efficiency Unit of the Office of Public Service and Science is currently conducting a scrutiny of government laboratories to determine the best ownership arrangements.[201] Some of these laboratories are conducting research of great relevance to industry; indeed Van den Bergh Foods (a subsidiary of Unilever) told us that Government support for the programmes in institutions such as the Institute for Food Research would be "important for the competitiveness of UK manufacturing".[202] When we asked the Chancellor of the Duchy about the scrutiny he replied:

> "In terms of institutions which have very long term basic research functions as their primary role, they are natural things for the state to own... It would be childish, in my personal view to waste time looking at whether or not you wanted to privatise the Laboratory for Molecular Biology. But there are other things that are living off contracts and so on which may now be fit enough."[203]

and

> "The procedure will be to judge in each case. I do not think I can give a simple procedure. It depends on the balance of whether they are living off contract research... or whether they are doing very long term work which needs such long-term contracts that you will be involved in the management of the thing anyway and it may be foolish to upset existing arrangements, as in the institutes of the MRC."[204]

164. **We see no reason why, provided it is conducted thoroughly and with due deliberation, and does not wreck Government science, the Efficiency Scrutiny should be feared,** ***as long as the Government's responsibility for the long term preservation of a knowledge base at least at the current level is taken into account in any decisions.***

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199 HL (1993-94) 12-I, paras 2.36-2.40.

200 Ibid see also para 5-12-13.

201 *Official Report*, 2 February 1994, Col 897 and 3 March 1994, Col 809-811w.

202 Letter from Van den Bergh Foods (not printed: deposited in the RO.) See also Mem. pp. 46, 235.

203 Q. 996.

204 Q. 998.

### International Programmes

165. International collaboration can allow companies to gain access to markets previously closed to them, to participate in projects beyond the capability of any one company, and to gain access to new technology. However, such collaboration is not always easy and there can be particular problems in the protection of Intellectual Property Rights (IPR); Mr Miller of Rolls Royce pointed out:

> "there are some quite strong restrictions on the transfer of technology from the United States elsewhere. We can use our ingenuity to let some of it rub off on us, but there is not much formal opportunity for transfer. In European military programmes... the system that has developed of allocation of particular parts of an aeroengine to different companies has produced a certain amount of exchange of the technology that is acquired in the design and development of an engine. Again I think that it is up to ourselves to use the opportunity with some ingenuity rather than having a formal scheme with all of it being given to us."[205]

**Collaboration can assist innovative UK industries; it cannot replace their own R&D which they need to retain international competitiveness.**

*Europe*

166. An increasing proportion of research funding for both industry and Higher Education Institutions (HEIs) is coming from Europe.[206] Indeed, the UK has proved markedly successful in attracting funds from the Framework programmes for European research and development: the UK received 19 per cent of such funding, in comparison with its average contribution to the EC Budget between 1987 and 1991 of 18 per cent.[207] The detailed effects of EC policies for research and development on the United Kingdom have been the subject of an extensive study.[208]

167. Like other Select Committees in both Houses, we have, in the past, been concerned about the possibility that European priorities might distort United Kingdom programmes, especially since the principle of attribution means that money allocated to EC programmes directly affects departmental budgets.[209] Mr Waldegrave did not believe the UK's domestic R&D had been distorted by attribution and that EC programmes "are well judged on the whole".[210] Although this assessment of EC research appeared to be shared by our witnesses who considered the UK should seek to use it more, many were still concerned about attribution.[211] The White Paper promised that:

> "Before negotiations on new Framework Programmes, the Government will take a strategic judgement on the best practicable balance between domestic and Community programmes."[212]

The report on the Impact of European Community Policy stated:

> "The system of attribution has the merit of controlling public expenditure and ensuring that policymakers consider EC spend alongside national activity. However, more flexibility is needed to cover circumstances where increases in EC spend are best exploited by increasing or maintaining national support rather than reducing it.

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[205] Q. 952.

[206] See Mem. p. 155.

[207] Figures from OST deposited in the RO.

[208] Office of Science and Technology, *The Impact of European Community Policies for Research & Technological Development Upon Science & Technology in the United Kingdom*, July 1993. [Hereafter The Impact of EC R&D Policies.]

[209] See also Mem. p. 197.

[210] Q. 1037.

[211] Mem. pp. 71, 83, 197.

[212] Cm 2250, p. 50, para. 6.11.

> The baseline above which attribution comes into play is now a significant part of the UK budget for R&D. Allocations should appear in the Annual Review of Government Funded Research and Development."[213]

**We agree.** We note that since the EUROPES baseline[214] is set in fixed cash terms at roughly the 1984 level the system is likely come to bite increasingly on UK R&D.

### INDUSTRIAL PARTICIPATION IN EU PROJECTS

168. Participation in EU projects offers industry a chance to engage in wider innovation networks than before. It is accordingly encouraging that two of the three most important reasons for undertaking research were "to gain access to complementary expertise/results" and "to develop longer term European links".[215]

169. The one area in which there may be problems is in the participation of SMEs where:

> "the United Kingdom is slightly more likely to be represented by large firms than by SMEs, probably because there are more large firms in the UK than the average for the EC."[216]

Given the UK's weakness in this sector, we welcome the fact that Business Links should provide a means for small companies to gain information about EC programmes of interest to them and the Government's efforts to pursue the results of EC research are efficiently disseminated.

### SUBSIDIARITY

170. In the recent negotiations on the Fourth Framework programme the United Kingdom has been pressing for the principle of subsidiarity to be applied. Mr Waldegrave agreed that this meant that large programmes beyond the resources of any single European country should be funded through the EU but that, apart from some pre-competitive and generic research programmes, other research should be funded at the national level.[217]

171. **We support the Government's emphasis on subsidiarity in research.** As members of the EU we have an interest in ensuring the scientific and industrial strength of the entire union. We strongly support collaboration in research and international collaboration can be most effective. However, such collaboration should be led by the companies and universities directly concerned. While international collaboration can both produce effective research and have wider benefits, the evidence we have received leads us to believe that in many cases, especially where near market research is concerned, the most efficient interactions between industry and the Science and Technology Base occur when both are based in the same country.

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213 *The Impact of EC R&D Policies*, p. xvii. A full description of the system of attribution will be found on pp. 71-72 of that Report.

214 Ibid p. xvii.

215 The Impact of EC R&D Policies, Table 5.3.1.2,p.44. See also Mem. p. 137.

216 *The Impact of EC R&D Policies*, p. 12.

217 Ev. Q. 1036.

## PART TWO: INNOVATION: THE WIDER CONTEXT

172. We have looked at the mechanisms by which innovation is directly implemented but such innovation cannot succeed unless the wider culture also supports it. However successful the OST may be in encouraging the Science Base to take part in the innovation process, that process will fail if the UK lacks the finance or the skills to take innovation to the market place. Mr Jackson of Celltech said "*our problem lies in the rate of commercialisation of new technology, not in the rate of creation of new technology*".[218] We now look at the reasons for this.

173. International comparisons show that UK companies are, on average, significantly less profitable than their competitors, and also that their rate of investment, both in capital equipment and in the development of new products, is less.[219] This is consistent with the loss of market share suffered by many sections of UK industry since the 1960's, but there appears to be no single explanation for this poor performance, rather it appears to be due to a complex of interacting factors, both external and internal to the company.

174. For convenience, we will divide these factors into the following broad categories, each of which we will examine in turn:

— the benefits of Research and Development expenditure to the country as a whole;
— the availability of finance and the terms on which it is available;
— management expertise and priorities; and
— the availability of skills.

### I THE BENEFITS OF RESEARCH AND DEVELOPMENT EXPENDITURE

175. The benefits of research can seldom be appropriated entirely by the researching agency, whether at the company, industry or national level. Research suggests that innovations benefit not only the companies which produce them, but spill over into other companies and even industries.[220] This leads to the argument that research should be left to others, and the benefit secured without the cost: it pays to join the free riders. A contrasting argument is that it pays the wider community, which shares the benefit, to subsidise the researching agency to give it sufficient incentive to undertake the research. Recent research has shed new light on these questions.

**R&D and Economic Growth**

176. The first question is the extent to which R&D expenditure does increase productivity. A study of UK manufacturing industry by Cambridge Econometrics[221] estimated that incentives to innovation (such as grants and fiscal incentives) yielded a pay back between two and three fold, well above other forms of public investment. Coe and Helpman[222] have examined the OECD national aggregate data on R&D and productivity in the G7 and 15 other industrial countries over the period 1970-90. They estimate that an increase in business expenditure on R&D substantially increases total factor productivity (TFP, which is the ratio of output to the inputs of labour and capital). The elasticities of total factor productivity with respect to the stock of R&D are shown in Table 1.

[218] Mem. p. 267. See also Mem. p. 56.

[219] See Ivan Yates *Manufacturing Growth and National Investment in Innovation, Investment and Survival*, Fig. 12, p. 137.

[220] See, for example Akira Goto and Kazuyuki Suzuki, *The Review of Economics and Statistics*, November 1989, Number 4, p. 563.

[221] Terry Barker, *Technological Competition, Manufacturing and Improved Economic Prospects in Innovation, Investment and Survival of the UK Economy*, edited by Ivan Yates, London 1992, pp 25-44, p. 42.

[222] Coe, DT and Helpman E 1993, *International R&D Spillovers*, Centre for Economic Policy Research Discussion Paper No. 840, London.

Table 1. R&D elasticities[1]

| | TFP growth (1970-90)% | Ratio of S(1990) to S(1971) | S(1990) % GDP | Elasticity with respect to: Domestic R&D | Foreign R&D in 1990 |
|---|---|---|---|---|---|
| US | 9.7 | 2.0 | 22.8 | 0.233 | 0.030 |
| Japan | 68.3 | 4.2 | 16.8 | 0.233 | 0.027 |
| Germany | 22.6 | 2.6 | 20.2 | 0.233 | 0.068 |
| France | 41.7 | 1.8 | 16.2 | 0.233 | 0.063 |
| Italy | 36.9 | 2.8 | 6.7 | 0.233 | 0.055 |
| UK | 12.9 | 1.2 | 21.1 | 0.233 | 0.073 |
| Canada | 17.0 | 2.7 | 7.1 | 0.233 | 0.071 |

[1] The elasticity is the percentage increase in total factor productivity due to a 1% increase in the stock of R&D. It is assumed to be the same for domestic R&D for each of the G7 countries. The stock (S) of domestic R&D is calculated as the accumulated sum of past business expenditure on R&D, discounted at 5 per cent pa. Similar results are obtained discounting at 10 per cent and 0 per cent pa. Each country's stock of foreign R&D is the sum of its trading partners' domestic R&D, weighted by the volume of imports received from them. By working with the stock of R&D accumulated over a period of 10 to 20 years, it is the medium term effect of R&D that is examined, with the direction of causality running from R&D to productivity.

177. Coe and Helpman found that all countries benefited from both domestic and foreign R&D. In the 15 smaller countries, TFP had a greater elasticity with respect to foreign R&D than to domestic R&D. G7 countries had a greater elasticity with respect to domestic R&D than to foreign R&D, meaning that they would gain more from increases in their own R&D than from just picking up the benefit of foreign R&D. We ourselves saw in Japan the effect that an innovative machine tool industry had on other parts of the economy. The Coe and Helpman paper gave rates of return of over 100 per cent at the national levels but the estimate of rate of return depends on the precise assumptions made.[223]

178. For the UK, with an elasticity of TFP of 0.233 with respect to the stock (S) of domestic business expenditure on R&D, with S being 21.1 per cent of GDP, the own rate of return on S is 110 per cent pa (0.233 x (100/21.1) x 100). The average own rate of return for G7 countries is 122 per cent pa. The average rate of return to the world as a whole from investment in R&D is 152.1 per cent pa. For the G7 countries the difference between the worldwide and the own rate of return is about 30 per cent pa. This implies a substantial international R&D spillover, but not so large a spillover as to fail to leave a substantial competitive advantage to each G7 country from its own R&D.

179. The estimates of TFP are not sensitive to a proportionate increase or reduction in the levels of R&D capital stocks in all countries, and so in particular would not be sensitive to a change in the rate at which R&D expenditure is discounted if R&D were constant in each country. But the rates of return are sensitive to such proportionate changes in the stock of R&D. However, a higher discount rate (30 per cent pa might be appropriate in micro-electronics), would give an even higher own rate of return, because the TFP return would arise from a lower stock. The calculation of rates of return also depends on macroeconomic policy being such that the increase in total factor productivity is translated into the growth of GDP.

[223] See letter from Bronwyn Hall to Clerk of the Committee. (Deposited in the RO.)

180. In the Coe and Helpman study estimated rates of return were 100 per cent or more. Rates of return on R&D stock found at the firm and industry level tend to be around 30 per cent to 40 per cent,[224] suggesting that there is a big spillover at the country level beyond the firm's own rate of return.

## FISCAL INCENTIVES FOR R&D

181. If much of the benefit from R&D expenditure stays within the country in which it is undertaken, yet the companies which finance the R&D do not capture all the benefits, what can be done to make it worthwhile for firms to undertake such valuable research? In 1991, the House of Lords Science and Technology Committee suggested that companies should be given tax credits for "the amount of real additional expenditure [on R&D] which a company makes over the previous year's total"[225] This recommendation was rejected.

182. Since 1981, the United States has had a tax system designed to reward such increases in expenditure, although there have been adjustments to the rates used. Bronwyn Hall has recently evaluated the effectiveness of the system.[226] Hers is the first study to examine a large sample[227] and to take into account the structure of the US tax credit, which relates the incentive to the firm to its own research expenditure. It has also been able to take account of longer term effects which are only now being seen, since firms cannot change their research strategy in response to short-term tax changes that may not last more than a year or two. It is therefore very much more thorough than earlier studies.[228] Such studies generally found that the tax losses to the Revenue exceed the increase in the R&D undertaken by firms. That would not in itself constitute a case against R&D tax credits if the rate of return spilling over to the country on business R&D is high. But the case is plainly stronger the lower the cost in loss of tax revenue. While the margin of error for the figures may be large, *Hall finds the additional R&D spending in the 1980s by the US system, in the short run, was greater than the revenue forgone; she suggests spending figures of $2bn pa as opposed to revenue losses of $1bn.*[229]

## IMPLICATIONS FOR THE UK

183. Provided they are relevant to UK conditions, these results could be highly significant. We see no reason, in this context, why the behaviour of companies in the UK should differ significantly from those in the US, as described by Hall. The research of Coe and Helpman cited above made comparisons with all the G7 countries, so their study seems applicable to the UK. Indeed, the kind of work in their paper could usefully be extended to take explicit account of other influences on total factor productivity, such as expenditure on education and training. Business R&D explains little over half of the variance in the international TFP data, so there is plenty of room to allow for other effects.

184. *The Coe and Helpman study, taken with that by Cambridge Econometrics and Bronwyn Hall, suggests the possibility of great returns to the United Kingdom.* On our calculation introducing a tax incentive to increase business R&D by 0.1 per cent of GDP pa for five years could increase the rate of growth of GDP by 0.8 per cent pa from the fifth year. The present level of business expenditure on R&D in the UK is about £8bn pa, or 1.36 per cent of

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[224]Goto, A and Suzuki, K. 1989. *R&D capital, rate of return on R&D investment and spillover of R&D in Japanese manufacturing industries.* Review of Economics and Statistics, LXXI, 4,555-564 and Suzuki, K. 1993. *R&D spillovers and technology transfer among and within vertical keiretsu groups:* evidence from the Japanese electrical machinery industry. International Journal of Industrial Organisation, 11,573-591 .See also Griliches.

[225]HL (1990-91) 18-I, para 9.41.

[226]Hall, B H 1993. *R&D tax policy during the 1980s: success of failure?* Journal of Tax Policy and the Economy, 1-35.

[227]Over 1000 firms accounting for 75% of US industrial research.

[228]Bernstein J L and Nadiri, M I. 1988. *Rates of return on physical and R&D capital and structure of the production process: cross section and time series evidence.* NBER Working Paper No. 2570. Mansfield, E. 1986. *The R&D tax credit and other technology policy issues.* American Economic Review, 76,190-194. General Accounting Office, US Government 1989. The research tax credit has stimulated some additional research spending. Report GAO/GGD-89-114, Washington DC.

[229]See Mem. p. 209.

GDP.[230] If this was increased over five years to £12bn pa, or 1.8 per cent of GDP, then, on calculations based on Coe and Helpman's work, this would increase the rate of growth of GDP by 0.8 per cent pa or £5bn pa.[231] The tax yield from the increased incomes would quickly exceed the tax loss from the tax credit.[232]

185. We raised the benefits of R&D spending both to the companies conducting the research and to the country as a whole with the Chancellor of the Duchy of Lancaster who told us "We have had discussions with the Treasury about this".[233] The Government has a range of incentives to encourage individuals to invest, such as the Enterprise Investment Scheme, which we discuss in more detail in paragraph 250 below. Such initiatives are welcome. There can also be tax advantages for the individual in investing through institutions such as pension funds. The question is whether tax incentives for spending on research and development at company level, which would have to be constructed to avoid distorting management decisions, would also be acceptable. Certainly, a tax credit system would be likely to fall within EC competition rules.[234]

186. The White Paper rested its resistance to general tax incentives for spending on research and development on the Government Reply to the Lords Committee's Report on Innovation in Manufacturing Industry. This used work done in the late 1980s; no more recent studies were referred to.[235] We were sufficiently impressed by the new results summarised above to ask a number of economists for their comments, both on the original papers and our interpretation of them. Their response was positive.[236] **We believe the time has come for a major re-examination of the case for fiscal incentives for investment in research and development, both at personal and at company level. Such a review should be conducted openly, and its conclusions should be considered by experts outside the Treasury.**

187. It is reasonable to suppose that a similar positive result would be found for additional expenditure on additional education and training for increased skills in the workplace and we suggest that this aspect should also be examined with an open mind.[237]

## II FINANCE

*An Overview of Factors Affecting Company Growth*

188. Company organic growth requires a level of profit which gives:

— scope for an appropriate level of RTDD on a continuing basis;
— sufficient investment in productive equipment;
— enough marketing activity to achieve a satisfactory market share;
— sufficient investment in education and training for all levels of the workforce; and
— scope for servicing loans and paying dividends.

Companies must seek a virtuous circle in which the above investments produce enough profit to them to continue and increase.

[230] See R&D 93, Table 2.4.2, Figure 32.

[231] This would increase the stock of business R&D at a rate building up to an additional £4bn. pa. With GDP £600bn. pa, and S 20 per cent of GDP, S is £120bn. £4bn. pa. is a 3.3 percent pa increase in S. With an elasticity of 0.233, the increase in GDP is 0.233 x 3.3 = 0.8 per cent pa.

[232] While the above calculation of the rate of return to increases in the stock of R&D depended on the rate of discount used in calculating the stock of R&D, this estimate of the effect on GDP, to a first approximation, does not depend on the rate of discount used.

[233] See QQ. 970-984, Q. 982.

[234] France has a system in which tax credits are granted for 50 per cent of the additional research over previous levels. (Projet de Loi de Finances pour 1994: Etat de la Recherche et du Developpement Technologique: 7.2.)

[235] Cm 2250, para 2.12, see also Mem. p. 208.

[236] Papers by Bronwyn Hall, Gavin Cameron and Paul Geroski have been deposited in the RO.

[237] See Mem. pp. 141, 228.

189. The complex interactions between the financial sector and industry tend to vary with the size of company. The smaller companies are usually funded, after the start-up stage, by banks; SMEs by a mix of bank finance and equity; larger companies and international corporations use a mix of banks, equity and international bond finance.[238]

190. Financial systems interact with industry through a number of mechanisms, which tend to differ from country to country, and are considerably different between the US and the UK on the one hand — so-called Anglo-Saxon capitalism — and those to be found in Germany (and much of the European continent) and in Japan (and the Pacific rim). These include:

— the ownership structure of companies;
— Corporate governance;[239]
— Behaviour and structure of the banking system; and
— Accounting conventions (and the legal system).[240]

191. Whichever part of the world is considered, many factors interact to form a complex system, which cannot easily be changed. It is increasingly accepted that there is, in the UK at least, a 'systems problem' which involves these interactions, and that it is not effective to apportion blame to any sector or group: because of the constraints of the overall system influencing their role an exchange of personnel between parts of the 'system' would see the 'new' people acting in exactly the same way.

192. The complexity of the financial system has been further increased by the globalisation of financial services and the money markets which has arisen from the technological improvements in communications, and by de-regulation of the markets such as the City's 'big bang'. There have been other changes, for instance the increase in the funds managed by UK pensions funds, unit and investment trusts and insurance companies now totalling about £350bn and the consequence that about 57 per cent of the equity of UK manufacturing companies is now owned by such funds.[241] Individual investors now have less impact on the behaviour of UK companies, and the fund managers and the system of rewards for their performance are now all important. The change which this development has produced affects not only the attitude of company managements, but also the degree of control which can be exercised by the ultimate 'owners' — ie the contributors to pension funds and individual shareholders, — of the company.

## The Management Of Risk

193. A management decision on investment for a new product usually leads to a design and development programme which takes between a couple of years for consumer goods to a decade or more for pharmaceutical and aerospace products before the product becomes established in the market place. In taking investment decisions management has to consider more than the technological risks — the factors to be considered include such key factors as inflation, interest rates, the exchange rate (very important for exports) and the rate of growth of the UK economy, and the way in which the tax system may affect predicted company profitability.

194.Few of these factors are within management's power to influence. In the face of this complex set of highly unpredictable variables, many UK companies have adopted a risk averse approach to investment. These problems are exacerbated by the volatility of the UK economy and relatively high cost of capital in the UK.[242] There is evidence that UK firms require rates of return of about 25 per cent/30 per cent, compared with 15 per cent/20 per cent for

[238]See Professor Colin Mayer, "The Financing of Technology "in Innovation, Investment and Survival of the UK Economy, pp. 141-164.

[239]Mem. p. 60.

[240]See Mem. pp. 31-32, 213.

[241]Share Register Survey Report - end 1992. For international comparisons see Mem. p. 121.

[242]Mem. pp. 60, 71.

the US, 12 per cent/14 per cent for Germany and 7 per cent/10 per cent for Japan.[243] This research is consistent with the returns expected by respondents to our questionnaire, at least for projects with some element of risk.[244] **The effect of requiring such high 'hurdle rates' of return is to exclude companies from a wide range of opportunities - open to their competitors - in projects with lower rates of return.**[245]

195. There have recently been suggestions that companies have not adjusted their rates of return to take account of lower inflation, and that the returns expected could be as much as 10 per cent above those required by the cost of capital.[246] Companies involved in long-term projects will be likely, however, to seek some longer-term evidence of low inflation before lowering the criteria.

196. The picture above seems consistent with the operation of the financial system in the UK and the observed investment decisions made by companies. It explains the poorer rate of organic growth of UK companies — and the UK economy — and also the apparent reluctance to exploit the whole range of inventions and new technology which is available from the UK Science Base. If it is correct it has depressing implications for the long term future of UK industry, which seems likely to contract still further. **Further study of the effects of the financial system on innovation and industrial growth is urgently required, and we urge that it be fully examined in the current Treasury Review.**

197. We cannot comment on all the factors identified above. Nevertheless, as politicians, in the course of this inquiry we have been convinced that there are problems in the complex interface between UK owned industry and the operations of the UK financial system, and we will look in more detail at those problems which we identified as particularly germane to the financing of innovation and investment in technology. Our comments are not intended to provide a full survey of the United Kingdom financial system as we understand our colleagues on the Trade and Industry Committee are also looking at these issues.

*Structure of UK Financing*

198. A broad distinction is often drawn between the "Anglo-Saxon" economies of the UK and US, in which companies usually raise money through equity traded on highly developed and very liquid stock markets, and the German or Japanese model, in which companies are privately owned, or part of groups — including banks — with strong cross-holdings, and ownership implies a long-term commitment and is much less volatile.

199. Herr Bruder of Commerzbank has suggested that the Anglo-Saxon system of corporate control leads directly to industrial weakness since the Stock Exchange's:

> "very efficiency and excellence have propelled it into a monopoly position; one however operated not in the interest of its users, but in the interest of its members... "

He maintains that the interests of investors and companies are largely opposed since:

> "the share designed as an instrument of long term investment is today treated by the financial markets in the Anglo Saxon environment like a short term money market instrument."[247]

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[243] *Innovation, Investment and Survival*, edited by Ivan Yates, Chapter 9, Figure 3. Based on *Explaining International Differences in the Cost of Capital*, Federal Bank of New York, 1989.

[244] Figures supplied in confidence.

[245] See also Mem. p. 6, which suggests that, regardless of the discount rate they use, companies are likely to underestimate the likely benefits of innovation, and Mem. p. 60.

[246] BZW in *Financial Times*, 25.1.94.

[247] Paper presented to the Foundation for Science & Technology on *Industry, Finance & Innovation. A Comparison of British & German Experience* at the Royal Society on 24 March 1992. Published in *Technology, Innovation and Society*, Summer 1992.

200. Others claim that the existence of a highly developed market ensures companies behave in a more competitive manner, and the threat of a take-over can help to correct management failings. Several witnesses claimed the relatively easy access to the markets provided by the UK system was an advantage.[248]

201. Witnesses told us that although the financial structure of the US was similar to that of the UK, (albeit with less influence from pension funds), the entire culture was less risk averse.[249] There were far more funds available for high risk ventures, and access to the small company orientated stock exchange, NASDAQ, meant investments were not as illiquid as in the UK.[250]

202. In contrast, the views of witnesses about the German and Japanese system could be summed up by Nomura who told us that industrial and bank cross-shareholdings meant:

> "Much closer and longer term relationships develop in Japan as a result, which many observers would see as a positive element in the Japanese economy and a major boost to industrial development. The same could be argued for Germany, which represents the other most successful economy in the world in the last two or three decades."[251]

As we shall see, not only are forms of ownership more stable in Germany and Japan and reinforced by differing forms of corporate governance,[252] there appears to be easier access to less expensive sources of long term finance.

203. No system is perfect. The US system succeeds because it combines high liquidity (albeit at a cost) with the toleration of a higher rate of risk, and of business failure, than in the UK.[253] While the German and Japanese systems have been markedly successful in the past, some of our witnesses suggested that, as the 'Anglo-Saxon' model became more widespread, they would prove dangerously inflexible in future. In Germany's case, this was thought to be made more likely by the strains of unification.[254] Nonetheless, **in the light of the evidence presented to us, we would agree with those of our witnesses who suggested that the UK financial system has been less successful at encouraging the growth of high technology companies than those of its competitors.**

## Corporate Governance And Ownership Structure

204. Many of the problems faced by that section of UK industry which depends on the stock market have been ascribed to its ownership structure. Most investment in the UK, particularly that in manufacturing industry, comes through institutions such as pension funds.[255]

205. Although the "proper measure of the performance of a fund manager is whether he ultimately meets the liabilities of the fund", a measure which implies a long run real return rate of between 3 and 5 per cent, fund managers may have their performance measured on a three or six monthly performance measure.[256] Witnesses from Kleinwort Securities were sure that the greater proportion of professional and institutional shareholdings in the UK by comparison with America "would go a considerable distance in explaining the difference in

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[248]Q. 864.

[249]Mem. p. 23, 267.

[250]QQ. 144, 145, 154, 469.

[251]Mem. p. 19. See also RSA Interim Report, p. 25.

[252]See for example, Peter E Hart, *Corporate Governance in Britain and Germany*, NIESR Discussion paper No. 31, December 1992.

[253]Q. 159.

[254]Q. 759.

[255]Pension funds, Unit Trusts and Insurance Companies are beneficial owners of 56.4 per cent of UK equity. Source: CSO: *Share Register Survey Report* - end 1992.

[256]Q. 746.

investment behaviour between the two markets".[257] Pension fund managers are also constrained by the fact that they act on behalf of trustees; it may not be appropriate for them to accept high risks.[258] In any case, although they are acting on behalf of owners of the company, they do not have any commitment to its long-term success.

206. This is a subject that goes far wider than finance for innovation. We will accordingly leave a detailed analysis of the role of the funds in the UK market to our colleagues on the Select Committee on Trade and Industry Committee. Nonetheless, we are convinced that a predominance of institutional, rather than personal, shareholdings, contributes to the problems we discuss. As Mr Jackson, Chairman of Celltech Group says:

"...government should consider with some urgency what steps can be taken to re-divert the savings stream so that more private individuals can contemplate investing in young companies a part (only a small part is needed) of their savings whilst exercising their right to make their own wealth and provide for their own futures."[259]

Many of our recommendations are intended to increase the incentives for investors to take a long term view and encouraging a greater number of individual shareholders.

**Economic Fluctuations**

207. There was a widespread perception in those answering our questionnaire that macro-economic instability had indeed caused problems for their business. Complaints of instability came from both large and small firms and were echoed by witnesses from the financial world.[260] However, in evidence to the Committee, Dr Dobbie of the DTI said:

"the most volatile economies have not necessarily been the least successful. If we look at Italy, for example, over the past 30 years it has been the most volatile of the G7 economies across a wide range of variations of the macroeconomy on growth, on interest rates and on inflation rates... yet Italy has grown substantially faster than the United Kingdom and, indeed, than France and Germany over the past 30 years."[261]

This, of course, is a Eurocentric view which also ignores the differences in ownership patterns between companies; much of Italian industry is government owned and has thereby enjoyed a high degree of State long-term support despite political and economic volatility; Italy's growth may have been better than that of Germany, France and the UK but it is, as the DTI's own figures show, only about half that of Japan.[262] In addition, the financial structure of the UK, in which many more companies are traded on the markets, may make industry more vulnerable to the effects of economic fluctuations than it would be elsewhere.

208. The DTI figures examine interest rates over a series of periods ranging from 8 to 11 years. When the data are compared on a year by year basis it becomes apparent that there has been far more short-term variation in UK interest rates than in those in Italy.[263] As Ivan Yates has said:

"in deciding on the figures to be put into a return on investment calculation, the Japanese are fairly sure what their average will be over the next few years, the Americans are less so and the British financial director in particular has to take into account a very significant

[257] Q. 729.

[258] Mem. pp. 125, 267.

[259] Mem. p. 267.

[260] Mem. pp. 31, 33, 60.

[261] Q. 815.

[262] T&ISC Ev. HC (1993-94) 702-vi.

[263] Ivan Yates, *Manufacturing Growth and National Investment, in Innovation, Investment and Survival*, Edited by Ivan Yates, London 1992, p. 126-8.

degree of variation... it is inevitable that the assumptions will be consistent with the upper boundary of pessimism, rather than the average of this oscillating parameter."[264]

209. Business decisions are taken by business people; on a matter such as the extent to which economic fluctuations affect their ability to invest and to trade we feel it proper to give weight to their judgment. As we shall discuss, **the UK's relative decline has not been caused by economic instability alone, but we regard it as a contributory factor. Government policy should be aimed at macro-economic stability and it should not be forgotten that both short-term and long-term instability increase the difficulty of business decisions.**

### The Stock Market and Innovation

210. The UK (and to a lesser extent, the US) stock markets have often been criticised for their 'short-termism'. Crudely speaking, the influence of the market has been held to drive up dividends and drive down investment, be it in modern plant, in R&D, in market penetration or training. If the market does not in itself act like this, it has been argued, it generates pressure on industrial managers to manage in short-term ways. This analysis, and variants of it, have been hotly disputed, and we will not rehearse all the arguments here[265] although we note that many of the companies which responded to our questionnaire and many of our industrial and academic witnesses considered short-termism a real problem.[266] However, there do seem to be particular problems with the stock market's approach to research and development expenditure.

211. For most companies, investment in innovation will be funded from retained profits. The UK tax system is unhelpful here, in that it encourages distribution rather than retention of profits.[267] Moreover, profits retained are dividends foregone; by international standards, the UK has a very high ratio of dividend distribution.[268] As National Westminster told us "UK companies are reported as spending twice as much on dividends as on R&D. By contrast, the top 200 international companies spend more than twice as much on R&D as on dividends".[269]

212. In spite of the obvious conclusions that might be drawn from this, witnesses from Kleinwort Securities assured us that research and development was taken into account in company valuation. Moreover, they asserted that, whatever their initial expertise, over time analysts would come to understand the industries in which they invested to an extent that would allow them to evaluate R&D. They were also clear that the market would support companies which invested in R&D if consistent past success suggested that that money would be well spent.[270]

213. However, analysts will not always recommend investment in companies with good research and development programmes. Dr Hiorns of Kleinwort Securities told us:

"there will be a reasonably sophisticated view of the life of the research programme. Admittedly it is not one that says: 'This company is investing a great deal of money which will reap a reward in five, ten years time. Let me therefore buy it now'. He [the analyst] may well calculate that he can buy it cheaper later on. In the same way, the boards of the companies that took various pieces of Plessey, calculated that Plessey had, in fact,

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[264] Ibid.

[265] See Mem. pp. 56, 57, 58, 61, 68, 69, 74, 110, 120-1, 125, 202, 216-7, 242, 245-6.

[266] See, for example, Mem. pp.53,72,202.

[267] See Colin Mayer and Ian Alexander: *Stock Markets and Corporate Performance: A Comparison of Quoted and Unquoted Companies*, p. 29, T&ISC, Mem. p. 210, and RSA Interim Report pp. 18-19.

[268] Mem. pp. 27, 33, 72.

[269] Mem. p. 27.

[270] QQ. 774—777.

invested in extremely good products; it had simply over-invested in too many products at the same time."[271]

This is reasonable behaviour from the point of view of the market but it has, in the case of Plessey, resulted in the break-up of a major UK company. One witness from industry cited the example of a German company which "did not pay a dividend for about five years but with support from their backers, which include at least one large chemical company and, of course, certain German banks, they not only survived but went on to expand in the early '90's."[272] As he concluded, "I don't believe the company could have survived (certainly as an independent entity) had it been a British, or indeed American, business!" A similar example is that of Ericsson, which persuaded its few large investors to forego dividends whilst it increased its R&D to a huge 22 per cent of sales in order to secure its dominant share of the world market in mobile telephone systems.[273]

214. One difference is the extent to which investors are prepared to trust the companies in which they invest. Markets can value companies either on a PE basis (that is on the price earnings ratio; the ratio of the price to the profit generated, regardless of whether that profit is distributed or reinvested in the company) or on a yield basis, which is based on the dividend paid out to shareholders.[274] Commenting on the yields expected of industry, Dr Hiorns explained that:

"a company paying a high yield lacks the confidence of the market and it is hence having to return capital to the capital pool in the economy. If the company enjoys the confidence of the investor the text book would say that therefore the investor in the company is confident that the management of the company can invest that dividend flow better in his own company than the fund manager controlling the pool can do elsewhere in the economy, that it is better that he should reinvest within the corporate entity, thus generating higher profits growth than the fund manager could who has received — or in this case, has not received — the dividend back."[275]

German and Japanese markets are much more PE based than UK ones: their investors have much more confidence in the profit generating capability of companies. This confidence is, in part, probably due to the difference in ownership and corporate governance arrangements which allow much more "insider" information to be made available to shareholders' representatives.[276] The difference may also be a telling example of the relative weakness of the UK economy; it may also spring from the different priorities of investors in different markets. It is also a reflection on the international nature of the London market: as witnesses suggested, the more international the market, the more likely that investors will be "predominantly interested in high profits very quickly and then moving on to something else."[277]

215. Where our witnesses were agreed, however, was that good communication between companies and financial backers made it more likely that research and development would be supported;[278] Mrs Sidaway of Kleinwort Securities agreed that part of the problem was the lack of communications skill on the part of both the City and industry.[279] The Bank of England cited:

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[271]Q. 786.

[272]Letter from Avon Rubber plc, dated 23 November 1993. Deposited in the RO.

[273]The UK Innovation Lecture 1994, by Dr Lars Ramqvist, President and Chief Executive Officer of Ericsson.

[274]QQ.739-742.

[275]Q. 742.

[276]See Colin Mayer and Ian Alexander: *Banks and Securities Markets: Corporate Financing in Germany and the UK*, Centre For Economic Policy Research, discussion paper No. 433.

[277]QQ. 771—2.

[278]Mem. pp. 11, 34, 60.

[279]Q. 777. See also mem. p. 57, 60.

"The importance of effective information flows between industry and finance, to facilitate an improved market culture in relation to investment in technological innovation; and a need for technologists to be financially aware when seeking investment finance"[280]

as one of the three broad points which most needed emphasis. Certainly, the industrial witnesses who expressed most satisfaction with the stock market as a source of funds were those who claimed good communications with their backers.

216. There have been a number of recent initiatives to improve communications. The DTI Innovation Advisory Board's Innovation Plans Handbook provides good practice guidelines for achieving a closer relationship with the Investment Community.[281] In addition, an Industry/City dialogue, entitled 'Engineering Consensus' has produced an 'Investment Relations Policy', stating 'the overriding requirement is for an open and consistent communications policy, providing sufficient detail to allow analysts to assess trading and financial trends'.[282] The evidence we have received leads us to support these initiatives. **However, we do not believe communication alone can solve these problems. Behaviour that is rational for those in the financial market place can have destabilising effects for industry. There appear to be significant advantages to German companies in their versions of corporate governance "insider systems" as Professor Colin Mayer describes them.[283] We consider that these aspects of corporate governance in the UK context should be given serious further consideration both by Government and industrial economists.**

### Start-ups and Growing Companies

217. The Medical Research Council (MRC) told us "Experience in the USA... has illustrated how effectively 'start-up' R&D companies can advance new research findings through applied research and early development".[284] While established companies fund growth through retained earnings, newer companies must rely on external sources of finance. If the financial system fails to support such companies adequately an important source of innovation will be lost.

218. The UK, broadly speaking, appears to have a comparative shortage of Small and Medium sized Enterprises (SMEs) — 3i told us:

"International comparisons show SMEs account for 32 per cent of non-primary private sector GDP in the UK compared to a figure approaching 50 per cent in the United States and Germany and 60 per cent in Japan."[285]

219. Many of our witnesses were of the opinion that the UK financial structures made it difficult for businesses to start and grow. The problems witnesses identified were:

— a shortage of venture capital directed to start up or to small but growing businesses;

— lack of 'development capital' for growing businesses;

— lack of understanding of businesses by the banks which lent to them; and

— the high cost of bank finance.[286]

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[280] Mem. p. 36.

[281] Mem. p. 64.

[282] *Engineering Consensus* (Sciteb) p. 7, Mem. p. 64.

[283] *Innovation, Investment and Survival*, Edited by Ivan Yates, p. 161.

[284] Mem. p.101.

[285] Ev. p. 92.

[286] See, for example, Mem. p. 35.

220. These complaints are based on a particular idea of how a small company should grow, which can be summarised as follows:

(1) the entrepreneur raises the capital to start his or her company;

(2) Further finance is later needed for expansion;

(3) If a venture capital company is not involved in stage 1, then it is approached in Stage 2;

(4) The company continues growing, and more finance is needed; further investments are sought from the venture capital sources;

(5) The company is floated on the Stock Exchange, or sold in a trade sale, enabling backers to realise their investment.

The role of the banks in this process is to provide loans, often secured against physical assets, or, alternatively, overdraft finance. This is a peculiarly Anglo-Saxon model, as we shall see, and even in the UK not all companies follow this model, and many successful companies remain in private hands. However, given these assumptions, we feel it is necessary to see whether the venture capital industry is capable of playing the key part assigned to it.

*Venture Capital*

221. The witnesses we examined from the financial sector shared the model of company development outlined above. This led them to a clear view of the respective roles of banks and venture capitalists. As Mr C Harrison of Ernst and Young described it:

> "Banks are trained not to lose money and make sure that the small margins on which they operate are adequate to sustain their profits, whereas venture capitalists are trained to look for winners and to make investments pay very handsomely so that they can pay for the losers."[287]

or, as a witness from Lloyds Bank said, "if you are looking for risk capital, I hope 100 per cent of your respondents will find the clearing banks unhelpful."[288]

222. Many of our witnesses felt this division of responsibility was not only understandable, but correct. It was argued that venture capital funds were investments knowingly made on a high risk, high return basis while banks should not be involved in early stage high risk situations since "their primary objective is to safeguard the assets of their depositors."[289] Moreover, the risks involved are of a very different nature, as Mr David Harrison of Lloyds Bank pointed out:

> "if you are going to take an equity investment, you have a very strong interest in the on-going profitability and growth and, above all, the return on equity that would be involved. Your position is quite different from that of a banker who is interested in the cash flow of a business and whether his loan is safe."[290]

Dr Summers of 3i agreed "it is a very different game that we are playing."

[287] Q. 56.
[288] Q. 397.
[289] Q. 61.
[290] Q. 404.

*Shortage of Funds*

223. This system appears rational but there are a number of problems. The first is the relative shortage of venture capital funds directed to start-ups and to high technology start-ups in particular. The total equity investments made by members of the British Venture Capital Association (BVCA) in 1992 was given as £1,250.8m[291]; in comparison National Westminster lent £10½bn to SMEs alone.[292] Moreover, the product positioning map for major firms in the investment capital sector sent by 3i showed only three companies directed to industry focused investments: 3i itself, ECI Ventures and Apax.[293] Other companies are involved, but they are small.

224. Our witnesses also stressed that many companies are directed to development capital in "relatively safe market sectors"[294] The Bank of England told us:

> "The majority of venture capital funds now specialise in development capital and, in particular, funds for MBOs/MBIs.[295] According to industry statistics, the proportion of such investments rose from 28 per cent of funds invested in 1984 to 64 per cent in 1992. In that year, start-up and other early stage investments accounted for only 7 per cent of funds invested, and the average size of each investment increased from under £400,000 in 1984 to £783,000 in 1992. The concentration on larger scale venture capital funding reflects the perceived relative attractiveness of MBO/MBI type investments during the 1980s."[296]

225. Mr Kirkpatrick of 3i told us that "sometimes you can say that start-up in a traditional sector is actually more risky than start-up in a high-tech sector"[297] and a survey of high technology firms in the St John's Innovation Centre showed a low failure rate of only 4 per cent.[298] In spite of this, there appears to be a perception that "any start-up is risky".[299] In consequence, such companies are less likely to be funded. Start-ups also require additional scrutiny. Schroder Ventures told us:

> "Our past experience has shown that start-up and development capital deals in general do not provide adequate returns to the funds we advise. Evaluating a start-up is much more difficult than evaluating a management buy-out/buy-in... The nature of start-up investments is that they require a high level of due diligence work prior to investment and monitoring post investment. In an MBO/MBI situation the deal is more clearly defined and as a result less demanding of SV's resources."[300]

Newmarket Venture Capital agreed that:

> "investing institutions are only rarely prepared to pay a higher rate of fee to support an appropriate level of management time for managing early stage technology investment."[301]

226. There is a further problem in the structure of most venture capital companies. They depend on raising money from independent, usually institutional sources, in a series of limited life funds. Such funds need to show early success in order to attract investors into subsequent funds. A witness suggested that 10 year limited partnerships could only invest in early stage

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[291]Ev. p. 95.
[292]Mem. p. 28.
[293]Ev. p. 96.
[294]Ev. Q. 68, see also Mem. p. 51.
[295]Management buy-outs/management buy-ins.
[296]Mem. p. 35.
[297]Q.466.
[298]Document from St John's Innovation Centre: deposited in the RO.
[299]Q. 468, see also Ev.p.101, Q60,Q466. Mem. pp 21, 35.
[300]Mem. p. 21, see also p. 35.
[301]Mem. p. 38.

long-term technology investments in the first two or three years of their life and "There is no fund structure which is really suitable for early stage technology based investment."[302]

227. Limited life companies need some way to realise their gains through the sale of their stakes in the company, either on the open market, or through a trade sale.[303] Our witnesses were agreed that there was great difficulty in finding such an exit especially since "despite the relative attractiveness of trade sales venture capitalists also prefer to have flotation as a viable option."[304] Even 3i, which is not a limited life fund, stressed the need for investors to realise their gains.[305]

228. Many of our witnesses felt that the market for shares in new, high risk, companies in the United Kingdom compared unfavourably with that provided by NASDAQ in America, especially since the abolition of the Unlisted Securities Market (USM).[306]

229. The Stock Exchange explained that the USM had been abolished because there was now no great difference between its listing rules and those of the main Exchange.[307] Listing rules for research based companies had also been relaxed, so that they could come to market before showing a profit, and recent measures have been taken to allow trade in shares where only one market maker is involved.[308] These changes are welcome but, as we shall discuss, more might be needed.

*Disadvantages for Industry*

230. We have been concerned to describe the workings of the venture capital market from the point of view of the financial markets. We should also remark that venture capital was the way of raising money our industry respondents judged to be least satisfactory. It has frequently been suggested that owners of SMEs resent losing control of their company, but other forms of finance, also involving dilution of control, such as flotation on the stock market, or private placement of shares were judged to be more satisfactory.[309] Clearly, the number of companies whose experience equipped them to comment on this was limited, but perhaps we should not assume that venture capital, even were it readily available, is self-evidently the "right" way to finance new companies. As the Bank of England pointed out:

> "the five to seven year time-horizon sought by many venture capitalists can be unattractive to some entrepreneurs, because of the need to establish a track record (of profits or, at least, in sales) for a prior period so as to maximise value at sale or flotation."[310]

Certainly, when St John's Innovation Centre in Cambridge surveyed technology based businesses only one of the 25 respondents had obtained finance from a venture capital source.[311] The fact that medium sized companies in the UK are more likely to seek listing than German ones may be the result of the lack of alternative sources of finance and pressure from venture capitalists rather than a free choice. Listing is only to be recommended if it is the result of free choice; the UK financial system may drive companies to market before it is appropriate.

[302] Mem. p. 39, see also Mem. p. 35.

[303] See Mem. p. 86,

[304] Mem. p. 36, see also Ev. p. 93, Q. 491, Mem, p. 21.

[305] Ev. p. 93.

[306] Q. 141, Mem. p. 39.

[307] Mem. p. 40.

[308] Mem. pp. 40-41.

[309] Appendix 2, Q 64.

[310] Mem. p. 36.

[311] *Results of Questionnaire: Finance for Growing Business*; St John's Innovation Centre, not printed.

*Business Angels*

231. The St John's Innovation Centre Survey also revealed that three-quarters of the businesses surveyed relied on informal sources of finance, such as family or friends. There have been suggestions that "Business Angels", individuals providing such finance, could provide more finance,[312] and two studies have suggested that funds available from Business Angels might be between £2-4 billion.[313] This figure is, of course, relatively low when set against the bank finance available,[314] and there is no guarantee that it is not over optimistic.[315] There is a further problem, in that companies may well have difficulty in finding such Business Angels. There are a number of initiatives to help overcome this problem including private schemes such as Venture Capital Report, which circulates details of companies to its subscribers, or the newly formed Enterprise Support Group.[316] The Department of Employment has also funded five Training and Enterprise Councils (TECs) to stimulate local business schemes. However, this means there are still a plethora of sources of funding and unless one of these schemes develops to become the recognised route by which companies contact prospective Business Angels, companies seeking finance will have to invest a great deal of time in pursuing each option.[317]

*Development Finance*

232. Many witnesses drew our attention to the high cost of product development, and suggested that UK companies were likely to fail to commit the resources needed for such development; some felt that this was a result of widespread under capitalisation.[318] Although, as we have seen, some witnesses claimed that most venture capital organisations were in reality providers of development capital, there was widespread agreement that growing companies faced difficulties in raising the further finance they needed thus inhibiting organic growth.[319]

233. Sir Robin Nicholson of the Advisory Council on Science and Technology (ACOST) told us:

> "Often you have the venture capitalist going in first and getting shares, effectively very cheaply, and the venture capitalist puts in relatively small sums of money. At that point, the product or products take off and there is a need to finance substantial growth in sales and a lot of working capital is required. There is a need to develop the second and third generation products before the cash is really coming in on the first and that seems to me to be the area where there is the greatest gap ... it is an area about which banks feel a bit uncomfortable because there is very little certainty there and venture capitalists feel uncomfortable because the rewards are much less than those to which they are used."[320]

3i operates as one possible source of such finance but although it is the largest institution in the market its funds are limited; *as Sir Robin said "it could be argued that we need another half dozen 3i's."*[321]

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[312] Mem. pp. 29, 36.

[313] T&ISC Ev. p. 346.

[314] See para 223 above.

[315] Indeed, the Government's estimate of the costs of the EIS as £50m may suggest that the figure is over optimistic. Standing Committee Proceedings, Standing Committee A, Fourteenth Sitting, 22.3.94, Col 777.

[316] *Sunday Times* 20.3.94.

[317] See: *The Venture Capital Report Guide to Venture Capital in the UK and Europe: How and Where to Raise Risk Capital,* Lucius Cary, 6th Edition, London 1993, pp.645-657.

[318] Mem. p. 24.

[319] See Mem. pp. 20, 24, 38, 51, 64.

[320] Ev. Q. 154. See also Mem. p. 35.

[321] Q. 158.

*Bank Finance*

234. The Bank of England told us:

> "While larger companies have access to the capital markets, banks are by far the most important source of external finance for the vast majority of smaller and medium-sized companies (SMEs). Furthermore, while larger companies borrow from the banking sector for a spread of purposes, banks have tended to limit themselves to funding smaller companies' working capital requirements. The general perception appears to be that it is very difficult to obtain financial backing for innovation projects from banks, either in the form of start-up or development capital (particularly where borrowing needs to be secured)."[322]

and

> "there is ... no inherent reason why banks should fund innovation projects as opposed to any other form of lending. ... However, the extent to which UK banks adopt a "liquidation" security-based approach to lending rather than a 'going-concern' approach may disadvantage borrowing requests for innovation programmes, particularly by SMEs."[323]

235. The division between banks and venture capitalists has meant they have been seen as needing different types of expertise. 3i has an industry department composed of industrial advisers, many of whom are qualified engineers and former managing directors or general managers of companies prior to joining 3i and suggests appropriate non-executive directors for the companies it supports.[324] The Apax Partners made a point of doing "deals according to our business expertise".[325] In contrast, Lloyds Bank told us that in order to assess risk "you need to be a trained banker, rather than a trained industrialist";[326] the vast majority of its graduate entrants have been in arts disciplines.[327] Yet some would say it is precisely this attitude that has led to banks "feeling uncomfortable" about development finance since they lack the expertise to assess the risks involved.

236. Some banks are increasing their efforts to understand the market and technical potential of the companies to which they lend. Barclays and National Westminster, the two major lenders in this area, have each taken steps to train specialists who can evaluate high-tech proposals, and provide support for innovative industries. Both banks allow access to venture finance.[328] Nonetheless, as Barclays' booklet "Starting a High Technology Company: Strategies for Success" makes clear, "Banks normally only lend money on a secured basis."[329]

237. As the Bank of England said, "finance specifically for investments geared to technological innovations is still not a typical part of Bank lending."[330] **We are particularly concerned that small companies appear over-reliant on volatile overdraft facilities, even for "quite long-term investments".**[331] This widespread use of overdraft finance may arise out of the preferences of SMEs, as the Bank implies, but witnesses from industry suggested that the use of overdraft facilities arose from the "relative lack of

[322]Mem. p. 33.
[323]Ibid.
[324]Q. 425.
[325]Q. 96. See also Mem. p. 51.
[326]Q. 404.
[327]Ev. p. 115.
[328]Mem. pp. 28, 31.
[329]P. 34.
[330]Mem. p. 33.
[331]Mem. p. 34.

availability of long term debt from UK banks".[332] National Westminster's commendable success in giving 49 per cent of finance to small and medium business on a medium term basis shows that reliance on overdraft finance is not inevitable.[333]

**Possible Remedies**

238. As we have seen, as far as growing companies are concerned there are problems with the availability of venture capital, particularly for new high technology companies, and with the terms on which most such capital is available. Yet Schroder Ventures told us that the banks:

> "have responsibilities to their shareholders and a requirement to perform and thus cannot be relied upon to take on low margin labour intensive work which offers a high risk of failure. The economies of small deal investments do not add up for them."[334]

What could be done to improve the situation?

*Banks*

239. The caution of the clearing banks is understandable. Nonetheless, their foreign counterparts manage to sustain a closer relationship to industry and remain profitable. Even though there was general agreement that German banks tended not to invest in early stage high risk equity[335], a witness from the venture capital industry identified the banks as a barrier to the expansion of venture capital in Germany.

> "Banks are prepared to give very long-term loans with low interest rates and stay with customers for a very long time. The spin off from that has been that the potential company owners in Germany are not aware of alternative means of financing. If they can convince the bank that they should have a long-term loan at low interest rates that is the route they will pursue."[336]

The tendency of medium-sized German companies to use long-term loans rather than overdraft finance has been attested by many academic studies and was referred to by many witnesses.[337] The German banks may be able to offer such loans because they have the expertise to assess a business's prospects.[338]

240. Certainly, we received evidence that overseas banks may be more likely to concentrate on a business's potential than banks in the UK. Yamazaki Mazak Machinery UK Ltd told us:

> "though the majority of our debt is carried by UK banks, they very rarely visit us — we are just an address and a collection of numbers to them. The Japanese banks visit us on a regular basis just to keep themselves informed on the general state of business — this is of great assistance to them in the assessment of risk."[339]

241. There are signs that this may be changing. Any change will be slow to come about, but **we hope banks will increasingly develop the expertise to lend against a company's expertise and likely prospects of success rather than security, and that they will be increasingly prepared to lend on a long-term basis. We agree with IBM that:**

[332] Letter from Dr C Gaskell, CBE, Managing Director of The 600 Group, plc, (not printed: deposited in the RO.)

[333] Mem. p. 27, see also p. 35.

[334] Mem. p. 22.

[335] Q. 58, Mem. p. 37.

[336] Ev. Q. 58.

[337] See Mem. p. 37.

[338] Ibid.

[339] Letter from Yamazaki Mazak Machinery UK Ltd, dated 25 November 1993. (Not printed: deposited in the RO). See also Mem. p.37,38,53,130.

**"Conditions attached to monies raised should reflect the objectives of the company and its long term prospects, rather than simply cover the risk against tangible assets."[340]**

*Development Finance*

242. The difficulties of financing SMEs are not confined to the UK. Some countries approach this problem through development banks, such as the German Kreditanstalt fur Wilderaufban (KfW) and the Japan Development Bank (JDB).[341] Both offer funding to companies which would find it difficult to raise finance through the private sector; including long-term, low interest finance to companies seeking funding for research projects. Both have some form of specialised evaluation of the projects they support. The JDB provided 6 per cent of its loans to "promote industrial technology"[342] (in 1992 this amounted to ¥149.8bn (£0.9bn)) at interest rates slightly below those charged by the commercial banks. In addition, funds are provided interest free to support a programme to "promote the foundation of research".

243. There are European Union attempts to increase the funding of SMEs. For example, the European Investment Bank is to collaborate with the banks and the European Commission to establish a European Investment Fund (EIF) which will provide loan guarantees for small and medium enterprises and European network programmes.[343] Its aim is to "try to address the thin and often highly volatile flow of long term debt and equity funds to Europe's small companies." Witnesses from Lloyds Bank suggested that the EIF's activities were likely to be concentrated "not only on the continent but towards the southern end of the continent."[344] There are a variety of other European initiatives of this sort.[345]

244. However welcome these European initiatives might be, we believe the United Kingdom could and should do more to help its own small and developing firms. The EIF will "complement existing loan guarantee" schemes of member states.

245. Our witnesses repeatedly drew our attention to the lack of government support for UK industry. As Barclays said:

> "At a specifically technology policy level, UK Government support in the form of grants, soft loans and other direct financial schemes to support technology is substantially lower than our European neighbours, eg Holland and Germany."[346]

246. The main UK aid is the DTI's Small Firms Loan Guarantee Scheme (SFLGS), which assists firms by acting as a guarantor for 70 per cent of a loan. If a business is less than two years old, SFLGS levies a 1.5 per cent (previously 2.5 per cent) premium on the interest charged by the lender[347] and is only useful when the applicant does not have sufficient security for the lender to be prepared to provide the loan on normal terms. Moreover,

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340 Letter from IBM dated 24 November 1993, p.2. (Not printed: deposited in the RO).

341 In 1993 the estimated total for new loans by the JDB was ¥2,400bn (£15.5bn); the total for KfW in 1991 was DM43.2bn (£16.6bn).

342 JDB hand-out during visit (not printed: deposited in RO.)

343 Financial Times 23.6.93.

344 Q. 444.

345 Including: *Eurotech Capital*, which consists of a network of financial institutions which have agreed to invest in SMEs involved in transitional high-technology projects. Total EC expenditure since the programme began in 1991 is in the region of £6.3 million. *European Seed Capital Funds* is an EC Pilot Scheme providing financial support, through the provision of interest free loans to 24 seed funds throughout the Community. *The Venture Consort scheme* is aimed at encouraging the growth of SMEs by establishing cross-border syndicates of venture capitalists. Approximately £8 million has been spent by the Commission on the scheme which ran from 1985-1993.

346 Mem. p. 31.

347 For companies more than two years old the premium is 0.5 per cent and 85 per cent of the loan can be guaranteed. Ev. Q 382, DTI Press Notice 16 August 93, P/93/478/4 Nov. 93 P/98/648.

evaluation of the proposal is conducted by the lender,[348] rather than by those with more specialised skills. £70.2m worth of loans were 'guaranteed' in 1991-92.[349]

247. **The market currently fails to support small and growing companies adequately, especially those in high technology areas.** As we have seen, venture capital is in short supply and even if it were more readily available, has some disadvantages. Some action is needed to correct this shortage of funding. The most radical solution would be the introduction of a Development Bank for the UK; we note, for example, that the clearing Banks and the Bank of England co-operated to establish 3i to deal with the problems of companies which lacked ready access to capital markets. There are other possible solutions, for example, the SFLGS could be reformed. Guarantees could be provided only through lenders who had the industrial and technical skills to evaluate proposals thoroughly, and the interest rate premium abolished. This would not only provide cheaper loans to companies participating in the scheme, but would encourage banks to ensure they fostered the expertise necessary to evaluate companies' prospects on a long-term basis. It would also ensure that Government was not involved in "picking winners". The SFLGS applies to any company: if the Government desired lower rates could be charged for high technology companies.

248. There are many ways of approaching such problems; we have simply sketched two which may merit further consideration. **We strongly recommend the current Treasury review should examine all the problems caused by the lack of development finance in detail and that the Government should produce concrete proposals for their solution.**

*Patient Capital*

249. The evidence presented to us has convinced us there is a real need to find sources of "patient capital", ie long-term funding, for new and growing businesses.[350] It is sometimes argued that the viable business can always find the funds it requires. The structure of the UK business sector, with its relative shortage of SMEs, demonstrates that this is not the case. Nor can institutional sources be expected to provide all the capital needed. As Mr Jackson said:

> "None of this can happen without people taking risks. The price, particularly the political price, lies in that notion of risk."[351]

ENTERPRISE INVESTMENT SCHEME

250. Many of our witnesses spoke of the potential for more finance from individual investors or business angels. The ability of innovative companies to attract 'patient money' through a loyal group of private shareholders was attested by the forty three shareholders of one company who wrote pleading for the reprieve of the recently abolished Business Expansion Scheme (BES).[352] The BES has been replaced by the Enterprise Investment Scheme (EIS) which, unlike the BES, does not extent to private rented property. Its encouragement of business angels will be similar to the BES and will extend to companies trading but not resident in the UK and to non-UK residents liable to UK income tax. In some respects this may be an improvement over the BES, since it allows investors to participate in the management of the company. **We welcome the Enterprise Investment Scheme; we trust that if it is abused, the Government will reform it rather than abolish it.**

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[348]Booklet published by the DTI, *Loan Guarantee Scheme*, p. 3.

[349]DTI Annual Report, *The Government's Expenditure Plans 1993-94 to 1995-96*, Cm 2204.

[350]Mem. p. 256.

[351]Mem. p. 267.

[352]Memoranda from shareholders of Walker Wingsail Systems plc. Not Printed: deposited in the RO.

### THE ROLE OF THE STOCK MARKET

251. Several witnesses remarked on the need for a healthy retail market for shares in small companies.[353] The current lower limit for market capitalisation on the Exchange is £700,000.[354] The Smaller Companies Working Party is considering proposals for "a distinct market catering exclusively for growth companies, possibly with lower admission thresholds leading to a corresponding reduction in entry and ongoing costs."[355]

252. The rules of the Stock Exchange, which, broadly speaking, require companies to have a three year trading record and stable management, and the Exchange's regulatory role, are designed

> "to facilitate capital raising by companies, while ensuring that investors have adequate information to make their investment decisions with confidence."[356]

253. We appreciate that the stock market has a role in protecting the investor.[357] Nonetheless, the current system, in which a shortage of venture and development capital is combined with relatively stringent listing requirements is a testimony to the risk aversion we have already noted. Investors in private placements of shares are expected to take responsibility for assessing the risks of their investment; we see no reason why a smaller companies market should apply rules as stringent as on the main exchange. However, we note the Exchange's suggestion that "if such a market became the inheritor of the tax breaks previously available to the BES, then it would be a highly attractive vehicle for new companies."[358] **We note that, whatever the availability of "business angels", they may have difficulty in identifying suitable investments. A smaller companies market, sharing some of the tax advantages of the EIS, could attract more such investors into the market.**

### CORPORATE VENTURING

254. There is no reason why financial institutions alone should support new businesses. One of our witnesses contrasted the situation in the UK with that in Japan where business groups were active in:

> "spinning off small companies and backing them by very large companies, providing them with distribution networks, providing them with management expertise, providing them with long-term funding and so on and so forth. I think actually in the Japanese economy you have actually seen a lot of corporate venturing or that sort of activity."[359]

255. Corporate venturing, by contrast, appears singularly ill developed in the UK. An ACOST Report recommended:

> "that DTI investigates ways in which corporate venturing activity may be stimulated in the UK, both directly and through linkages with the institutional venture capital industry."[360]

but Dr Richard Summers of 3i was sceptical of a scheme of this kind:

> "All of the efforts we have made to generate spin-offs in the UK have not produced the volume of interest that we had hoped but I can give you no explanation why."[361]

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[353] Mem. p. 267.
[354] Mem. p. 40.
[355] Ibid.
[356] Mem. p. 39.
[357] Ibid.
[358] Mem. p. 40.
[359] Ev. Q. 450.
[360] ACOST Report, *The Enterprise Challenge: Overcoming Barriers to Growth in Small Firms, 1990*, p. 38.
[361] Ev. Q. 448, see also, Mem. p. 22.

The company investors he was able to cite were Japanese.[362] Similarly, on a visit to St John's Innovation Centre, many of the small companies we met had alliances with overseas companies.

256. Here we need to understand why British industry does not help itself. Many witnesses commented on the reluctance of United Kingdom companies to collaborate with one another. In our view this is a serious weakness, and on the face of it one which industry alone can overcome. However, it is likely that the apparent reluctance of larger UK companies to foster such collaboration and lack of corporate venturing activity reflects their own difficulty arising from risk aversion, relatively low profit, high distribution of profits and low levels of investment, particularly in the development of new products, which we noted earlier. **This needs to be studied further and we suggest that the DTI should examine it.**

257. While the main thrust of our observations above focuses on difficulties faced by the smaller, fast-growing high technology companies, essentially the same overall problem is faced by the larger companies sustaining a high investment in RTDD. These companies are important to the health of their industrial sectors and as a whole. Forty such companies carry out about 84 per cent[363] UK industrial R&D and they too must be allowed to operate in an environment which does not disadvantage them relative to their international competitors.

258. We conclude that beneficial changes can be introduced to achieve this objective; for instance, tax incentive schemes to encourage increased levels of RTDD and capital investment, together with positive encouragement to investors — in particular the Pension Funds — to take a long-term view.

259. We recognise that the City of London's long-established role as an international financial centre generates important earnings, and we would not wish to jeopardise it. However, the City is also a major source of funds for domestic industry, and **we have already noted that the difficulties in valuing R&D and in financing innovative companies lead us to believe that if UK industry is to flourish the attitudes and structures of the financial institutions in the United Kingdom may need some adaptation.**[364] This change will be evolutionary but it is important it develops as quickly as practicable; we cannot at this stage determine whether it will be toward the risk acceptance of the US model or the stability of the German or Japanese one. We have suggested changes that draw upon the best aspects of both. We have also noted that certain interventions by Government are necessary. We trust that, if implemented collectively, these changes will encourage the development of a new financial culture which positively seeks a partnership with manufacturing industry to encourage long-term organic growth and thereby enhance overall UK economic performance.

## III PEOPLE

260. There is a vicious circle in the UK education system as low skills bring low performance and rewards, and industry and Government should join to break that circle. Even when skills are valued, there seems to be a reluctance to acquire those skills which might be of most use to industry. We were disturbed to learn from Warwick University that "there have been cases in the past where there has been reluctance to take the course [in management of innovation], and this often has been due to either a fear of 'technology' or a belief that technological innovation is about getting dirty hands rather than performing the 'clean roles' worthy of senior managers."[365] The Science and Engineering Research Council (SERC) told us that "the British research culture has traditionally placed greater emphasis on the acquisition of knowledge than its application — that is science rather than

[362] Ev. QQ 447—450. See also Mem. p. 5.

[363] The 1993 UK R&D Scoreboard, June 1993; see also Mem. p. 26.

[364] See Mem. pp. 6-7.

[365] Mem. p. 19.

engineering.[366] As we have seen, until recently there has been bias against industrial collaboration in academia. **We agree with the many witnesses who emphasised the importance of manufacturing for the economy, and who felt that our culture fails to value it sufficiently.** As TWI told us, many wider problems would be solved if manufacturing was "regarded by all as an *absolute* requirement for long term prosperity".[367]

261. The reasons for the low status of industry are many, and cannot be addressed by industry alone. Yet, as the Royal Academy of Engineering said, "industry gets what it seeks and rewards".[368] The Engineering Council agreed that while starting salaries for engineers were competitive, the prospects for salary growth were limited in comparison with those in other countries, and later agreed that, unlike some other professions, such as accountancy and law, engineering and science did not offer the opportunity for people to do very well in a short time.[369]

262. The DTI has produced evidence for the Trade and Industry Committee showing that the differentials between skilled, semi-skilled and unskilled workers are far lower in the UK than elsewhere.[370] German engineers are far more likely to progress to a seat on the Board than their English counterparts.[371] Moreover, whereas in Germany higher degrees lead to higher remuneration, few of those undertaking post-graduate research in the UK do more than catch up with those of their colleagues who joined companies straight from their first degree.[372]

263. **If industry were seen to reward high skills with high pay, and with enhanced career opportunities, then not only would more qualified people be attracted into industry, but, in the long term, more people would appreciate the value of qualifications.**

### Management Skills and Priorities

264. There was a widespread perception among our witnesses that British managers, by comparison with those elsewhere, were under-qualified, particularly in scientific and engineering disciplines.[373] There was agreement that innovation would only be possible if management was prepared for it,[374] and that British managers were likely to take a short term view.[375] This may manifest itself in the way in which management incentives are tied to the company's short-term performance, executive mobility and the reward systems within companies.

265. Good management is vital for all businesses, and is as important for technology based companies as any other. Indeed, Dr Richard Summers of 3i told us it was rare for a company backed by Investors in Industry to fail because the quality of its technology: the usual cause was the quality of its management.[376] Evidence from the CBI was that the UK ranked 16 out of 22 countries on "the extent to which enterprises are managed in an innovative, profitable and responsible manner."[377]

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[366] Mem. p.85.

[367] Mem. p.53.

[368] Mem. p.245.

[369] T&ISC Ev. HC (1993-94) 41-v, QQ. 1632, 1652.

[370] T&ISC Ev. HC (1992-93) 702-vi, p. 223.

[371] NIESR, Report No. 6.

[372] Ibid; see also Mem. p. 130.

[373] See, for example, Ev pp 92-93, Mem. pp. 8, 11, 13, 23, 30, 51, 53, 79, 120, 130, 202, 242.

[374] Mem. pp. 63, 234.

[375] Q 454, Mem. p. 38.

[376] Q. 460, see also mem. pp. 26, 38.

[377] Mem. p. 65.

266. Some of the management failings of UK industry appear to interact with the short-comings of the financial system noted earlier. The aspect which is most closely linked to the financial system is the use of financial information in measuring performance and in deciding on investment.[378] We have already noted the high returns on investment expected by UK companies. In addition performance tends to be measured on profitability which, as the RSA has noted, "is a lagging rather than a leading indicator".[379]

267. The temptation to appoint managers with financial expertise and to concentrate on the short-term financial position is understandable, given the financial pressures on UK industry which we have already noted. However, such concentration on financial skills may exacerbate UK industry's tendency to evaluate projects in financial rather than strategic terms, in ways which are not to the company's long-term benefit. This will particularly affect innovation, where there is always likely to be some risk. It has been suggested that successful German and Japanese companies, which are more likely to be led by those with technical qualifications, consider new projects in terms of market share, or the way in which a product fits into their range rather than rates of return.[380]

268. A study for the Economic and Social Research Council (ESRC) suggested that, even in UK conditions, it may benefit companies to consider such strategic reasons for investment rather than relying on financial measures alone.[381] The authors identify an essential tension between the "engineering-driven desire for new technology and the accountants' need to quantify the benefits of the new technology".[382] A manager with a science and engineering background appeared to "place greater emphasis on growth than on profits *vis a vis* other types of managers."[383] In the long term, this emphasis benefits the firm. These results are not conclusive and factors such as the ownership of a company, and whether it is independent or part of a group, also affect outcomes, but they are persuasive.[384]

269. *The presence of scientists or engineers on a board is not a sufficient condition for success. But the inclusion of those able to appreciate the possibilities offered by science and technology may enable a board to respond to the market more effectively than it could otherwise have done.* The Managing Director of Vinten told us: "I am frequently surprised to find how few companies who claim to be 'engineering' have qualified engineers on the Board."[385] Companies must ensure that those with scientific or technological expertise are not confined to technical roles. We are convinced that "modern business requires managers who understand technology, and scientists and engineers who understand business issues".[386]

270. In Germany and Japan highly trained technologists are likely to be deployed in many parts of a company. Dr Maund, of Yamazaki Mazak UK, a UK subsidiary of a Japanese company, told us that in Japan:

> "When they [graduates] have become useful members of society they are very frequently horizontally moved, which is I think another excellent thing. You very rarely get the degree of specialisation that you get in an English company. Here you come in and enter as an engineer and you will stay an engineer until you draw your retirement pension if you are not careful. In Japan it would never happen. You might not finish up running the finance department but certainly anything short of that could be in marketing, in

[378] See Mem. p. 27.

[379] *Tomorrow's Company: the Role of Business in a Changing World: Interim Report RSA: The case for the Inclusive Approach, February 1994 (hereafter: RSA Interim Report).*

[380] Yamazaki follow up; *Head to Head; The Coming Economic Battle Among Japan, Europe and America,* Lester Thurow, London 1992, pp.124-133; Mem. p. 19, Q. 374.

[381] *Qualified Scientists and Engineers and Economic Performance*, Derek Bosworth and Rob Wilson, in *New Technologies and the Firm*, ed Peter Swann, London and New York 1993, p. 171, see also Mem. pp. 1, 51.

[382] Ibid p. 166.

[383] Ibid p. 171.

[384] Similar effects are noted in the RSA Interim Report, p. 9.

[385] W. Vinten: covering letter, (not printed: deposited in the RO). See also Mem. pp. 126, 157.

[386] Mem. p.11, see also pp.13,53.

manufacturing, in production engineering, as a natural course of your development through the company."[387]

271. Respondents to our questionnaire identified a lack of engineering and scientific personnel. Clearly, given that technical and engineering skills are in short supply, it is tempting to keep those who possess them in technical functions rather than move them through a variety of departments as a Japanese company might. However, if the predictions that companies will increasingly need to use a variety of external sources of knowledge are correct, then the need for such skills will increase, since without them the company will not be able to identify its requirements and find the right source of technology. We agree with the many witnesses who told us that technically-literate managers were essential if a company was to make the best use of the science and technology base available, whether that base is within the company itself or outside it. We recognise that this will pose a problem for industry.

**272. Attempts to ensure that managers have scientific understanding will exacerbate skill shortages in the short term since scientists and engineers may be moved from technical functions. However, unless such skills are fostered and encouraged, British industry will remain uncompetitive and one of the key failings of its management will remain uncorrected. Unless scientists and engineers are offered a route to the top they will remain in short supply.[388] Other careers than industry will be more attractive to graduates, and prospective undergraduates will not be motivated to study science and engineering in preference to other topics that appear to offer better chances of reward.**

## The Availability of Skilled Personnel

273. Shortages in management skills were suggested to us as only part of a general shortage of appropriately skilled personnel in the United Kingdom. Shortages were identified:

— at technician level
— at graduate level.[389]

### *Technicians' Skills*

274. As far as intermediate skills are concerned, the National Institute for Economic and Social Research (NIESR) has demonstrated the importance of a well trained workforce for productivity, and for the successful introduction of new technology.[390] It is clear, from their comparisons, that the UK is not as successful at imbuing these skills as its competitors. This evidence is reinforced by the results of our survey, which showed that, even in a recession, the availability of technical personnel had caused problems for over half the respondents.[391] Sir Anthony Gill, the Chief Executive of Lucas, told us that a higher proportion of sales income had to be spent on training than in other countries where Lucas operated,[392] and the Executive Director of R&D at Ford told us:

"We are concerned that the general secondary and tertiary education system in this country is falling behind competitor nations in terms of the level of competence in basic mathematics, natural science and applied engineering."[393]

275. The Government is attempting to address these problems through its reform of the education system and, in particular, through the introduction of the National Curriculum,

[387]Q. 708.

[388]See Mem. p. 102.

[389]See Mem. pp. 26, 42, 63, 72, 79, 113, 124, 207.

[390]Andy Green and Hilary Steedman, *Educational Attainment and the Needs of Industry: A Review of Research for Germany, France, Japan, the USA and Britain*, NIESR Report Series No. 5, 1993.

[391]Appendix 2, A. 4.10.

[392]Q. 532.

[393]Q. 547.

(which of course has wider implications than for technical training alone) and of new vocational qualifications.

## THE NATIONAL CURRICULUM

276. We note that the Final Report on the National Curriculum and its Assessment says 'Evidence from formal inspection has shown that the introduction of the National Curriculum has begun to produce improvements in the key subjects of English, mathematics and science.'[394] The National Curriculum is now being modified in the light of experience, but this core of English, mathematics and science is being protected. In addition, Sir Ron Dearing, Chairman of the School Curriculum and Asessment Authority, has recommended that technology should remain as part of the statutory curriculum after the age of 14 since "we have suffered from an inability to translate scientific discovery into wealth-generating industrial and commercial projects"[395], and that there should be a minimum of a short course in a modern foreign language. We welcome these proposals.

277. We also welcome the evidence we received indicating that the Department for Education expects 80 per cent of 14 to 16 year olds will take double science, and that the substitution of a double science course for separate GCSEs in biology, chemistry and physics is expected to reduce the imbalance between boys and girls taking physics and biology.[396] Indeed, the introduction of the GCSE has undoubtedly seen a change in the proportion of 16 year old boys and girls passing exams in science subjects. In 1987 about 26 per cent of girls and 34 per cent of boys achieved an 'O' level grade A—C or equivalent in a science subject. In 1992, the most recent year for which figures are available, 36.6 per cent of girls and 36.5 per cent of boys achieved GCSE grades A—C in at least one science subject. The same proportion of girls were successful in mathematics.[397] However, we note the possibility that girls may come to opt disproportionately for single science, the attainment targets of which cover a narrower range of science knowledge, skills and understanding than that of double science.[398] Since we took this evidence, both the Royal Society and the Association for Science Education have expressed concern that the curriculum review prescribed the single time allocation as the statutory minimum for science. The Royal Society is concerned that the statutory minimum will "too soon become seen as the normal option for a majority of pupils, particularly in those schools that do not have a tradition of offering broad and balanced science education".[399] **The case for reliance on single science is not proven. We recommend that trends in the take-up of double science, and the extent to which one sex predominates in the subject, are carefully monitored in the future. It would be a cause of great concern if double science came to be seen as a predominantly male subject.**

## VOCATIONAL TRAINING

278. General National Vocational Qualifications (GNVQs) and National Vocational Qualifications (NVQs) are intended to provide vocational training, and to ensure that this training is more closely relevant to industry than hitherto. Their reception has been mixed; industry representatives and educationalists have both praised and criticised them.

279. The criticisms of the new system may be summarised as follows:

— the course content of NVQs, in particular, is too narrow, and inadequately tested;
— successful courses, such as BTec, are being abandoned in favour of untried NVQs;
— there is confusion over the multiplicity of training providers, training and qualifications available; and

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[394] *The National Curriculum and the Assessment, Final Report*, Ron Dearing, December 1993, (pub. SCAA, 1994) p. 43, para 5.13.

[395] Ibid, p. 45, para. 5.21.

[396] QQ. 241—246, Q 247.

[397] *The Rising Tide*: A report on Women in Science, Engineering and Technology, HMSO 1994, p.10.

[398] Q. 248.

[399] Royal Society Press Release.

— responsibility for education and training is divided between too many government bodies.[400]

280. In principle, NVQs and GNVQs represent an attempt to ensure that education and training systems in the United Kingdom provide a spread of qualifications suitable for all abilities. Moreover, we are pleased that the Government, and industry, through the CBI, TECs and Local Enterprise Companies (LECs), are co-operating to improve the qualifications of the workforce through the National Education Training and Targets, especially since their policy is to reduce the gap at supervisor level by ensuring at least half the age group gain NVQ level III, junior technician level.[401] There have been suggestions that these targets need to be made more demanding and that, to achieve comparability with Japan or France, 80 per cent of the age group should reach NVQ level III by the year 2000.[402] We agree that targets should be set no lower than those in competing countries.

281. Both the National Curriculum and the NVQs/GNVQs are evolving systems; it is regrettable that there should be problems in their implementation but it is perhaps inevitable. **We note the Education Committee have been taking evidence on the evolution of the National Curriculum at regular intervals. The reorganisation of the education system for 14 to 19 year olds will, in the long-term, have profound effects on our ability to innovate successfully; we hope our colleagues will consider such matters as science and technology education and the implementation of NVQs and GNVQs in the course of their scrutiny.**

## *Graduate Skills*

### The Supply Of Scientists and Engineers

282. Many witnesses expressed concern about the graduate skills base. Certainly, if industry does evolve in a way which offers greater rewards for scientists and engineers, there may well be a shortage of such skills. As the Committee on Women in Science, Engineering and Technology said:

> "The number of applicants of both sexes for science and engineering courses in Higher Education has been lower for a number of years than the number applying for arts, humanities, social sciences and business studies. Policies to encourage more girls to study science subjects address part of the more general problem of attracting more able young people of both sexes into careers in science and engineering."

We agree with the Committee that:

> "there are many obstacles which deter talented women from studying SET [Science, Engineering and Technology] or make it difficult for them to achieve their full career potential. However, there is a rising tide of awareness that the loss of ability and skills caused by gender bias is neither acceptable nor in the national interest ... there is a sound economic case for attracting and retaining more women in SET. Not least is the need to harness the ability and skills necessary to improve the UK industrial position in increasingly competitive world markets."

The Committee further recognised that recruiting and retaining women scientists and engineers at all levels of employment would:

[400] See *All our Futures*, a Channel 4 commissioned report; NIESR discussion paper No. 33, *Britain's Industrial Skills and The School-teaching of Practical Subjects* (March 1993).

[401] Q. 341.

[402] *Financial Times*, 26 February 1994.

"increase the pool of labour from which high calibre scientists, engineers and technologists, and the future leaders in SET, can be drawn, and create a workforce with a greater diversity of skills."[403]

283. The range of specific skills mentioned was wide and varied from sector to sector, but problems in recruiting engineers were mentioned by at least one respondent in each of our six sectors, and were mentioned frequently in responses from the "engineering sectors": aerospace, automotive and machine tools.[404] The UK output of engineers appears low in comparison with Germany and Japan; many undergraduates opt for "purer" scientific disciplines. Moreover, the UK system depends on further training after graduation. As Professor Foster of the Engineering Council told the Trade and Industry Committee:

"... in this country, ... the courses are shorter but we do emphasise the need for training following the course and the relevant practical experience."[405]

284. It is clear that, if industry is to deploy more scientists and engineers in management roles, and if the universities do respond to industrial demands, there will be a need for more engineers with a wider training. The need for engineering skills is not confined to "engineering based" industry. There are welcome moves to increase the profile of engineering, and attempts to ensure the profession presents itself in a coherent way.[406]

COURSE CONTENT

285. Two general complaints were of a lack of design skills, especially in engineers, and a lack of management and communications skills.[407] Sir Robin Nicholson of ACOST told us:

"I think many people in industry — certainly myself included — feel that our courses are too narrow for a large part of the graduate supply into industry and we would feel that some training in the application of science, in its exploitation and in innovative management techniques would suit a typical graduate for a career in industry better than the present very narrow course."[408]

There is a certain difficulty in meeting these points. If the existing three year degree is broadened to include management topics, then its technical content may be reduced.

286. This circle could be squared if, as Sir Robin suggested, there were far more diversity in the types of degree on offer.

"I think our views would be that the system needs to provide a greater range of product, if I might put it that way, and that presently it is rather narrowly focused to a certain type of graduate where the evidence is that the supply exceeds demand. I believe industry would be happy to see an arrangement in which some people did a broader and, inevitably, slightly shallower course over three years and brought in some of the subjects I mentioned and other people did the same depth of course in science and engineering and did a fourth year, in a total technology course or something like that. Still others could do a two year course which would be, as I said earlier in answer to another question, more comparable to a City & Guilds type qualification."[409]

[403] *The Rising Tide*: A report on Women in Science, Engineering and Technology, HMSO 1994, p.1-2.

[404] See also T&ISC Ev. HC (1993-94) 41-v, Q. 1623 and Mem. pp. 79, 115.

[405] T&ISC Ev. HC (1993-94) 41-v, Q. 1626.

[406] See *Engineering into the Millenium*, April 1993, published by the Engineering Council on behalf of the Council of Presidents.

[407] Mem. pp. 54, 95.

[408] Q. 202.

[409] Q. 203.

287. Such diversity was also welcomed by Mr Waldegrave.[410] Professor Graeme Davies, Chief Executive of the Higher Education Funding Council for England (HEFCE) told us that the HEFCE was already encouraging universities to offer a wider variety of courses.[411] It is clear that Professor Davies has consulted industry widely on the type of courses which should be offered. Universities themselves are responsible for the degrees they offer, and some universities told us they actively consulted local industry about the courses they prepared.[412] If graduates from such courses are more likely to obtain employment than those from others the courses will flourish. If industry is conservative in its recruitment policy, it must shoulder some of the blame for the narrowness of skills on offer.[413]

288. Moreover, as Professor Foster told the Trade and Industry Committee, some of the reason for a lack of industrial experience in engineers, at any rate, has been a decline in the number of placements industry is prepared to make available to students on sandwich courses.[414] This kind of problem is beyond the power of the universities to solve. Nonetheless, we accept there may be problems in ensuring that graduates and post-graduates have the combination of technical and business skills they need.[415] Some universities are addressing this; Imperial College, Manchester Business School and Warwick University sent us details of their courses on the management of technology, and there appear to be attempts to link science and engineering departments with colleagues in management schools.[416] Similarly, there are attempts to introduce MBAs and MScs in areas which can loosely be defined as "management of innovation".[417] There are also welcome attempts to increase the availability of courses for those with some management experience who are likely to benefit greatly from such opportunities.[418] **These initiatives to combine technical and business skills within courses are welcome. If science and engineering degrees become recognised as likely routes to management positions their popularity should increase. However, their success can only be judged by their capacity to attract students and those students' ability to find employment.**

### THE NEW ARRANGEMENTS FOR POST-GRADUATE TRAINING

289. The White Paper "Realising our Potential" proposed that students who wished to take a PhD should generally undertake an MSc first. This would not only give a chance to assess their aptitude for research, it should also give a wider range of skills, such as communications skills, which would be useful in any career.

290. The response to the proposal from our industrial witnesses was mixed. As the Chancellor of the Duchy told us:

> "the response from industry has varied quite dramatically from chemicals and pharmaceuticals... who ... like the present structure, to the engineering industries who have supported us very strongly."[419]

Some witnesses, especially in the sectors most directly related to the Science Base, were particularly concerned about the reduction in the number of PhDs the proposal might entail.[420] We share that concern.

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[410] Q. 1021.

[411] Q. 1077.

[412] Mem. pp. 142, 170.

[413] See Mem. p. 19.

[414] T&ISC Ev. HC (1993-94) 41-v, Q. 1629.

[415] Mem. p. 216.

[416] Mem. pp. 14-16, 18.

[417] Mem. pp. 11, 12, 14, 19.

[418] Mem. pp. 13, 14, 17, 188.

[419] Q. 1021.

[420] QQ. 645-649. See also Mem. p. 75 and *Government White paper on Science, Engineering and Technology, Commentary by the Chemical Industries Association*, p. 5, deposited in RO.

291. The House of Lords Select Committee addressed this issue in its Report on "Priorities for the Science Base". Their Lordships were concerned that the result would be "a weaker Science Base", and rejected the idea that industrial or commercial factors should be added to research training since "**what industry wants from the Science Base is world-class researchers with firm understanding of the fundamentals of their science.**"[421]

292. Since the Lords' Committee reported, the OST has issued a consultation paper, setting out the proposals in more detail. We believe this may go some way to meeting the Committee's concerns. The paper allows flexibility in allowing some students to register directly for a PhD, and suggests that at least 60 per cent of the time spent on a Research MSc should be devoted to a research project.[422]

293. The increasing need for networking and systems integration suggests that those of our respondents who sought post-graduates with superior communications skills are on the right track. Whether the White Paper proposals will provide these is a different question. The 'Parnaby' doctorate in engineering recently introduced by the SERC is another approach to meeting the need for good communicators and achievers, with understanding of operational process. **The Government also has a series of schemes such as the Teaching Company Scheme which are designed to give post-graduates experience of industrial perspectives. These appear highly regarded and were widely used by our respondents. They should continue.**[423]

294. The new arrangements will be phased in over a number of years, "so that higher education institutions have time to adjust and develop courses" and to "allow institutions to learn from each other's experience".[424] Industry will also need to learn how best to use the new skills available.

295. It may be some time before industry realises the value of a broader training for post-graduates and becomes willing to reward people who have spent at best seven years in higher education, on low stipend. Until then, it would be wise to introduce new arrangements in a flexible way.

296. **Once the new arrangements for research training have begun, their effectiveness should be carefully monitored, with particular regard to the differing requirements for the training and supply of post-graduates across disciplines and across the sectors which draw upon those disciplines. Neither the Science Base nor industry is uniform, and that diversity should be respected.**

*International Comparisons*

297. It is relatively easy to compare the attainments of school-leavers in different countries. The structure of graduate education, and the stage at which industry recruits graduates varies widely from country to country. The UK system relies on a relatively short first degree, with a high proportion of students leaving on graduation. Those who remain in academe take higher degrees which are short by international standards, the cost of which is usually met by the state. The Japanese degree structure is similar, except that students are likely to be self-financing, and:

> "There are some prestigious universities which will generate more scientifically orientated graduates but then there is a whole raft of other bodies which are, as far as we can see, emphasising the vocational aspects in the courses they give."[425]

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[421] HL (Session 1993-94) 12—I, paras 282—3.

[422] *Realising our Potential: A Strategy for Science, Engineering & Technology, A New Structure for Postgraduate Research Training Supported by the Research Councils*, Consultation Paper, Office of Science and Technology.

[423] Mem. pp. 17, 63, 94, 100, 110, 147, 169, 180, 212, 216.

[424] op.cit. paras 34 and 35.

[425] Ev. T&ISC HC (1993-94) 41-v, Q. 1627.

298. In contrast, the German system produces two clearly differentiated types of first degree. The National Institute of Economic and Social Research (NIESR) states that training is divided between:

"*Fachhochschulen* (FH) whose four-year diploma courses are highly practically-orientated,

*Technische Universitaten* (TU) and *Technische Hochschulen* (TH) whose diploma courses require in excess of six years to complete (including a six-month period of industrial experience). The academic standards required for entry to University diploma courses are higher than for FH courses and their content is more theoretically advanced and more orientated towards training in research techniques."[426]

299. While PhDs in Germany and the UK are broadly comparable, the students at both Max Planck and Fraunhofer Institutes finance themselves, often through carrying out contract research for industry.

"Upon completion of their PhDs, former student assistants from both type of institute are highly regarded for their experience of industrial project work and for having worked in an inter-disciplinary environment. They are also well-placed to maintain or initiate contacts between their employers and technical specialists based in universities and independent institutes — and thus continue to have advance information about new research results which may take two years or more to be formally published."[427]

300. Dr Maund of Yamazak Machinery UK Ltd told us:

"There is an interesting comparison that we frequently make with our Japanese colleagues as to the level of skill with which the engineer from college comes into us as a graduate from college. In Japan he goes into our parent company. Our general Japanese opinion is that they are better educated here than what they would probably receive in Japan. It is not my opinion, it is theirs."[428]

301. The German system produces people with qualifications that are both broad and technically advanced. It is correspondingly expensive, and part of that expense falls on industry, since students are often financed through research contracts. The British and Japanese systems produce cheaper, more narrowly qualified graduates. The Japanese accept this trade off, and train to compensate for it. The British, as we have seen, tend to complain that the output of the university system is not as they would wish. Higher skills for the generality of British graduates could be achieved by following either the German or Japanese models. Whichever course is followed, and whether government or industry pays, it will cost more to produce such skills.

*Future Reward Systems*

302. We have considered the need for skills and industry's valuation of such skills in the current situation. There are indications that, for many companies, the working patterns of the future may differ radically from those of today.[429] The analysis of our survey suggests a shift from "firm-specific" expertise, in which much knowledge is implicit and based on long-term experience of a particular organisation, to "profession-specific" expertise, in which companies will "buy in" the resources they need.

303. There are some indications that the move to individual responsibility for training has already begun; in the introduction of "training credits" to those seeking technical qualifications and the increasing popularity of such courses as the MBA. The Engineering Council has expressed concern at such developments, saying:

[426] NIESR, No. 6, 1994, p. 4.

[427] Ibid, p. 55.

[428] Q. 708.

[429] For example, The Royal Society of Arts and Manufactures (RSA) Report suggests skilled people will become increasingly important to a company while companies may also wish to deploy staff in a more flexible manner.

"It is not clear that individuals at an early stage of their career have either the information on which to act or the ability to find and determine their own training."[430]

304. It is not clear how far these trends will grow, and it is unlikely that they will involve all sectors, or all disciplines, to the same extent. Complex engineering systems are always likely to demand team work and a sustained knowledge of the project which it may well be necessary to hold "in house". But if such changes come about, then they present both an opportunity and a threat for industry in the United Kingdom.

305. The opportunity they offer is that the United Kingdom already has strong self-governing professional bodies in areas such as medicine and law. The existing engineering and scientific institutions provide a base for similar bodies, although their role will need to change.

306. **The UK tends to undervalue science and engineering skills. If employers do not reward skills, there will be an unwillingness to acquire them. If the skills are not available, this may prevent industry from knowing what it is missing. Particularly in an economy in which profession-specific skills are more important than firm-specific ones, it would seem that professional institutions, backed by government, will have a key role to play.**

[430] T&ISC Ev. HC (1993-94) 41-v, Q. 1645.

## PART THREE: THE ROLE OF GOVERNMENT

307. **We believe that the innovative capacity of United Kingdom industry, in particular its manufacturing industry, will be vital for the country's future.** The benefits of innovation, and of the research, design and development which precede successful innovation cannot be captured by the innovator alone; the overspills will benefit the entire economy. As we have seen, investment in civil RTDD is relatively low in the United Kingdom and must be encouraged. The reluctance of industry to invest appears to be related to the structure of the financial system in the United Kingdom exacerbated by macro-economic volatility. There are further problems in the low status of industry and the availability of skilled workers. These problems are too long-standing and diverse to be solved quickly, but we have made recommendations which may begin to deal with them. We must now look at the Government's overall responsibilities.

308. The prime responsibility for ensuring that innovative and competitive technology is brought to the market place rests with industry, as many of our respondents noted. However, government has a crucial role in helping to create a favourable environment for industry including long-term economic stability and low inflation in which such innovation may flourish. We have already discussed individual initiatives designed to assist industry; it is revealing that the respondents to our questionnaire clearly felt that these were peripheral. There were frequent complaints of *government* short-termism, of lack of support for industry, and of lack of coherence.[431]

309. Sir Denis Rooke told us:

> "An efficient wealth creating society cannot be constructed overnight and it is certain that many initiatives will have to be pursued for a decade or more to achieve optimal success. It is of crucial importance therefore that policies introduced by the Government to assist the wealth creation process achieve wide consent and are not seen as 'party political' instruments. Equally they need to be maintained in a stable fashion, not subject to tinkering or stop/go performance."[432]

310. There is an unfortunate impression that Government schemes are introduced piecemeal, and there is no central cohesion or long term view in government.[433] Too often departments seem to set individual priorities in the light of this year's crisis without considering the overall impact of their policies. The Director of Engineering of British Aerospace told us:

> "what we need to be concerned with nationally is, does that whole system produce the effect that we all want rather than getting too caught up in sharply defined responsibilities between this group and that group."[434]

311. **There are welcome signs that the Government, through the Office of Science and Technology (OST), is attempting to take the long view to create a stable and consensus based climate.[435] However, this task cannot be left to the OST alone. The OST will not succeed unless all departments, including the Treasury, are seen to share the belief that the UK's long-term future rests on world class innovative industry.**

312. The Government cannot impose its policies on industry; it must be alert to industry's concerns and respond to them when it can.[436] To be a properly informed listener, the Government must also be aware of the technological possibilities open to it, through regular interaction with the Science and Technology Base.

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[431] Mem. pp. 120, 153, 211, 213.

[432] Mem. p. 231.

[433] See Mem. p. 72.

[434] Q. 946.

[435] See Mem. p. 74.

[436] See Mem. p. 62.

313. The Government must recognise that it has a vital role as a broker in technology networks: while it should not attempt to usurp the role of industry in determining what industrial research should be carried out, it has a role in encouraging such research, and in providing information about suitable partners. Accepting this role will not only assist industry, but will also ensure the Government is in close touch with the resources of the entire Science and Technology Base.

314. The awareness of industry's needs and of the resources available to it must shape policy in Europe as well as in the UK. Indeed, here an informed government is most likely to help. Later we suggest a number of areas in which policy could be refined in ways which make it more supportive of innovative industry. Many of these suggestions will have implications for European policy, and should be pursued vigorously at the European level.

315. While many individual policies may remain even after such a change of emphasis, the balance of power between departments may alter. The two leaders in this process must be the OST and the DTI. The OST's role is crucial. It is the overseer of the Technology Foresight Process and the department most directly responsible for the Science Base. The DTI, of course, with its role of sponsorship for industry, must be intimately involved both in the Foresight Process itself, and must use the process to inform its policy, and to press, where necessary, for changes in the policies of other departments. It must consider the extent to which the needs of industry are being, or could be, met by the Science Base. For this reason we will concentrate on roles these departments must play if Government is not only to support industry, but to be seen to do so, thereby restoring industry's confidence. First, however, we will look at the way in which policy across government can assist innovation.

## I SECTORAL CONSIDERATIONS

316. Our inquiry has shown that innovation is diverse in nature and Government policy must take account of this. Sectors will differ in the extent to which the networking mode of innovation predominates, in their requirements for firm-specific or profession-specific skills, and also in the extent to which new product design, using established technology or the introduction of radically new products, is the key to competitiveness.

317. Sectors will also differ in the extent to which Government Procurement, regulatory approval and standardisation affects innovation within the sector. For example, in telecommunications firms can gain huge advantage through access to the process of establishing international standards. As another example, the aerospace industry is heavily influenced by defence procurement and by Government actions such as launch aid for new aircraft. In fields such as pharmaceuticals and agricultural chemicals, regulatory controls have a great effect on the innovation process, as can health service procurement (or health care regulation, as is now being demonstrated by the impact of the Clinton proposals in the US).

318. It is beyond the scope of this inquiry to recommend policies covering all sectors. Even within the six sectors on which we have concentrated, we can only give examples of the kind of policies which will be required — there will be further policy needs in these sectors, and many more in other sectors.

319. These policies will *not* comprise a 'plan' for the sector. Nor will they involve picking winners or national champions. They will, however, need:

(a) A very clear understanding of the process of innovation in each sector;

(b) The encouragement of networks in and around each sector;

(c) Based on this understanding of the sector's innovative processes, and informed by its network, the identification of the critical points for Government policy, particularly these parts where a modest expenditure of public funds can make a real difference to innovation;

(d) Implementation of policy in a manner which takes account of the changing international scene in each sector. We would emphasise that we regard 'UK industry' as industry, regardless of ownership, which innovates in the UK.

*Purchasing*

320. Aerospace and Pharmaceuticals, two of the most successful sectors in our survey, are also the two most directly reliant on government purchasing.[437] GATT rules and European Directives restrict the extent to which governments favour companies based in their own countries in awarding contracts, but government purchasing policies can still be used to foster a climate of innovation — or to inhibit it.[438]

321. The prime example of this is the Pharmaceutical Price Regulation Scheme (PPRS), which was widely praised as a system which encouraged companies to base research facilities in the United Kingdom, but did so without loading excessive costs onto the public purse.[439] In contrast, the introduction and subsequent extension of the limited list was seen as a development which could reduce or eliminate research in the areas to which the list applied.[440]

322. Many witnesses felt the Government could use its purchasing power more effectively. A number suggested that the government was using the customer-contractor model to drive down prices rather than acting as an "intelligent customer"[441] and that the system worked to discourage research and technology.[442] The Construction Industry Council said:

"There is a strong case for using public sector procurement methods to encourage forward-thinking attitudes in the industry — good practice, the pursuit of quality, the avoidance of simple reliance on lowest bids, to stimulate innovation and RD&D. Such conditions may similarly be created through contribution to the deliberation of EC Directives and legislation on the industry, including explicit recognition of the importance of construction within the programmes of the Fourth Framework."[443]

323. **The Government should see its considerable purchasing power as one of the means by which it can foster a climate which is receptive to innovation. This should not mean over-specifying contracts, but it should lead to the award of contracts on wider grounds than price alone. We welcome the Treasury Guidance for the Private Finance Initiative which recognises that the advantages in terms of stimulating innovation may in exceptional cases justify alternatives to competitive tendering.[444] We hope that, insofar as EU and GATT rules allow it, similar rules will be applied to general government purchasing.**

DEFENCE SPENDING

324. The one area in which the directives on government purchasing do not apply is defence procurement. The United Kingdom spends considerable amounts on such R&D but many witnesses criticised its lack of commitment to the country's "knowledge base" and the limited "spin out" from defence to civil areas.[445] The Defence Research Agency (DRA) is

[437] Mem. pp. 225, 246.

[438] Mem. p. 24.

[439] Appendix 1, p. cx.

[440] Minutes of Evidence taken by the Health Select Committee, HC (Session 1993-94) 80-iii p. 117.

[441] Mem. pp. 20, 67, 196..

[442] Mem. pp. 22, 31, 93.

[443] Mem. p. 69, see also Mem. p.197.

[444] HM Treasury: *Private Finance; Competition and the Private Finance Initiatives Guidance for Departments*, March 1994.

[445] Mem. p. 115, 117, 119.

making increasing efforts to ensure "spin out" from defence related research is secured wherever possible, and we welcome this,[446] but questions still remain.

325. Mr Waldegrave told us:

> "The American policy for the support of science and technology in general has, for many years, partly at least been through the use of military contracts... That has not been our policy here — I do not want to blame this on the Treasury — for rather clear reasons of policy. We have said in the past — and this was articulated very clearly in the early 1980s — that the mission of the Defence Department was defence and that if we as a Government or we as a society wanted to support science more widely we should do that explicitly and that it was unfair to ask the Ministry of Defence to purchase things that were not related to their mission... On the other hand, I can see the argument you are making. As the Ministry of Defence is a large user of basic science skills, for example, in mathematics, it might be legitimate to say that it is part of its mission to ensure that those underlying skills are produced. This would be a shift of policy, but it is worth debating."[447]

We consider that the "technological base" of the country is wider than the Science Base. Many of the skills which should be supported and retained lie in industry.[448] As defence spending falls, it will be necessary for the Government to maintain its commitment to innovation, as the scope for "spinout" from a diminishing volume of defence research itself diminishes. **Like all government departments, the MOD has an obligation to act as an "intelligent customer" and work to sustain the base needed for future purchases. Indeed, we consider the MOD should have as an objective being as helpful to UK industry as the Department of Defense is to US industry.**

*Regulation*

326. Regulations have a part to play in fostering an innovative climate. The pharmaceuticals companies which responded to our questionnaire told us that the UK system for clinical trials, which combined rigour with speed and a certain flexibility, was one of the factors contributing to the sector's success; the establishment of the European Medical Evaluation Agency in London was widely welcomed as it provided an opportunity to apply those standards more widely.[449]

327. Over-regulation and out-dated regulations can act to inhibit industry and should be avoided.[450] Setting standards too early can, as evidence on Open Systems demonstrated,[451] stifle innovation rather than encourage it. However, intelligent use of regulations for standard setting can provide a spur for industrial improvement:[452] standards for the home market should be set at a standard which ensures products can be exported. Regulations should not be used as a form of non-tariff barrier to trade. In setting regulations, the Government should consult industry and the Science Base[453] and should seek to ensure that common standards are applied throughout the EU. In addition, every government department should be conscious of the implications of the standards they use in its purchasing policies.[454]

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[446] Mem. pp. 253-255.
[447] Ev. p. 22.
[448] See Mem. p. 72.
[449] Appendix p.
[450] See Mem. pp. 74, 81, 82
[451] Mem. p. 239.
[452] See Mem. pp. 9, 94.
[453] See Mem. p. 94.
[454] Mem. p. 81.

## II THE DTI

328. The DTI must have a leading part to play in any government policies to encourage innovation. It has recently taken energetic steps to do this. We welcome the re-organisation of the department to allow more emphasis to be laid on particular sectors. We also welcome the DTI's new emphasis on technology diffusion, both through the Business Links and through the overseas technology brokerage service. We have already drawn attention to the need for government to increase its role of 'broker', and for the need for improvement in the ways in which potential partners in innovation can learn about one another.

329. We are, however, concerned that in reducing its direct support for R&D the DTI may be ignoring the opportunity to aid British industry in other ways, especially since funding has been reduced by transfer of the LINK programme to the OST. **The DTI has a crucial role in the interface between government and industry. Even if it provided no direct funding for innovation at all it would still need to understand industry's innovation needs.** In particular, it should be aware of the networks provided through the Science and Technology Base, and of any deficiencies in those networks. To do this properly it will need to listen to industry and use the Foresight Process. **We are accordingly concerned that the DTI's decision to discontinue the post of Chief Scientific Adviser will weaken its ability to act as an informed listener.**

330. The DTI also has a responsibility to encourage the use of good design in industry.[455] We would welcome an initiative which encouraged more attention to the importance of design in engineering, as a focused activity within the overall innovation campaign.

331. As we have seen, public funding for the Science and Technology Base is largely directed towards the Science Base itself, including the Higher Education Institutions (HEIs). Much of the DTI's role may be to suggest ways in which the Science Base can better interact with industry. It must be remembered, however, that the Science Base has other tasks besides this, and that in many cases such interaction requires both money and time and produces additional pressures on already stretched academics. We have already noted DTI schemes to encourage HEIs to identify and market their resources: more might be required. Professor Davies of the Higher Education Funding Council for England (HEFCE) felt that the DTI gave less support to HEIs than the development agencies (or their equivalents) in Scotland and Wales were able to do through the Funding Councils in their countries.

> "the Welsh Office augment the research funding of the Welsh Funding Council directly from its development budget outside of the education budget. They provide, on a bid basis, I think an extra £3 million, which was about as much money as they were putting into research development themselves as opposed to that which was driven by a formula. Now that is not an opportunity that exists in England."[456]

**If the DTI is to have a role in suggesting priorities for the Science Base and ways in which Higher Education Institutions should interact with industry, there will be occasions when it will have to provide some funds to support such interaction.**[457]

332. The DTI must also ensure that attention is not focused too closely on the Science Base, which cannot provide all the external research and technology industry will need. It must be alert to the differing requirements of sectors based on chemical and life sciences, and those based on physics, which may find it easier to co-operate with RTOs than HEIs. We repeat that **the DTI must recognise its responsibility for identifying and maintaining the wider knowledge base that industry requires in Government laboratories, in Research and Technology Organisations and in industry itself.**

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[455] Mem. pp. 199, 230.

[456] Q. 1103. See also Mem. p. 113.

[457] See Mem. pp. 93, 95, 164.

*Small and Medium Sized Enterprises*

333. A surprising number of respondents to our questionnaire felt the policy of focusing on Small and Medium sized Enterprises (SMEs) might risk diluting the wider knowledge base. SmithKline Beecham told us:

> "It should be appreciated that, historically, SMEs often failed to exploit their markets and that only big companies may have adequate breadth of vision and resources to conduct Foresight. Therefore, the White Paper proposal to divert resources from large to small enterprises must be viewed cautiously."[458]

Dr Robinson of the DTI defended the new policy, saying:

> "the focus on small and medium enterprises does not mean that we are not supportive of large companies. It does not mean that. Secondly, I think that we need to recognise that small and medium enterprises might mean what is called a technology follower but might also mean a technology leader, and increasingly many of the developments in technology are coming out of small companies."[459]

and "with small companies we can make a difference".

334. We understand the DTI's choice of priorities, especially given the relative weakness of the SME sector in the United Kingdom. Nonetheless, we are concerned at the cut in direct support for research at a time when industrial research is at best static, and UK joint ventures are static.[460] While we agree there is no point in funding industry to do something it would have done anyway, or which might not be worth doing at all, **Government has a role in providing resources which will encourage long term research, in industry as well as in the Science Base. These resources need not, and indeed should not, attempt to influence the main thrust of company research, but they should encourage longer term thinking. As we have seen, industry's own research base provides it with the expertise it needs to fund and use other sources of information; this increase in absorptive capacity is worth supporting.**

*Inward Investment*

335. We have been impressed by the potential in inward investment to boost the innovatory and technical capacity of UK industry.[461] The influence of new manufacturers from Japan in raising standards throughout the supply chain has been considerable. We consider the Government's encouragement of such investment has been a success.[462] **Companies which both operate plants and conduct R&D in the UK should be regarded as part of the UK industrial base.**

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[458]Ev. p. 138, see also Mem. p 71.
[459]Ev. Q. 885.
[460]Mem. p. 27.
[461]Mem. pp. 114, 249.
[462]Mem. p. 226.

# III THE ROLE OF THE OST

## Technology Foresight

336. An important means by which OST will perform its role both as co-ordinator of policy across government and as broker between science and industry is through the Technology Foresight process, which the White Paper described as not only:

> "a means of gaining early advance notice of emerging key technologies but also as a process which will forge a new working partnership. This partnership, and networks which develop from it, should bring together scientists and working industrialists who are best placed to assess the significance of emerging technological trends and market opportunities."[463]

*The Role of Foresight in Fostering Networks*

337. The Japanese Science and Technology Agency, which comes under the aegis of the Ministry of International Trade and Industry (MITI), conducts a 30 year forecast of the technologies likely to be significant in the future every five years. This is based on the Delphi technique, involving a large scale consultation exercise.[464] The outcome of this survey is published and broad priorities for government funded R&D projects are influenced by it. The degree of use made of the results of the exercise by industry is open to debate; where success seems to lie is in the strong networks which have been established within and between industrial sectors. Each company is primarily influenced by its own long-term technological perspective.

338. We believe that one of the key functions of the Foresight system should be to strengthen existing networks involving science and industry and to create new ones. As the Lords' Committee has said, if participation were to be confined to those already in existing networks:

> "then Foresight would be an exercise in preaching to the converted, and would only waste the time of a great many people who could be more profitably employed."[465]

339. Indeed, the value of Foresight will be determined by its ability to identify key infrastructure needs and reach the parts of industry which experience particular difficulty in innovation. Nissan maintained:

> "... we must have a basic strategic infrastructure of industry. We need to be able to source basic materials and commodities steel, glass, plastic, fasteners especially those of the highest product quality. However we cannot be pre-eminent in everything so we should decide what is of strategic benefit to industry and the economy."[466]

340. It has been suggested that some sectors such as machine tools or office electronics are of fundamental importance for the long term future of industry as a whole because of their function in producing tools for others to use. The London Business School told us of a study which:

> "traced back the innovations used by firms to increase their productivity to the source sector which produced them in the first place, and tried to ascertain which source sectors produced the most valuable innovations. The results were ... surprisingly clear: the Engineering sector as a whole (and Electronic and Instrument Engineering in particular)

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[463] Cm 2250, para. 2.27.

[464] See the Parliamentary Office of Science and Technology's *Report on UK Technology Foresight*, published in January 1994, for further details of the various techniques as well as the wider issues involved.

[465] HL (Session 1993-94) Paper 12-I, para 3.69.

[466] Mem. p. 273.

> were the source of those innovations which had far and away the biggest effect on users' productivity growth."[467]

341. The Foresight process should also assist industries in which there may be structural barriers to innovation. For example, we were told innovation at company level was difficult in the construction industry since it would benefit the end user rather than the contractor or sub-contractor. Moreover, the structure of the industry which contained a high proportion of SMEs and relied heavily on sub-contracting meant there was little competition to offer such innovation.

342. **The Foresight Programme should provide a forum in which industry and government identify what would be needed to provide a "basic strategic infrastructure" and discuss such issues as the need for innovation in different sectors of the economy.**

*The Role of Foresight in Deciding Priorities*

343. The Japanese system of Foresight draws on the results of the Delphi survey to outline broad areas in which public research will be funded: it goes no further.

344. The Chancellor of the Duchy of Lancaster told us that, while the Foresight Process would probably come to the same conclusions about likely technology changes as similar exercises elsewhere have done:

> "Part of the purpose of this operation is to link actual British industry and commerce, which exists or plausibly could exist, to technologies which are coming along."[468]

It would also identify areas in which British research priorities could be ordered, in the light of both domestic and international strengths.[469]

> "You may even come to the following type of very rebarbative decision which will be unpopular but may be right, namely that a subject is extremely important and we should not do it because it is being done very well elsewhere and we can buy into somebody else's technology much more cheaply."[470]

345. While it may be rational to focus effort where it will be most effective, **the Government should be aware that it can require a high degree of expertise to identify the technologies one should 'buy into' to be a 'close follower' of development elsewhere in the world.** The Science Base will need to maintain some expertise even in areas which have not been identified as priorities for the UK.

346. Many witnesses stressed that Technology Foresight should not lead to narrow concentration on applied research.[471] Professor Scott-Wilson, formerly Technical Director of British Aerospace's Commercial Aircraft Company, stressed:

> "The Science through to Innovation chain can never be about solving short-term market problems. We have to generate a strategy which is based on an assessment of the competitive marketplace of 10 to 20 years hence."[472]

The Government appears aware of this: Sir John Cadogan, the Director General of the Research Councils, told us that Foresight would lead to decisions on underpinning rather than applied technologies: for example, a recognition that fuel cells would become increasingly significant would suggest research into, for example:

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[467]Mem. p. 7.

[468]Ev. Q. 1011, see also Mem. p. 222.

[469]See for example, Mem. pp. 27, 62.

[470]Ev. Q. 1013.

[471]Mem. p. 75.

[472]Mem. p. 221.

"fundamentals of solid state; catalysis; permeability of the materials in the cell; what materials? completely new materials; interface science. Those ... will then support and flow through to fuel cells. But also they will flow through to other things."[473]

347. There is also awareness of the need to ensure that some research remains undirected. The Chemical Industries Association told us:

"Allowance needs to be made for a degree of diversity to ensure that "curiosity" research is not stifled and cross-disciplinary research is not discouraged,"[474]

and SmithKline Beecham warned that "too much directional policy may reinforce fashion and the same fashion in most countries thereby wasting resources."[475]

348. **We agree that Foresight should offer long term vision.** As the Lords' Committee has said, if:

"it degenerates into a means for the DTI to shape the Science Budget, it may cause serious damage."[476]

There is no sign that either government or industry is currently taking a short term view. We would be most concerned if it appeared there was pressure to use the Foresight Process in a narrow way. If it succeeds it will, in the long term, grow into a means by which both government and industry can identify problems and priorities across a wide range of sectors. Industrial organisations, both national and sectoral, should use the knowledge gained in the process to suggest ways in which their industries could be better supported. When those policies require government help, the department concerned should be able to take a broad and informed view in preparing its response.[477] **Foresight should be a means to enable the Government, industry and the Science Base to work effectively together, not just a way to determine the priorities of the Science Base.**

*The OST's Role as Co-ordinator*

349. Government departments need to be well-informed of the technical fields for which they are responsible, whether it be production for the DTI, construction for the Department of the Environment, or Forensic Science for the Home Office. Each department has generally had its own Chief Scientific Adviser and many have their own research laboratories. The availability of such expertise plays an important part in informing departments' policies. Government spending on science and technology goes far wider than departmental laboratories, and much of this departmental spending affects both Science Base institutions and industry. While we accept that it is for individual departments to set their own priorities in the light of their policy needs, fluctuations in departmental spending have in the past led to problems for research councils. There have been suggestions that the departments have not, in fact, been acting as "intelligent customers", concerned for the long term health of their supply base, but have perhaps been overly concerned with cost reduction or have been concerned with their own policies in ways which could damage other departments.[478]

350. The introduction of concordats between departments and research councils is a welcome development, which may solve this problem, but there is still the difficulty of co-ordinating research across government departments. Here, the OST is to have a role, both in compiling the annual Forward Look, the research proposals from each department, and in the Public Expenditure Survey (PES) Round. The Chief Scientific Adviser (CSA) described his role in the PES Round as follows:

[473]Ev. Q. 1014.

[474]Mem. p. 75, see also mem. p. 79.

[475]Ev. p. 136.

[476]HL (Session 1993-94) Paper 12-I, para 3.70.

[477]See, for example, Mem. p. 71.

[478]HL (1993-94) 12—I, para 2.38. Mem. pp. 95, 120, 122.

"All I can do is to try to influence how much money is put into S&T and where it is put in. That I am able to do by talking to the Treasury at the beginning of the PES Round, talking to the Departments and then inputting my views to EDX on which the Chancellor sits. It is on EDX that the decisions are eventually made. ... But I have to say that I do not have control over how a spending Minister in a Department decides to apportion the funds once he has sorted that out at the EDX level."[479]

Shortly after the establishment of the OST we reported:

"We consider the CSA should have a role in the PES Round at departmental level, on inter-departmental issues and in determining the total of government funded R&D and its distribution. We hope that as the OST grows in authority that this role will become more significant."[480]

Since then the Lords have said the CSA needs to have "an effective voice, taken seriously by the Treasury, on departmental science spending bids and on their congruence with the Forward Look". **We stand by our original recommendation and suggest the Lords' Committee's proposal that the Chief Scientific Adviser be "empowered to expose inconsistencies in the science plans of departments to public scrutiny"[481] represents the least the Government could do to implement it.**

351. "Realising our Potential" reported "A common theme ran through most responses: the importance of maintaining and improving the United Kingdom's scientific and engineering excellence and skills and their application. The Government shares this sense of urgency. The United Kingdom's competitive position rests increasingly on our capacity to trade in goods and services incorporating or produced by the latest science and technology."[482]

352. The White Paper focused on the need to build on the strengths of the Science Base and direct Government expenditure on research and technology most efficiently. However, as we have seen, this will not solve all the problems industry faces in using innovation effectively to maintain its technological lead. The purpose of the ambitious programme set out in the White Paper will only be achieved if the Government is committed to reducing barriers to innovation *wherever they may occur*. This will require action which may be led by the OST, but will extend far beyond its strict departmental remit.

[479] Ev. Q. 1035.

[480] HC (1992-93) 228—I, para 18, p ix.

[481] HL (1993-94) 12—I, para 2.78, p. 23.

[482] Cm 2250, para. 1.14.

## SUMMARY

### INTRODUCTION

353. However committed to partnership between the Science Base and Industry the OST may be, its efforts will be ineffectual if they are not matched by action elsewhere in government and industry. (Para 18)

## PART ONE: INNOVATION, RESEARCH, TECHNOLOGY, DESIGN AND DEVELOPMENT

### THE PROCESS OF INNOVATION

If Government policy is to encourage innovation then the processes by which innovation takes place must be fully explored and widely understood. Policies introduced without understanding will at best be inefficient and at worst counter productive. (Para 46)

### INNOVATION NETWORKS

To innovate successfully a company or individual must have access to and the ability to utilise a range of expertise or networks, depending on the nature of the project they are undertaking and the stage of that project's development. (Para 52)

Successful innovation does not depend on one process or a set number of approaches; it is dynamic and evolutionary. We welcome the efforts currently devoted to the understanding of innovation and recommend that they should continue. (Para 56)

### THE SIGNIFICANCE OF INNOVATION IN DIFFERENT SECTORS

It is for industry to identify and carry the innovation it needs through to production, but government policies should assist these processes. Such policies will only be effective if they take account of industry's varying needs. (Para 57)

Innovation links are becoming steadily more complex, and the nature of that complexity varies from sector to sector. This reinforces our belief that an understanding of the innovation networks used by each sector will be vital if Government policy is to be effective. (Para 61)

If the model of the innovation network is accepted, then the Office of Science and Technology, as the central department most closely connected with the Science Base, will have a central role in government. Yet the Government will also have to maintain an awareness of all the networks open to industry. (Para 61)

### LOCATION OF GOVERNMENT FUNDED R&D

Industrial spending on R&D in Germany and Japan is far higher than here. This not only means a greater part of these countries' science and technology base is located in industry, but it also gives industry the expertise necessary to absorb science and technology developed elsewhere, including in the UK Science Base. (Para 69)

### UK UNIVERSITIES: A DIVERSE SYSTEM

The problem is not that universities are diverse; it is that, for the uninitiated, it can be difficult to identify the institution most likely to be able to help with a particular problem. The diversity of the university system will be a strength rather than a weakness, as long as there are efficient ways for industry to find the most appropriate source of help. (Para 75)

### BUSINESS LINKS

Business Links should be able to provide information about national as well as local sources of technological expertise and the databases necessary for this should be developed. (Para 77)

The DTI must ensure that Technology Counsellors are seen as a potential source of information about industry's requirements that Government can draw upon, as well as providers of a service for industry. Moreover, if the Technology Counsellors in Business Links are to be fully effective they will require adequate resources and leadership from the DTI. (Para 78)

### The Science Base And Industry

We welcome the new emphasis on partnership between the Science Base and industry, and we will examine the ways in which it can be made more effective. (Para 83)

We agree with the Chancellor of the Duchy of Lancaster that it is important that the universities, and indeed, the Science Base as a whole, should be a partner to industry, but also agree that "we do not want them to lose the things which only they can do". (Para 83)

### The Application Gap

There must be Government policy to encourage linkages between the Science Base and Industry sensitive to the differing relationships with the Science Base maintained by different sectors and by different sizes of companies. (Para 92)

### Industrial Influence On Government Funded Research

The Chancellor of the Duchy of Lancaster's sensitivity to the wider responsibilities of the Science Base is welcome. It is not appropriate for publicly funded research in the Science Base to be driven by the short-term needs of industry. However, we believe it is possible to conduct research which is both of the highest international quality and, where relevant, applicable to industry. (Para 98)

### Direct Science Base/Industry Interaction

In the exchange between the Science Base and industry both parties must work at successful communication; failures are not the fault of the Science Base alone. (Para 101)

### Liaison With Industry

The Technology Audits Scheme and the Industrial Units Scheme are very welcome. We trust that they will be repeated if necessary. (Para 109)

Universities should not be compelled to see every interaction with industry as a source of immediate profit. While informal relationships between industry and academia may lead to difficulties in strict accounting terms, they serve to strengthen the country's industrial and academic base. Moreover, such links may lead on to more formal contracts. (Para 112)

### Recovery Of Overheads

Industry must be prepared to pay the full costs of the near market research it contracts to universities. (Para 113)

### Intellectual Property

It is important that universities should protect their Intellectual Property Rights (IPR) appropriately. Nonetheless, we agree with Dr Robinson, the former Chief Scientist of the DTI, that the current diversity of arrangements for exploitation is a strength rather than a weakness. (Para 120)

### Identification Of IPR

We reiterate our concern at the difficulties caused to our researchers by a lack of a "grace period" between publication and patent application, and urge the Government to do whatever it can to ensure the harmonisation of IPR in a way which allows such a grace period. (Para 123)

ACADEMIC REWARDS

It would be a great loss if the increase in student numbers and the way in which the research selectivity assessment was organised combined to make an unbridgeable division between teaching and research, especially industrially relevant research. (Para 125)

Academic success and the quality of academic research should be linked. However, the measures of research quality used in the past have discriminated against research undertaken with industry. We support the initiatives to widen the criteria used in assessing performance and to increase the status of industrial research. (Para 129)

INDUSTRIAL RESEARCH

A high degree of both management and technological or scientific expertise will be needed to ensure the effectiveness of new ways of operating, and, in those companies large enough to sustain such a department, the corporate research function will be vital. (Para 138)

DTI SUPPORT FOR COLLABORATIVE RESEARCH

We understand the Government's unwillingness to provide funding for research that would have taken place without such support. However, government does have a role in encouraging and, where necessary, supporting industry's attempts to take a long-term view. (Para 144)

The DTI should monitor the effects of its withdrawal of funding from industrial collaborative research to focus on technology transfer activities, and be prepared to adjust its policy if it appears the amount of long-term research is being reduced. In addition the effectiveness of the Advanced Technology Programmes should be examined and an evaluation published. (Para 144)

RESEARCH AND TECHNOLOGY ORGANISATIONS AND GOVERNMENT LABORATORIES

We consider that both independent Research and Technology Organisations and Government Research Laboratories are valuable and cost-effective parts of the Science and Technology Base. (Para 150)

INDEPENDENT RESEARCH AND TECHNOLOGY ORGANISATIONS

There is no fixed pattern for Government support for RTOs. There should be awareness of the ways in which changes in policy may affect them and may affect the Science and Technology Base. (Para 156)

GOVERNMENT RESEARCH LABORATORIES

We do not believe that the value of a government laboratory, even one operating in areas of direct relevance to industry, can be judged by its ability to meet departmental needs or to attract contract research alone. There may be cases where a Government Research Laboratory is a valuable part of the Science and Technology Base and its expertise should be maintained. (Para 160)

The DTI's role in monitoring the expertise available in government laboratories or former government laboratories should be wider than simply ensuring that its own research needs can be met. Industry should be widely and publicly consulted on matters affecting Government laboratories. (Para 162)

THE EFFICIENCY UNIT SCRUTINY

We see no reason why, provided it is conducted thoroughly and with due deliberation, and does not wreck Government science, the Efficiency Scrutiny should be feared, *as long as the Government's responsibility for the long term preservation of a knowledge base at least at the current level is taken into account in any decisions*. (Para 164)

INTERNATIONAL PROGRAMMES

Collaboration can assist innovative UK industries; it cannot replace their own R&D which they need to retain international competitiveness. (Para 165)

EUROPE

We agree with the Report prepared by the United Kingdom Impact Study for the Office of Science and Technology and the European Commission that there is a need for flexibility in the system of attributing money spent on EC programmes to departmental budgets, and that allocations should appear in the Annual Review of Government Funded Research and Development. (Para 167)

SUBSIDIARITY

We support the Government's emphasis on subsidiarity in research. (Para 171)

**PART TWO: INNOVATION: THE WIDER CONTEXT**

R&D AND ECONOMIC GROWTH

We believe the time has come for a major re-examination of the case for fiscal incentives for investment in research and development, both at personal and at company level. Such a review should be conducted openly, and its conclusions should be considered by experts outside the Treasury. (Para 186)

THE MANAGEMENT OF RISK

The effect of UK companies requiring high 'hurdle rates' of return is to exclude companies from a wide range of opportunities - open to their competitors - in projects with lower rates of return. (Para 194)

Further study of the effects of the financial system on innovation and industrial growth is urgently required, and we urge that it be fully examined in the current Treasury Review. (Para 196)

STRUCTURE OF UK FINANCING

In the light of the evidence presented to us, we would agree with those of our witnesses who suggested that the UK financial system has been less successful at encouraging the growth of high technology companies than those of its competitors. (Para 203)

ECONOMIC FLUCTUATIONS

The UK's relative decline has not been caused by economic instability alone, but we regard it as a contributory factor. Government policy should be aimed at macro-economic stability and it should not be forgotten that both short-term and long-term instability increase the difficulty of business decisions. (Para 209)

THE STOCK MARKET AND INNOVATION

We do not believe communication between companies and their financial backers alone can solve the problems associated with funding research and development investment. Behaviour that is rational for those in the financial market place can have destabilising effects for industry. There appear to be significant advantages to German companies in their versions of corporate governance "insider systems" as Professor Colin Mayer describes them and we consider that these aspects of corporate governance in the UK context should be given serious further consideration both by Government and industrial economists. (Para 216)

BANK FINANCE

We are particularly concerned that small companies appear over-reliant on volatile overdraft facilities, even for quite long-term investments. (Para 237)

BANKS

We hope that banks will increasingly develop the expertise to lend against a company's expertise and likely prospects of success rather than security, and that they will be increasingly prepared to lend on a long-term basis. We agree with IBM that:

> "Conditions attached to monies raised should reflect the objectives of the company and its long term prospects, rather than simply cover the risk against tangible assets." (Para 241)

DEVELOPMENT FINANCE

The market currently fails to support small and growing companies adequately, especially those in high technology areas. (Para 247)

We strongly recommend that the current Treasury review should examine all the problems caused by the lack of development finance in detail and that the Government should produce concrete proposals for their solution. (Para 248)

ENTERPRISE INVESTMENT SCHEME

We welcome the Enterprise Investment Scheme (EIS); we trust that if it is abused, the Government will reform it rather than abolish it. (Para 250)

THE ROLE OF THE STOCK MARKET

We note that, whatever the availability of "business angels", they may have difficulty in identifying suitable investments. A smaller companies market, sharing some of the tax advantages of the EIS, could attract more such investors into the market. (Para 253)

CORPORATE VENTURING

The reasons for the reluctance of UK companies to collaborate with each other need to be studied further and we suggest that the DTI should examine this. (Para 256)

The difficulties in valuing R&D and in financing innovative companies lead us to believe that if UK industry is to flourish the attitudes and structures of the financial institutions in the United Kingdom may need some adaptation. (Para 259)

PEOPLE

We agree with the many witnesses who emphasised the importance of manufacturing for the economy, and who felt that our culture fails to value it sufficiently. (Para 260)

If industry were seen to reward high skills with high pay, and with enhanced career opportunities, then not only would more qualified people be attracted into industry, but, in the long term, more people would appreciate the value of qualifications. (Para 263)

MANAGEMENT SKILLS AND PRIORITIES

Attempts to ensure that managers have scientific understanding will exacerbate skill shortages in the short term since scientists and engineers may be moved from technical functions. However, unless such skills are fostered and encouraged, British industry will remain uncompetitive and one of the key failings of its management will remain uncorrected. Unless scientists and engineers are offered a route to the top they will remain in short supply. Other careers than industry will be more attractive to graduates, and prospective undergraduates will not be motivated to study science and engineering in preference to other topics that appear to offer better chances of reward. (Para 272)

THE NATIONAL CURRICULUM

The case for reliance on single science in the National Curriculum is not proven. We recommend that trends in the take-up of double science, and the extent to which one sex predominates in the subject, are carefully monitored in the future. It would be a cause of great concern if double science came to be seen as a predominantly male subject. (Para 277)

VOCATIONAL TRAINING

We note that the Education Committee have been taking evidence on the evolution of the National Curriculum at regular intervals. The reorganisation of the education system for 14 to 19 year olds will, in the long-term, have profound effects on our ability to innovate successfully; we hope our colleagues will consider such matters as science and technology education and the implementation of National Vocational Qualifications and General National Vocational Quaifications in the course of their scrutiny. (Para 281)

GRADUATE SKILLS

Initiatives to combine technical and business skills within courses are welcome. If science and engineering degrees become recognised as likely routes to management positions their popularity should increase. However, their success can only be judged by their capacity to attract students and those students' ability to find employment. (Para 288)

THE NEW ARRANGEMENTS FOR POST-GRADUATE TRAINING

The Government has a series of schemes such as the Teaching Company Scheme which are designed to give post-graduates experience of industrial perspectives. These appear highly regarded and were widely used by our respondents. They should continue. (Para 293)

Once the new arrangements for research training have begun, their effectiveness should be carefully monitored, with particular regard to the differing requirements for the training and supply of post-graduates across disciplines and across the sectors which draw upon those disciplines. Neither the Science Base nor industry is uniform, and that diversity should be respected. (Para 296)

FUTURE REWARD SYSTEMS

The UK tends to undervalue science and engineering skills. If employers do not reward skills, there will be an unwillingness to acquire them. If the skills are not available, this may prevent industry from knowing what it is missing. Particularly in an economy in which profession-specific skills are more important than firm-specific ones, it would seem that professional institutions, backed by government, will have a key role to play. (Para 306)

## PART THREE: THE ROLE OF GOVERNMENT

We believe that the innovative capacity of United Kingdom industry, in particular its manufacturing industry, will be vital for the country's future. (Para 307)

There are welcome signs that the Government, through the Office of Science and Technology (OST), is attempting to take the long view to create a stable and consensus based climate. However, this task cannot be left to the OST alone. The OST will not succeed unless all departments, including the Treasury, are seen to share the belief that the UK's long term future rests on world class innovative industry. (Para 311)

PURCHASING

The Government should see its considerable purchasing power as one of the means by which it can foster a climate which is receptive to innovation. This should not mean over-specifying contracts, but it should lead to the award of contracts on wider grounds than price alone. We welcome the Treasury Guidance for the Private Finance Initiative which recognises that the advantages in terms of stimulating innovation may in exceptional cases justify alternatives to competitive tendering. We hope that, insofar as EU and GATT rules allow it, similar rules will be applied to general government purchasing. (Para 323)

DEFENCE SPENDING

Like all government departments, the MOD has an obligation to act as an "intelligent customer" and work to sustain the base needed for future purchases. Indeed, we consider the MOD should have as an objective being as helpful to UK industry as the Department of Defense is to US industry. (Para 325)

THE DTI

The DTI has a crucial role in the interface between government and industry. Even if it provided no direct funding for innovation at all it would still need to understand industry's innovation needs. (Para 329)

We are concerned that the DTI's decision to discontinue the post of Chief Scientific Adviser will weaken its ability to act as an informed listener. (Para 329)

If the DTI is to have a role in suggesting priorities for the Science Base and ways in which Higher Education Institutions should interact with industry, there will be occasions when it will have to provide some funds to support such interaction. (Para 331)

The DTI must recognise its responsibility for identifying and maintaining the wider knowledge base that industry requires in Government laboratories, in Research and Technology Organisations and in industry itself. (Para 332)

SMALL AND MEDIUM SIZED ENTERPRISES

Government has a role in providing resources which will encourage long term research, in industry as well as in the Science Base. These resources need not, and indeed should not, attempt to influence the main thrust of company research, but they should encourage longer term thinking. As we have seen, industry's own research base provides it with the expertise it needs to fund and use other sources of information; this increase in absorptive capacity is worth supporting. (Para 334)

INWARD INVESTMENT

Companies which both operate plants and conduct R&D in the UK should be regarded as part of the UK industrial base. (Para 335)

THE ROLE OF FORESIGHT IN FOSTERING NETWORKS

The Foresight Programme should provide a forum in which industry and government identify what would be needed to provide a "basic strategic infrastructure" and discuss such issues as the need for innovation in different sectors of the economy. (Para 342)

THE ROLE OF FORESIGHT IN DECIDING PRIORITIES

The Government should be aware that it can require a high degree of expertise to identify the technologies one should 'buy into' to be a 'close follower' of development elsewhere in the world. (Para 345)

We agree that Foresight should offer long term vision. (Para 348)

Foresight should be a means to enable the government, industry and the Science Base to work effectively together, not just a way to determine the priorities of the Science Base. (Para 348)

THE OST'S ROLE AS CO-ORDINATOR

We stand by our original recommendation on the role of the Chief Scientific Adviser in the PES Round contained in our First Report of Session 1992-93, and suggest that the Lords' Committee's proposal that the Chief Scientific Adviser be "empowered to expose inconsistencies in the science plans of departments to public scrutiny" represents the least the Government could do to implement it. (Para 350)

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ABRC | — Advisory Board for the Research Councils |
| ACOST | — Advisory Council on Science and Technology |
| AFRC | — Agricultural and Food Research Council |
| ATP | — Advanced Technology Programmes |
| BERD | — Business Enterprise R&D |
| BES | — Business Expansion Scheme |
| BTG | — British Technology Group |
| CBI | — Confederation of British Industry |
| CSA | — Chief Scientific Adviser |
| DASA | — Defence Analytical Services Agency |
| DfE | — Department for Education |
| DRA | — Defence Research Agency |
| DTI | — Department of Trade and Industry |
| EC | — European Community |
| EIF | — European Investment Fund |
| EIS | — Enterprise Investment Scheme |
| ESRC | — Economic and Social Research Council |
| EU | — European Union |
| GATT | — General Agreement on Tariffs and Trade |
| GDP | — Gross Domestic Product |
| GERD | — Gross Domestic Expenditure on R&D |
| GFCF | — Gross Fixed Capital Formation |
| GNVQs | — General National Vocational Qualifications |
| HEFCs | — Higher Education Funding Councils |
| HEFCE | — Higher Education Funding Council for England |
| HEIs | — Higher Education Institutions |
| IEE | — Institute of Electronic Engineers |
| IFBERD | — Industry Financed Business Enterprise R&D |
| ILO | — Industrial Liaison Office |
| IPR | — Intellectual Property Rights |
| JDB | — Japan Development Bank |
| JITA | — Japan Industrial Technology Association |
| KfW | — Kreditanstalt fur Wilderaufban |
| LEC | — Local Enterprise Company |
| MAFF | — Ministry of Agriculture, Fisheries and Food |
| MBI | — Management Buy-in |
| MBO | — Management Buy-out |
| MITI | — Ministry of International Trade and Industry (Japan) |
| MoD | — Ministry of Defence |
| MRC | — Medical Research Council |
| NAO | — National Audit Office |
| NERC | — Natural Environment Research Council |
| NIESR | — National Institute of Economic and Social Research |
| NVQs | — National Vocational Qualifications |

| | |
|---|---|
| OECD | — Organisation for Economic Co-operation and Development |
| OST | — Office of Science and Technology |
| PE | — Price/Earnings ratio |
| PES | — Public Expenditure Survey |
| PPRS | — Pharmaceutical Price Regulation Scheme |
| R&D | — Research and Development |
| ROPAs | — Realising Our Potential Awards |
| RSA | — Royal Society of Arts and Manufactures |
| RTDD | — Research and Technology, Design and Development |
| RTOs | — Research and Technology Organisations |
| SERC | — Science and Engineering Research Council |
| SET | — Science, Engineering and Technology |
| SFLGS | — Small Firms Loan Guarantee Scheme |
| SMEs | — Small and Medium sized Enterprises |
| SPRU | — Science Policy Research Unit, University of Sussex |
| S&T | — Science and Technology |
| TEC | — Training and Enterprise Council |
| TFP | — Total Factor Productivity |
| USM | — Unlisted Securities Marker |

# APPENDIX 1

## The Questionnaire: Commentary

## Part 1: Overview

### Introduction

1. The process of innovation is complex. Innovation involves the confluence of many factors including the application of new knowledge - whether from science or technology, the competences held by firms, the perceived level of commercial and technological risk, the cost of capital, and the regulatory environment. In order to get a view from industrialists on the relative importance of these various factors, a questionnaire was prepared. It was, first, tested on a small number of firms (Questionnaire A) and then sent to a larger number (Questionnaire B). It was felt that significantly different answers to some of the questions might be sector specific. The population surveyed therefore included firms from six sectors. The sample included small as well as large firms.

2. Fifty five responses have been analysed. Fifteen to Questionnaire A, and 40 to the shorter Questionnaire B. The six industry sectors were covered: aerospace, automobile, food & drink, machine tools, electronics & office equipment, and pharmaceuticals. The companies varied widely in size from those with less than 100 employees to those employing over 10,000. Company status also varied, between independents, subsidiaries and divisions of UK companies, and subsidiaries of foreign companies.

### Innovation and Technology

3. In general, UK companies regarded themselves as innovative in comparison with their competitors. Two thirds had corporate strategies that spanned over five years. However, technological novelty alone is rarely sufficient for commercial success. When asked to rank the factors determining competitiveness in their industry, quality, service, and price all ranked above product/process novelty. In product competitiveness, novelty ranked below product reliability, product design, quality, safety features, and relations with suppliers. Even in technology-based industries competition on the basis of price and quality may be more intense than through technological performance improvements.

4. This is also reflected in the fact that 30% of the companies derived over half of their income from products introduced over seven years ago, and a further 40% of the companies derived between a quarter and half their income from products introduced over seven years ago. Only 12% derived over half their income from products introduced in the last three years. Sectoral differences exist; ranging from electronics companies with high turnover from recent products to pharmaceuticals which depend on long-life products. The importance of new technology for these companies is apparent from these responses.

5. Nonetheless, 95% of the companies believed that technology and innovation were becoming more important to their operations. The remaining 5% claimed that these factors had been very important in the past and remained important today. No firm claimed innovation and technology were becoming less important. This was reflected in the fact that two thirds of the companies had increased the proportion of turnover devoted to Research Technology Design and Development between 1981 and 1991.

6. In organising their product development the great majority of companies employed multi-functional teams, and nearly 90% used product or project champions. The majority of companies also employed formal project appraisal systems for assessing the financial return on projects or new products prior to launch and in many cases quantitative appraisals with a target rate of return were used. These systems always included non-R&D inputs and almost always had inputs from all the company's functions.

**Relations with the Science Base**

7. The importance of external sources of science and technology in facilitating companies' own R&D activities varied widely between those companies that believed it to be unimportant to those that believed it to be crucially important. When asked whether external science and technology were becoming more or less important to companies' long term competitiveness, there was a greater indication that it was becoming gradually more important. It is apparent from these responses that for some industries the Science Base is important, whilst for others it is of little direct importance. For example the view that universities are important to their search for new technology and scientific fields is strongly held by the pharmaceutical industry but it is much less evident in, say, the motor vehicle industry. The reasons for the divergence of views may be due to the specific nature of the innovation in different sectors. In what follows an attempt is made to understand the range of responses in terms of the characteristics of those sectors in which product and process innovations are dominated by design and those which are not. The hypothesis is that in those sectors dominated by design considerations, the links with the Science Base are obscured by the imperatives of the design process. This may account for the fact that links between innovation and the Science Base received such varied answers from respondents.

**Training and Skills**

8. The great majority of the companies have formal training and professional development policies, which embrace training for all levels of the company. Most of the companies spent between 1% and 2% of turnover on training, the level being decided on a balance between needs and what is affordable. Two companies spent nothing on training. About half regarded the amount of expenditure on training as sufficient, others were constrained by available time and money. Difficult trading conditions through the recession reduced training in some companies.

9. Nearly half the companies had experienced difficulties in recruiting in the recent past, although a few of these had found difficulty only in specialist areas. Nearly a third of the companies which had not had difficulties in the past expected to have them in future, when the recession was over. The need for skills varied according to sector; Food and Drink and Aerospace found little difficulty at present. The skills most commonly identified as in short supply were in engineering, both mechanical and software, technicians and those who were able to combine "leadership roles" and technical expertise. The one exception was the Pharmaceuticals sector, where shortages were also identified in chemists, statisticians, personnel with an understanding of IPR and more specialised areas. In spite of the recession, over half of the smaller group of companies asked specifically about the availability and quality of technical staff said this had caused them difficulties over the previous five years, and a larger majority expected such problems in the future.

**Manufacturing**

10. Not all of the companies surveyed were engaged in manufacturing. Those that were, were asked to judge the vintage of their plant and equipment in relation to their foreign and UK competitors. On average, the companies believed their equipment to be of the same vintage as their international competitors, and slightly more modern than their UK competitors. Only a quarter claimed to have equipment older than their foreign competitors, whilst nearly half claimed more modern equipment.

11. Over the last five years the companies have tended to reduce the number of suppliers they use, whilst fostering closer ties with those that remain. Where sourcing is increasingly from abroad, this is mainly due to a lack of UK suppliers rather than quality or reliability problems.

**Finance**

12. Seventy percent of the companies had raised significant amounts of external finance during the last seven years. But in only 27% of cases was finance for innovation an important (more than one third) part of the company's needs for external finance. The preferred source of finance was the bank loan, which was used by 70% of the companies raising external finance. No other source was used by more than half the companies, but bond finance, loan finance and public placement of shares each attracted a third. Venture capital was used by only two companies, although more commented upon its usefulness. It should be noted that in the survey the questions about the cost of capital were raised in the context of innovation and research and development expenditures. In terms of the survey responses R&D was taken to be RTDD — that is, research, technology, development and design. In most cases, these activities are funded internally - usually from retained profits and not directly from financial markets such as those available to start-ups from venture capital funds of various kinds.

13. Asked to rate sources of finance, high approval was given to public issue of shares and bond finance; bank loans were found acceptable by all but one company, and approval was also given to loan finance, private shares, and investments by corporate partners. Only venture capital received a negative rating.

14. Of the minority who found bank loans less than a fully satisfactory source of finance, the majority complained of high interest rates, which are largely out of the bank's control. Other complaints of "lack of understanding" or "absence of long term finance" were given by only a few companies.

15. Short termism is often perceived as a major problem for innovative, technology based companies in the UK, but most companies that raised finance through the placement of shares were satisfied with this source of finance. Only four were less than fully satisfied. Of these, three gave 'short-termism' as one of the reasons for this dissatisfaction. However, company responses relate primarily to the matter of raising finance and it is perhaps not surprising, given the City's expertise and the general level of understanding of those involved on both sides, that responses were generally satisfactory. The robustness of these responses requires more detailed analyses. For example, it is possible that different sizes of firms need or make use of different parts of the financial system. In this regard, Mayer (ref) has indicated that small companies rely on banks, medium-sized plc's on banks and equity, while large companies make use of banks, equity and bond markets. Venture capital is used only by start-ups and buy-outs and for companies trying to make the transition to a small or medium-sized firm.

**Role of Public Policy as it Relates to Innovation**

16. Sixty percent of the companies had participated in a government scheme to assist innovation and manufacturing activities. The schemes cited included Link, Case, Alvey, and a variety of innovation initiatives from the DTI. Eighty per cent claimed the schemes were 'highly useful' or 'useful', and only 10% found them 'unsatisfactory' or 'very unsatisfactory'. However, 40% of companies had not participated in any scheme

17. Government purchasing was important to the aerospace companies, the office equipment companies, and the pharmaceuticals companies. It was of little or no importance to the vehicles, machine tools, and food and drink companies.

18. A third of the companies had benefited from government actions that enhanced their competitiveness during the past five years. A variety of actions were stated but the pharmaceuticals sector recognised the value of government efforts to extend and protect patent terms.

19. Asked what government could do to enhance innovativeness and competitiveness, the companies called for tax incentives and grants, not only for R&D but also for equipment and tooling. There was some appeal that the Science Base be targeted to key technologies, and closer relations between higher education and industry. The aerospace industry appealed for a long term strategic view to be taken of its sector, and for the government to match support available in other countries. The pharmaceuticals sector was concerned about reform of the

Pharmaceutical Price Regulation Scheme and the Limited List. They were concerned that the present arrangements concentrate on the cost of the drugs themselves rather than taking a wider view of costs to the NHS. They appealed for doctors to be given the freedom to prescribe the drugs of their choice. The view that government should use public purchasing to assist industry rather than seeking lowest cost suppliers was echoed in the aerospace sector. Other respondents claimed government could help most by maintaining sound macro-economic conditions with low interest rates, low inflation, and stable currency.

**Overall Environment: UK and Abroad**

20. Overall the companies regarded the UK as having a less favourable general environment for innovation than its major competitor countries. Only one company regarded the UK as being more favourable for innovation than the US, and only 3 regarded the UK as being better than Japan. This contrasts with 36 and 40 companies that thought the UK less favourable than the US and Japan respectively. The respondents also regarded the UK as less favourable than Germany, France and Taiwan. Only in pharmaceuticals, and to some extent in electronics and office equipment, is the UK regarded as having a favourable environment for innovation. However, in both these sectors the UK is seen as less favourable than the US and Japan, and in office equipment, also less favourable than Taiwan.

21. The companies justified their reasoning in a variety of ways but three themes emerged. Firstly, they claimed that manufacturing and particularly engineering are culturally undervalued in the UK. They appealed to government to raise the profile of industry, and encourage young people to seek careers in manufacturing. Secondly, they complained of "short-termism" in the UK financial markets, contrasting with long-term, low cost finance available in Japan, and the readiness of German banks to invest in industry. These general comments may appear contradictory to the respondents' earlier comments regarding finance but as has been indicated they may reflect the experiences of companies of very different sizes in different money markets. Finally, the companies regretted the lack of greater government participation in industry. Aerospace and vehicle companies in particular called for government to have a long term vision with strategic objectives. The success of the pharmaceuticals as well as aerospace and defence industries involves the interplay of many factors, including, the underlying quality of scientific research, the ability to recruit good quality people, an effective and efficient system of regulation, quality driven by high standards of safety, a stable government purchasing regime, government support — through pricing mechanisms — for internationally competitive levels of R&D. Whilst the US is seen as being advantaged through its larger, and freer market, the UK is less bureaucratically regulated than in France and Germany.

22. Despite their impression that the UK was not a particularly favourable environment for innovation, the companies generally regarded themselves, perhaps complacently, as being as or more innovative than their competitors in the other advanced countries. By contrast they regarded their UK customers as being generally less demanding than customers in other countries.

## PART II: Issues Pertaining to Individual Sectors

### 1. The Framework of Analysis

23. The aim of the inquiry is to examine the ways in which the Science Base is, or can be, connected to the process of developing innovative and competitive technologies in industry. We have carried out a questionnaire survey of industrial sectors; food and drink, pharmaceutical, office electronics, machine tools, automotive vehicles, and aerospace. A range of questions were asked of some 80 firms, including some follow up questionnaires in several cases. For many of these firms - pharmaceuticals would be the great exception — the question of linkages between the Science Base and technology development is hard to grasp, and for many it is rather an abstract notion, too remote from the way their business is perceived. As a consequence, it was necessary to work carefully through the responses to be sure that the information sought on links with the Science Base had been given, but perhaps expressed in a different way.

24. To help in this exercise a simple framework using three analytical dimensions was being employed. The first dimension identifies the particular part — i.e. physics, or chemistry, or biology — of the Science Base which a particular sector draws upon. Though this classification does not identify a unique, one to one, correspondence with a particular part of the Science Base it has some heuristic value in suggesting the predominant form of linkage that might be expected.

25. The second dimension pertains to the type of linkages that can exist between the institutions which produce and use knowledge. Five models of possible ways the Science Base could be linked to companies were developed and each sector was investigated to see what model was dominant in it, as well as whether the dominant model was changing.

26. Third, the question of linkages has to do with the attitudes of individuals and firms to their external environment. This complex set of relationships can be summarised under the notion of firm architecture. Firm architecture exhibits at least two broad types of competences - firm-specific ones and profession-specific ones. The former refers to competences which relate to the particular technologies which the firm utilises, while the latter refers to more generalised skill which may be used by a number of firms.

*(i) Physics: vs. chemistry-based sectors*

27. In the sectors where the interfaces between mechanical, electrical, electronics and software are very difficult to determine, such as motor vehicles, aerospace and office equipment, the linkages with the Science Base are indirect because the product realisation process is driven by design considerations rather than direct applications of discoveries made say, in physics. Because of the complexity of the problems that they face, firms in these sectors tend to rely on linkages with customers and suppliers first before they make requests of the Science Base. Of course, the suppliers themselves may have close links with the Science Base. In chemically based sectors, such as food, the direct application of discoveries in chemistry may be more evident and therefore, as one might expect, industrialists reported more frequent interactions with the Science Base. The perception of a direct link to the Science Base is even more explicit in the responses from the pharmaceutical industry where the underlying science of molecular biology is pursued within a general context of application. This may perhaps help to explain why in the physics based sectors industrialists tend to look to the Science Base institutions as the source of trained manpower while in pharmaceuticals they also expect a steady flow of discoveries. In the chemical sectors there tends to be a mixture of perceived roles for the Science Base. To an extent, then, the distinction between physics-based, chemistry-based and biology based industrial sectors account for the different replies made about the relation of firms to the Science Base.

*(ii) Five Models of the process connecting the Science Base to innovative technology*

28. Model 1. This is a conventional linear model. Ideas flow from academia direct to large companies, sometimes with the assistance of Industrial Liaison Offices or Regional Technology Transfer Offices. Contract research and consultancies for companies by academics are sometimes found in this model.

29. Model 2. New technology is developed in a start-up company. This may involve academics founding new high-tech firms who develop the technology past the prototype stage, sometimes, but not always, with finance and management assistance from venture capital firms. Start-up firms generally need to cooperate with large firms, and sometimes are eventually taken over by them.

30. Model 3. In this model the company — usually a large one — is the locus of R&D and technology development. Contributions from academia in this model are mainly via the recruitment of qualified people.

31. Model 4. The spin-out model in which large, or well-established companies are the source of the entrepreneurs who leave and set up small firms.

32. Model 5. The networking model. Here, small firms cooperate with each other, and with RTOs and academia, to tackle problems too large for a single firm. Not infrequently large firms, too, are brought into the network.

*(iii) Competences*

33. John Kay uses the term "architecture of the firm" to describe the network of relationships within and around firms, among employees and with customers and suppliers. Different firms have different architectures. He says that:

> "The value of architecture rests in the capacity of organisations which establish it to create organisational knowledge and routines, to respond flexibly to changing circumstances, and to achieve easy and open exchanges of information. Each of these is capable of creating an asset for the firm - organisational knowledge which is more valuable than the sum of individual knowledge, flexibility, and responsiveness which extends to the institution as well as its members."[1]

34. People who have spent many years in one large organisation, and who function well in that organisation, sometimes have great difficulty when they move elsewhere and have to do without the organisational routines they have, for such a long time, taken for granted. Such people rely on the architecture of the firm, and their competences are particularly firm-specific. (Japanese firms have shown how important organisation is in increasing efficiency not just individual levels of skills (McKinsey Report). In any case, real understanding of how the company really works (functional architecture) is essential to produce a change which results in real improvements.

35. In contrast, profession-specific competences are more readily transferable from one organisation to another. These competences may need no permanent organisation for their deployment, as in the case of consultants who move from helping one firm to helping another. Profession-specific competence does not imply the inability to work in a team. On the contrary, a higher level of team working skill will generally be needed to achieve results without the support of the established ways of doing things which firm-specific architecture provides. Profession-specific competence sometimes includes the ability to span organisational boundaries and to make explicit the tacit knowledge shared by members of an organisation, readily usable by them, but not by outsiders.

36. Firm-specific competences tend to be needed for continuous improvement, what is called "kaizen" in Japanese. On the other hand, profession-specific competences tend to be

[1]John Kay, *Foundations of Corporate Success How Business Strategies Add Value*:Oxford University Press, Oxford, 1993, p. 66.

needed for step-change innovation, since such radical innovation often disrupts the architecture of the firm.

37. There is some evidence in the questionnaires to indicate that the emphasis in linkages with the Science Base is moving from relatively straightforward mechanical - action at a distance - linkages to more interactive, dynamic exchanges. Correlated with this is a shift, as networking becomes more dominant, from firm-specific to profession-specific competences. To some extent this is borne out by the sectoral data that is presented in the next section.

**2. Sectoral Analysis**

38. In this part of the report we want to draw attention to some of the issues faced by firms in the sectors surveyed. These have been suggested in part by the data that has been collected in the questionnaires but also in part by the view of experts concerned with the particular sectors that we have been able to consult. This sector analysis helps to identify the sorts of problems which firms perceive themselves to be facing and so provide some guidance as to what further information might be sought. Clearly the problems that face each of these sectors are to some extent peculiar to it, but there may also be items which are common among them.

39. Although comparable figures are difficult to obtain, an impression of the relative 'health' of each sector can be derived from examination of existing data. Of the six sectors under examination only pharmaceuticals and aerospace, have increased their trade balances between 1980 and 1992. Office electronics' trade balance has worsened slightly, but remains positive. The other three sectors have shown a significant decline, particularly the automotive sector, where a small negative balance of £172 million (1992 prices) in 1980 had increased to £2,840 million by 1992[2].

40. The UK is the world's second largest exporter of *pharmaceutical products, the eighth* largest producer, and has a trade surplus with the rest of the world of £1,427 million. Our share of the world market has, however, decreased slightly from 14.8% in 1975 to 13.6% in 1990.[3] This may not be significant as Germany which has the largest share of the world market, also decreased its share from 17.8% to 15.6% over the same period. Statistics for the US also show a decline from 7.1% in 1975 to 5.7% in 1990. Figures for France and Japan, on the other hand, show marginal increases over the same period.

41. The UK's aerospace sector in 1992 had a trade surplus of £2,340 million. However, the UK's rate of growth, when compared with competitors', is at a relatively low level. The UK aerospace sector grew by only 1.5% over the years 1980 to 1991. This compares with growth over the same period for Japan, Germany, France and the USA of 8.5%, 8.0%, 4.0% and 3.3% respectively[4].

42. The *office electronics* sector has seen a marked improvement in its trade balance in office machinery, from a negative balance of £55 million (at 1992 prices) in 1981 to a surplus balance of £191 million in 1992. Telecoms, on the other hand has seen a deterioration: from a trade surplus in 1981 of £287 million (at 1992 prices) to a surplus of only £36 million by 1992.

43. Although considered to be a successful sector *food and drink* has a negative trade balance of £3,987 million. Figures for the sector show steady growth of 17.1% over the period 1975 to 1992.[5] This contrasts with figures for Germany and France of 51.6% and 35.3% respectively. Japan's growth has been similar to the UK's, at 18.3%.

44. The UK automobile industry showed a 16.5% **decline** over the period 1975 to 1992. This again contrasts with Japan, Germany and France which had **increases** of 146.1%, 90.0%

[2] Minutes of Evidence taken by the Trade and Industry Committee, HC 702-iii, Session 1992-93.

[3] United Nations Industrial Development Organisation, Handbook of Industrial Statistics.

[4] Trade and Industry Committee's Report on British Aerospace Industry, HC 563-I, table 1

[5] Index of Industrial Output, from OECD Indicators of Industrial Activity.

and 65.0% respectively. However, the UK figures also show a 21.3% increase between 1985 and 1990, followed by a decline in 1990-1991 and slight improvement between 1991-1992. Figures for Germany reflect steady growth even in recessionary years. Japan also saw steady growth until 1992, when there was a 2.0% reduction.

45. In the *machine tool sector*, the UK's share of world exports fell from 10.4% of the world total in 1970 to 7.5% in 1980 and 5.0% in 1990[6]. Since 1985 the UK has had a trade deficit in this sector. However, between 1987 and 1991 production of machine tools in the UK grew by 15%. The two leaders in this field are Germany and Japan. Germany has seen a fairly slow decline over the period 1970 to 1990 from 33.3% of the world market to 24.6%, but still has the largest share of the world market. The Japanese industry's market share increased from 4.3% in 1970 to 22% in 1985.

46. In preparing these brief scenarios the effort has been divided between specialist advisers as follows: aerospace (IY), pharmaceuticals (GF), office machinery (SPRU), food and drink (GF), automobiles (SPRU), and machine tools (SPRU).

**Food and Drink**

47. The UK has a successful food and drink industry, including UK-owned international majors and SMEs and companies which are part of overseas-owned international groups. The food and drink industry contributes considerably more added value to the UK economy than does basic agriculture. The industry appears currently to be holding its own in international competition, and should be able to do so in the future.

48. Innovation is of great importance to the industry. However, the "linear model" in which discoveries in basic science are picked up by industry and developed into products, is particularly inappropriate for the food and drink sector.

49. Although no single model describes innovation in the industry, a usual pattern of innovation is that firms make a careful analysis of the market, including trends in consumer preferences, trends in retailing and the positioning of firms' current products and those of competitors. Then firms identify opportunities for new products and by combining technological and marketing capabilities, generate candidate products for test marketing and further development.

50. Innovation in processing technology is also important, and again tends to be 'need driven' involving continuous improvement in processing costs, through the elimination of waste, lower energy consumption, and so on. Improvement in processing technology, of course, interacts with product innovation, since lower cost and novel processing capabilities can help to generate new market opportunities.

51. Food safety is all important. Novel ways of ensuring that food and drink do not become contaminated, and of testing its safety, can be of great value to the industry. Nutritional science, including the contribution which various diets make to human health, is becoming increasingly significant, leading to many opportunities for product innovation.

52. Institutional Links. There seem to be sound links between UK institutions in this sector. These include links with universities (old and new), the AFRC (especially its Institute of Food Research, located in Reading and Norwich), the industry's research associations (for example, the Campden Food and Drink Research Association, covering the industry as a whole, and located at Chipping Campden) and industrial firms, large and small, although there appear to be some difficulties in ensuring small companies were part of the network.

53. This network provides a continuous flow of information about technology, markets, safety matters and regulatory issues. It provides an accessible resource for problem-solving and idea-generation. In some ways, this network is similar to the successful networks in the electromechanical industry sector so evident in Germany. If this comparison is correct, it is

[6]Table 7.5.

an important indication that a dispersed system of technological interaction, including SMEs as well as large firms, can work in the UK. Because this sector is increasingly drawing on the chemicals and biological sectors of the Science Base, some respondents mention close, direct links with the university sector. Equally, the technologies of packaging are driven by design and safety considerations and probably have indirect linkages to the physics base but these were not reported as such.

54. Model 3 clearly applies to some extent in this sector since there are several large firms with strong R&D centres in the industry. However, large firms also appear to use Model 5, since they are included in the innovation networks which are a feature of the industry. The industry provides many examples of mergers and acquisitions, and of both management buy-out and buy-ins. From this perspective Model 4 applies. Many competences relevant to the industry are not firm-specific.

55. The networking model, Model 5, applies to much of the industry, with profession-specific competences to the fore, in marketing as well as in technological areas. Networking extends outside the Food and Drink industry proper, into links with farmers on the one hand, and with retailers on the other. The House of Commons Agriculture Committee's Second Report (The Trade Gap in Food and Drink)) makes the point that the expansion of this cross-sector networking is important in the UK.

56. The real depth of involvement of this sector with the Science Base may still be obscured by the fact that much innovation in the sector lies in packaging where design is crucial. The use of new materials in packaging clearly depends upon developments in chemistry but the food and drink sector may leave this aspect of the innovative process to its suppliers.

**Pharmaceuticals**

57. Over half the respondents commented on the importance of NHS procurement policies for the UK pharmaceutical industry. Firms wanted a better dialogue between the NHS and industry, more attention to novel drugs and to the effects on export by UK industry, and more cost/benefit analyses, rather than simply concentrating on the drugs bill. The Pharmaceutical Price Regulation Scheme (PPRS) was being reconsidered during the period when the responses to the questionnaires were being prepared. This reconsideration is now complete and the impact of the new arrangements needs to be carefully monitored.

58. Pharmaceuticals is one of the UK's most successful industries and this success is based on continuing innovation. It appears from the responses so far received that the factors supporting innovation include:-

(1) The quality of UK academic science, at least in the fields of biology and chemistry, and the well-trained people it produces.

(2) The UK's system for the regulation through clinical trials of new drugs. The system appears to combine rigour with speed and a certain flexibility.

(3) The support for innovation provided by NHS purchasing, notably the Pharmaceutical Price Regulation System.

(4) For the future the establishment in London of the European Medical Evaluation Agency will be important for the UK and for the development of new drugs in Europe. The location of the Agency in London increases the possibility that procedures developed in the UK and which are highly valued by industry and government in other countries will be incorporated into standard operating procedures of the new Agency.

59. Detailed responses, particularly those from Sir Richard Sykes, Deputy Chairman and Chief Executive of Glaxo plc, and Dr Brian Newbold, support the above analysis of those factors specific to the UK which favour innovation in the industry.

60. Institutional links. By comparison, for example, with motor vehicles, this sector does not involve continuous sequence of design-based product/process improvements. According to the hypothesis advanced above, linkages between the Science Base and the pharmaceutical industry should appear more prominently because they are not buried in the complexity of the design process. Indeed, this is borne out by the responses in the questionnaires.

61. A number of comments were made on the strength and industrial relevance of the UK Science Base. Most felt that it was a major asset, and should be protected. Favourable comments about the LINK and CASE schemes were made by four respondents. One firm commented that university industrial liaison offices needed to become much more professional. Another supported the White Paper's new approach to PhD training, involving an initial Masters degree, and emphasised that curiosity-driven and mission-driven research were not antithetical.

62. Of all the sectors, pharmaceuticals appear to have the most explicit links to the Science Base. As indicated, this may be due to the fact that there is little dependence upon the design process. The pharmaceutical industry is chemistry-and biology-based and this may account for the fact that more direct linkages with universities, for example, are perceived to be important.

63. It is clear that until ten years ago, Model 3 was by far the most important one in the industry and still describes much of the industry's pattern of innovation. However, the revolution in biology and the rapid growth of biotech firms (there are now some 1200 biotech firms in the US, mainly in health care) has changed the picture. As a consequence Model 2 is becoming more significant. The journal Bio/Technology (Vol.11, No. 11, p. 1212, November, 1993) quotes John Wilkinson, Chairman of the largest heath care consultancy firm in the US, as saying that: "several leading pharmaceutical companies plan to shift between 35% and 50% of their internal research spending to biopharmaceutical companies."

64. There are a limited number of examples of the spin out model — Model 4, while Model 5 applies to the industry in general, to some extent, and to bio-tech firms in particular.

65. Before the emergence of biotech, in the area of medicinal chemistry, firm specific competences were all-important in research. That has changed a great deal, with academics now moving to senior research positions in the biotech and pharmaceutical industries, and vice versa. In development, firm-specific competences remain important, with some firms being able to develop drugs much more rapidly than others, through superior firm architecture.

**Office Electronics**

66. The office electronics sector is a highly competitive global industry. It is characterised by a transition from hard to soft technologies; that is away from equipment manufacturing towards software development. The industry has the view that the lack of long term vision and consequent investment in telecoms on the part of UK government means that the industry is falling behind the US and Japan. Nonetheless, the competitive environment keeps most of the firms in the sector ahead of European competition, possibly because the demand for new products and services is stronger in Japan, US, Taiwan, than in the UK or Europe.

67. Institutional links. When developing a new scientific field, some firms indicated that they would approach universities, but in relation to technology or marketing expertise they would be more likely to make use of a wider range of knowledge producing organisations and marketing firms as well as DTI. Interestingly some firms indicated that when seeking to open up new business opportunities they would first think of approaching DTI. In this sector, the interaction is primarily with the physics base, but because of the importance of design these relationship tended not to be perceived as important.

68. Again Model 3 was the most common one in this industry, with IBM as the industry leader doing most of its R&D in-house, including the Hursley Laboratory in the UK, Model 1 is also used on occasion. But the industry in now shifting rapidly towards Models 4 and 5, as large firms de-centralise and as Silicon Valley culture spreads to the UK, as, for example, to the areas around Cambridge.

**Machine Tools**

69. This sector regards itself as threatened for a variety of reasons. For example, some believe that tax and depreciation allowances, particularly in Japan and Taiwan tend to depress the opportunities for the UK. Others feel that though the UK has capacity for innovation in this sector, the market place is not sufficiently open to innovation. The view is that Japan, by contrast, has a more innovative culture, and that the industrial base is more focused, perhaps under the encouragement of MITI. The US and France favour large investments while the UK prefers to move forward in incremental steps. Some firms focused on the cost of borrowing, on energy and transportation costs as important sources of a depressed rate of innovation. For some, the UK sector is characterised by short-termism; by lack of support and strategy for UK manufacturing industry generally. Government support is too restrictive if a company is not an SME. Funds are only available for projects not close to the market. Firms feel that this policy should be more flexible. (The main threat to the machine tool industry is from the collapse of the UK market (and other markets in a world wide recession)). See also the evidence given by Mike Bright regarding the three key technologies post 1930, and the types of customer-encouragement to buy the latest technology used by the Japanese government. Hey (ref) points to a cascade effect on the machine tools sectors of behaviour in other sectors; for example in CD's, videos and books — where large companies reduce investments in order to survive a recession and as a consequence UK machine tool companies experience a collapse in orders, banks get nervous. Since many machine tools firms are SME's they are most vulnerable to prolonged order loss and are threatened with collapse.

70. Institutional links. A few firms in the sector indicated that if they needed to learn about a new scientific field they would either approach universities or perhaps AMTRI. For new technologies or to explore new business opportunities they would tend, in the first instance, to go to either customers or suppliers. This sector is an instance, par excellence, of the importance of design. Again links to the Science Base through physics are not perceived to be as relevant as links to customers and suppliers.

71. This is an industry which has traditionally operated within Model 3, but which moved towards Model 5 when electronics became essential to the innovation process. It now appears to be moving back to Model 3, while retaining an element of Model 5, since major tool users are increasingly being networked into the innovation process.

72. Possibly as new materials become more important in manufacturing, there will be an increasing shift towards Models 2 and 5, since firm-specific competences may no longer be the key to innovation. If so, this may present an opportunity for the UK to improve its weak position in machine tools, providing the academic base in materials science remains strong.

**Motor Vehicles**

73. The changing importance of technology and innovation to the firm is a direct result of increasing competitiveness internationally and increasing customer sophistication plus growth in importance of environmental legislation. Some firms believe that their competitiveness could be enhanced by tighter control of inflation, by reform of trades union legislation, by more grants to support CAD/CAM installations, and by creating schemes which provide higher quality technicians and apprentices. Recently the industry has been trying to improve its innovative performance by adopting the techniques of lean production.

74. There is widespread agreement on the need to enhance the overall competitiveness of the motor vehicle sector through the harmonisation of standards, by developing a more integrated approach to the standard setting process, and by reducing the costs of environmental legislation. Companies have also indicated that they need assistance in their export activities. This is accomplished in part through low inflation, competitive exchange rates, educated workforce, etc., but also through good diplomatic relations to encourage some export markets, for example, in China. A regimen is needed in which there is reduced emphasis on acquisition cost and short term budgetary constraints. Procurement policy needs to be more positive by encouraging the take up of new innovative products — eg electric vehicles.

75. Institutional links. The motor vehicles industry's relationships with the Science Base are extensive but not strategic (The Rover-Warwick University Programme may be an exception). Interactions are through universities when companies want to acquaint themselves with a new scientific field but the frequency with which this type of information is required is not high. Help with new technologies is more frequently required and in these cases firms are more likely to go to customers, suppliers or other component manufacturers. There is a long tradition of knowledge exchange using supplier/customer networks. These links are very important to the overall pace of innovation. Interestingly, some firms believe that the pace of innovation would be improved if Government could reduce delays by evaluating applications for grants more quickly, and by extending programmes like EUREKA beyond the pre-competitive phase. Tax concessions for R&D are essential, but so is the need for government and industry working together to find imaginative ways of reducing the company burden of R&D funding. In general, there is a need to improve attitudes towards manufacturing as opposed to the service industries, and to help change the relatively poor image that engineering and engineers currently enjoy.

76. Historically, this sector is driven by design and so innovation is perceived to be influenced more by customers and suppliers, than by links with universities. But with the electronics, automation, software and new materials being absorbed into the design process, new linkages may emerge with the Science Base. An exemplar of what is possible in terms of technological innovation and international competitiveness in the motor vehicle industry is given by the UK record in the production of Formula 1 racing cars. For some this is a good indicator of what is possible when innovation is not hog-tied by finance and short-termism.

77. A networking model, like Model 5 but involving large firms, is increasingly relevant to this industry, as component suppliers are drawn more closely into the innovation processes of large firms. University involvement is still largely along the lines of Model 1, with some exceptions such as Rover-Warwick Programme. A small high-tech model, on the lines of Models 2 and 4 also applies. The UK has strong specialist motor vehicle manufacturers and research/consultancy firms.

**Aerospace**

78. The industry has for a number of decades been one of the most globalised, with innovation driven by strong rivalry in both commercial and military aviation. The world market has a very strong US presence arising from long-term government policy, a high per capita GDP and a large domestic passenger market. In all countries with a significant aerospace industry there is a degree of government support, and there is a strong natural technological interface between civil and military aeronautics. Both sectors are characterised by the long timescale for major projects, typically five to ten years for the development phase, followed by twenty (or more) years of quantity production and incremental development of the type, often followed by a further couple of decades in service. In military programmes the R&D is almost invariably funded by government as the initial, usually the only, customer; government assistance is usually given for some types of civil R&D (eg aerospace) and also for risk reduction in relation to the cyclical economic effects arising from the long term nature of civil development and production, as in the case of re-payable 'launch-aid' made available by the DTI to UK airframe and engine manufacturers.

79. Industrial structure is characterised by three groups of companies. The assemblers responsible for the overall design and development and delivery to the customer (eg British aerospace, Boeing etc), the engine manufacturers (Rolls-Royce etc) and the major equipment suppliers. The competitive edge of industry is determined by the ability to manage the process of overall design, which integrates a large number of sub-systems into a safe and reliable whole, with a margin of performance and price over those aircraft already available or in service.

80. Links with physics-based science tend to predominate, but industrial structure and the many types of technology involved mean that examples of all models 1 to 5 can be found. Historically the role of government research agencies (NASA in US, RAE Farnborough in UK etc) has been very important, with linkages to the 'HE Science Base' less so, but nevertheless an important element in the operation of 'overall networking' and essential in

maintaining the supply of well trained people for industry. This is inevitable in an industry where the cutting edge of innovation is within the companies and contact with the 'Science Base' is at its strongest in solving the many problems which inevitably arise during the design and development phases, particularly when new phenomena emerge in a disguised form, for the first time.

81. Since the 1960's there has been a determined move towards international collaboration, particularly within Europe. This is partly to ensure competitive capability to prevent US dominance (eg Airbus relative to Boeing), but also as the only effective way to manage the fewer, but larger and increasingly expensive programmes, which are arising. This has resulted in steadily increasing levels of co-operation between the European companies which have developed the ability to both compete on some projects and collaborate on others; this requires each to maintain its own knowledge base, or intellectual property, at a high level in order to be able to compete effectively for a share of the next programme, while sharing existing knowledge with a wide variety of companies on current programmes.

82. Companies have increasingly turned to collaboration on basic, or pre-competitive Research programmes, using the BRITE and EURAM models and seeking funding from the European Commission, to supplement their own investment and the funds from national governments. There is evidence that despite these efforts there is a short fall relative to the US, where more substantial funding is made available to domestic industry through a variety of sources including 'dual-mode' technology defence funding.

83. Due to the high degree of co-operation within Europe, and also with US companies, there is a considerable degree of transparency as regards both professional and organisational competences, and the adaptation of industrial company architectures to the evolving environment, economic and military, is relatively clear. Further European integration will involve company mergers, a phase which has already started.

GENERAL CONCLUSIONS

84. As the external environment becomes more dynamic and competitive, there is some evidence of a shift from a rather passive reliance on new technology arising independently from the Science Base (Model 1) to the more interactive modes characterised by Models 4 and 5. As firm architecture comes to interact more closely with other knowledge bases, the dominant competence in the innovation process is shifting from firm-specific ones to profession-specific ones, the latter exhibiting the quality of flexibility and interchangability in their interaction with knowledge bases held by others. In making such generalisations care needs to be taken as to the characteristics which govern the innovation process in specific sectors. At the same time the identification of linkages to the chemical and biological sections of the Science Base become more explicit, even though firms that rely heavily on design still exhibit indirect and therefore less easily identified interactions with the Science Base. In this, physics and materials science seem to be undervalued in terms of their contributions to firms' competitiveness.

85. A further implication of this shift in policy relates to the kinds of facilitation that can be performed by government and the sorts of management training that needs to be provided by (and for) industry.

86. For example, a strong influence on the way innovation takes place in industry, particularly the UK industry, is the trend towards decentralisation of R&D away from corporate labs to divisional or factory levels. This trend, sometimes involving the complete closure of corporate R&D, has been mentioned by several witnesses.(see evidence from R. Coombs of Cromtech [UMIST]). Also some industries (aerospace, environmental effects, eg $CO_2$ emissions etc.) still depend on large scale facilities such as wind tunnels etc which eventually can only be funded at the national level or at the international level (aerospace since 1960s) in Europe.

87. This move indicates a weakening of Model 3 overall, giving more scope for Models 2 and 5. It is also a move away from firm-specific competences to professional ones, which in part explains the growing perception of the need for an expansion in training in technology

management. In the past, much of such training was firm-specific. Now, there is a need for people who can manage technology and innovation networks, and they will have to be trained by the engineering faculties/business schools. At the same time, to the extent that sectors depend on the new technologies based upon materials science, molecular biology, computers and telecommunications linkages with the Science Base are becoming more numerous and explicit.

# APPENDIX 2

## Questionnaire Statistical Analysis

*Questionnaire Analysis by the Science Policy Research Unit at the University of Sussex*

*Note:* Answers "Q" are from both questionnaires. If the question number in questionnaire B is different the number is also given (BX.X). Where answers only refer to questionnaire A, answers are numbered "A". In answers to both questionnaires, answers to questionnaire A are occasionally separated out and presented in square brackets [ ].

## 1: Background

### Industry Groups

| Industry | All Responses | Responses to Questionnaire A |
|---|---|---|
| Aerospace | 13 | 4 |
| Automobile | 17 | 3 |
| Food and Drink | 12 | 3 |
| Machine Tools | 11 | 2 |
| Office Equipment | 10 | 2 |
| Pharmaceuticals | 16 | 3 |

### Q1.2: Company Status

| Status | Number | Questionnaire A |
|---|---|---|
| Independent | 28 | 6 |
| UK Subsid | 17 | 4 |
| UK Division | 3 | 1 |
| Foreign Subsid | 27 | 6 |
| Close Company | 4 | 0 |

Foreign subsidiaries: 2 Canadian, 2 French, 2 German, 3 Japanese, 1 Swiss, 15 US, 3 not given.

### Sectoral Analysis

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Independent | 6 | 4 | 6 | 2 | 2 | 9 |
| UK Subsid | 4 | 6 | 4 | 3 | — | — |
| UK Division | 1 | 1 | — | — | — | 1 |
| Foreign Subsid | 3 | 5 | 1 | 4 | 8 | 6 |
| Close Company | — | 1 | 1 | 2 | — | — |

### Q1.3: Turnover 1991-92 and Annualised Rate of Growth 1981-82 to 1991-92 (adjusted for inflation)

| Turnover 1991-92 | No. | (Per cent) | QA |
|---|---|---|---|
| £0-£10.0 million | 12 | (16) | 1 |
| £10.1-£100.0 million | 24 | (31) | 4 |
| £100.1-£1,000.0 million | 22 | (29) | 5 |
| £1,000.1+ | 19 | (25) | 7 |
| Not given | 2 | | — |

| Growth 1981-91 (per cent) | No. |
|---|---|
| Negative to −5.1 | 1 |
| −5.0 to −0.1 | 5 |
| 0.0 to 5.0 | 2 |
| 5.1 to 10.0 | 3 |
| 10.0+ | 3 |

3 inadequate data

### Turnover: Sectoral Analysis

| Turnover 1991-92 | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| £0-£10.0 million | 1 | — | 3 | 4 | 1 | 3 |
| £10.1-£100.0 million | 2 | 9 | 1 | 6 | 1 | 5 |
| £100.1-£1,000.0 million | 8 | 2 | 3 | — | 6 | 3 |
| £1,000.1 million + | 2 | 5 | 5 | — | 2 | 5 |
| Not given | — | 1 | — | 1 | — | — |

**Q1.4: Employment 1991-92, and Annualised Rate of Growth 1981-82 to 1991-92.**

| Employment | No. | (Per cent) | QA | Growth 1981-91 (per cent) | No. |
|---|---|---|---|---|---|
| 0-100 | 10 | (13) | — | Negative to −5.1 | 1 |
| 101-500 | 20 | (25) | 4 | −5.0 to −0.1 | 4 |
| 501-2,500 | 14 | (18) | 2 | 0.0 to 5.0 | 3 |
| 2,501-10,000 | 16 | (20) | 4 | 5.1 to 10.0 | 1 |
| 10,001+ | 19 | (24) | 7 | 10.0+ | 2 |

6 inadequate data

**Employment 1991-92: Sectoral Analysis**

| Employment | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1-100 | 1 | — | 3 | 2 | 2 | 2 |
| 101-500 | 2 | 5 | — | 8 | — | 5 |
| 501-2,500 | — | 6 | 2 | 1 | 2 | 3 |
| 2,501-10,000 | 8 | 1 | 2 | — | 4 | 1 |
| 10,001+ | 2 | 5 | 5 | — | 2 | 5 |

**Turnover per Employee, 1991-92 (£'000)**

| TO/Emp | All[A] | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|---|
| To 50.0 | 13[3] | 2 | 3 | 3 | 2 | 1 | 2 |
| 50.1-75.0 | 22[4] | 7 | 8 | 2 | 4 | — | 1 |
| 75.1-100.0 | 14[3] | 2 | 1 | 1 | 3 | 3 | 4 |
| 100.1-150.0 | 17[5] | 1 | 4 | 3 | 1 | 3 | 5 |
| 150.1+ | 13[2] | 1 | 1 | 3 | 1 | 3 | 4 |

**Q1.6: Percentage of turnover derived from products newly introduced in the past . . . (except last column—percentage of turnover derived from products over 7-years-old)**

| Per cent | 3 years | 4-5 years | 6-7 years | Over 7 years |
|---|---|---|---|---|
| 0-5.0 | 8 | 8 | 9 | 15 |
| 5.1-10.0 | 16 | 7 | 7 | 5 |
| 10.1-25.0 | 12 | 24 | 25 | 3 |
| 25.1-50.0 | 10 | 14 | 12 | 20 |
| 50.1-100 | 10 | 3 | 3 | 13 |

No details: 23

**Sectoral Analysis: Percentage of turnover derived from products introduced . . .**
**A. In the past 3 years**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-5.0 | — | 2 | 2 | — | — | 4 |
| 5.1-10.0 | 5 | 1 | 4 | 1 | 1 | 4 |
| 10.1-25.0 | 3 | — | 3 | 3 | — | 3 |
| 25.1-50.0 | 2 | 5 | 1 | 1 | 1 | — |
| 50.1-100 | — | 2 | — | 3 | 5 | — |

**B. Over 7 years ago**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-5.0 | 1 | 5 | — | 4 | 4 | 1 |
| 5.1-10.0 | 2 | — | — | 1 | 2 | — |
| 10.1-25.0 | 1 | — | 2 | — | — | — |
| 25.1-50.0 | 6 | 4 | 5 | 2 | 1 | 2 |
| 50.1-100 | — | 1 | 3 | 1 | — | 8 |

**Q1.7: Percentage of output exported, 1991-92**

| Exported per cent | No. (per cent) | QA |
|---|---|---|
| 0-10.0 | 25 (35) | 6 |
| 10.1-50.0 | 17 (24) | 4 |
| 50.1-75.0 | 15 (21) | 2 |
| 75.1-100.0 | 14 (20) | 3 |
| Not given | 8 | 1 |

**Sectoral Analysis**

| Exported per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-10.0 | 1 | 3 | 10 | 2 | 3 | 6 |
| 10.1-50.0 | 5 | 7 | 1 | 2 | 1 | 1 |
| 50.1-75.0 | 4 | 5 | — | 4 | — | 2 |
| 75.1-100.0 | 3 | 1 | 1 | 3 | 3 | 3 |
| Not given | — | 1 | — | — | 3 | 4 |

**A Change in proportion of output exported, 1981-82—1991-92**

| Increased | Same | Reduced |
|---|---|---|
| 9 | 4 | 2 |

No answer 2

**A1.10: Is your share of the . . .**

| | Increasing | Stable | Decreasing |
|---|---|---|---|
| World Market | 5 | 5 | 4 |
| UK Market | 2 | 9 | 4 |

No answer: World market 3, UK market 2.

| World Market Share | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Increased | 1 | 1 | 1 | — | 1 | 1 |
| Stable | 1 | 1 | 1 | 1 | — | 1 |
| Decreased | 1 | 1 | — | 1 | 1 | — |

| UK Market Share | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Increased | 1 | — | — | — | 1 | — |
| Stable | 2 | 1 | 3 | 1 | 1 | 1 |
| Decreased | — | 2 | — | 1 | — | 1 |

**A For your main product type(s)**

| | Increasing | Stable | Decreasing |
|---|---|---|---|
| Export Markets | 8 | 3 | 3 |
| UK Market | 4 | 5 | 6 |

No answer: Export markets 3, UK market 2.

**A1.11: What percentage of the following functions are conducted in the UK:**
**a: For your company**

| | Less than 50 per cent | 51 to 99 per cent | All (100 per cent) |
|---|---|---|---|
| Research | 3 | 5 | 7 |
| Design | 3 | 5 | 5 |
| Development | 3 | 7 | 5 |
| Production | 5 | 4 | 5 |
| Purchasing | 2 | 6 | 5 |
| Sales | 5 | 4 | 5 |
| Financial Management | 2 | 4 | 9 |

Totals do not always equal 17 due to non-relevance.

**b: For your parent company (if you are a subsidiary company).**

| | Less than 50 per cent | 51 to 99 per cent | All (100 per cent) |
|---|---|---|---|
| Research | 4 | 1 | 1 |
| Design | 4 | 1 | 1 |
| Development | 4 | 1 | 1 |
| Production | 4 | 1 | 1 |
| Purchasing | 2 | 0 | 1 |
| Sales | 3 | 1 | 1 |
| Financial Management | 2 | 0 | 1 |

**A1.13: What is the importance of the following factors in determining competitiveness in your sector of the market? (Rank 1 to 5, 1=not important, 5=crucially important).**

| | 1 | 2 | 3 | 4 | 5 | Ave |
|---|---|---|---|---|---|---|
| Price | — | — | 2 | 7 | 7 | 4.3 |
| Quality | — | — | 1 | 2 | 13 | 4.7 |
| Service | — | 1 | — | 8 | 7 | 4.3 |
| Innovation | — | 3 | 3 | 2 | 8 | 3.9 |

No answer: 1.

**Sectoral Analysis: Price**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — |
| 2 | — | — | — | — | — | — |
| 3 | — | — | 1 | — | — | 1 |
| 4 | 2 | — | 1 | 1 | 2 | 1 |
| 5 | 2 | 3 | 1 | 1 | — | — |

**Sectoral Analysis: Quality**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — |
| 2 | — | — | — | — | — | — |
| 3 | 1 | — | — | — | — | — |
| 4 | 1 | — | — | 1 | — | — |
| 5 | 2 | 3 | 3 | 1 | 2 | 2 |

**Sectoral Analysis: Service**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — |
| 2 | 1 | — | — | — | — | — |
| 3 | — | — | — | — | — | — |
| 4 | 1 | 1 | 1 | 1 | 2 | 2 |
| 5 | 2 | 2 | 2 | 1 | — | — |

**Sectoral Analysis: Innovation**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — |
| 2 | 1 | — | — | — | 2 | — |
| 3 | 2 | — | — | 1 | — | — |
| 4 | — | 1 | 1 | — | — | — |
| 5 | 1 | 2 | 2 | 1 | — | 2 |

**A1.15: Have you manfactured products under licence during the last five years?**
Yes: 9, No: 8.

**A1.16 a: What percentage of current sales do licenced products represent?**
**b: What percentage of value does this represent?**

| Percentage of current sales | No. |
|---|---|
| 0 (none) | 2 |
| 0.1-5.0 | 2 |
| 5.1+ | 2 |

No details: 3

| Percentage of value | No. |
|---|---|
| 0 (none) | 2 |
| 0.1-20 | 2 |
| 20.1+ | 2 |

No details: 3

**A1.18: If you do have a licencing-in policy, is licencing-in products becoming more or less important to your company? (Rank 1 to 5, 1=much less important, 3=same, 5=much more important.)**

| 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 7 | — | 3.4 |

Not relevant: 7.

**A1.20: Does your company have an overseas operation?**
Yes: 11, No: 6.

**A1.21: If "yes", which of the following activities do you perform abroad?**

| | Yes | No |
|---|---|---|
| Marketing, Sales and Distribution | 11 | 0 |
| Servicing | 9 | 2 |
| Product Development | 9 | 2 |
| Product Adaption | 8 | 3 |
| Manufacturing | 8 | 3 |
| Other | 2 | 9 |

Not relevant: 6.

**A1.22: Are your foreign based operations:**

| | Increasing | Stable | Decreasing |
|---|---|---|---|
| Marketing and Sales | 9 | 2 | 0 |
| Distribution | 7 | 3 | 0 |
| Servicing | 4 | 5 | 0 |
| Product Development | 4 | 4 | 0 |
| Product Adaption | 5 | 3 | 0 |
| Manufacturing | 5 | 3 | 1 |
| Other | 2 | 1 | 0 |

Totals are not consistent due to non-relevance.

**A1.24: Do you, in general, consider yourself to be an innovative company?**
Yes: 17, No: 0.

## 2: Company Policy and Structure

**A2.1: Does your company have a stated long-term vision?**
Yes: 17, No: 0.

**A2.3: What is the time span of your corporate strategy?**

| 1-3 years | 3-5 years | 5-10 years |
|---|---|---|
| 1 | 5 | 11 |
| 6 per cent | 29 per cent | 65 per cent |

**Sectoral Analysis**

| Time Span | Aero | Auto | Food | M/ Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1-3 years | — | — | — | 1 | — | — |
| 3-5 years | — | 1 | 2 | 1 | 1 | — |
| 5-10 years | 4 | 2 | 1 | — | 1 | 3 |

**A2.4: How do you rate the importance of the following in achieving a competitive edge for your products? (1=not important, 5=crucially important).**

| | 1 | 2 | 3 | 4 | 5 | Ave. Rank |
|---|---|---|---|---|---|---|
| Product design | — | — | — | 3 | 11 | 4.8( 2) |
| Product reliability | — | — | — | — | 14 | 5.0( 1) |
| Product customisation | — | 2 | 3 | 5 | 3 | 3.7(10) |
| Product durability | — | 2 | 1 | 3 | 6 | 4.1( 8) |
| Safety features | — | — | 2 | 1 | 11 | 4.6( 4) |
| User-training facilities | 2 | 2 | 3 | 4 | 1 | 3.0(14) |
| After-sales services | — | — | 3 | 3 | 7 | 4.3( 6) |
| Credit arrangements | 2 | 5 | 5 | 3 | — | 2.6(15) |
| Life cycle costs | 1 | — | 5 | 3 | 4 | 3.4(13) |
| Quality of process technology | — | 1 | 3 | 7 | 4 | 3.9( 9) |
| Quality and reliability of output | — | — | — | 3 | 12 | 4.8( 2) |
| Environmental impact | — | 2 | 5 | 5 | 2 | 3.5(11) |
| Innovation | — | — | 4 | 2 | 9 | 4.6( 5) |
| Relationship with suppliers | — | — | — | 7 | 7 | 4.5( 6) |
| Tariff barriers | 6 | 2 | 3 | 2 | 2 | 2.5(16) |
| Non-tariff barriers | 6 | 1 | 4 | 2 | 2 | 2.5(16) |
| Regulatory requirements abroad | 1 | 1 | 7 | 2 | 4 | 3.5(11) |

Totals do not equal 17 due to non-relevance, and no answers.

**Sectoral Analysis: Average Scores**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Product design | 4.7 | 5.0 | 5.0 | 5.0 | 4.0 | nr |
| Product reliability | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | nr |
| Product customisation | 3.7 | 4.3 | 3.0 | 4.5 | 3.0 | nr |
| Product durability | 4.3 | 5.0 | 2.5 | 5.0 | 3.0 | nr |
| Safety features | 5.0 | 5.0 | 5.0 | 4.5 | 3.0 | nr |
| User-training facilities | 2.7 | 2.0 | 2.5 | 4.5 | 4.0 | nr |
| After-sales services | 4.0 | 4.0 | 4.5 | 5.0 | 5.0 | nr |
| Credit arrangements | 2.3 | 2.7 | 2.2 | 3.0 | 3.5 | 2.5 |
| Life cycle costs | 4.0 | 3.0 | 3.5 | 5.0 | 3.5 | nr |
| Quality of process technology | 3.3 | 4.3 | 4.7 | 4.5 | 2.5 | 4.0 |
| Quality and reliability of output | 4.7 | 5.0 | 5.0 | 4.5 | 5.0 | 4.5 |
| Environmental impact | 2.3 | 4.7 | 4.0 | 3.0 | 3.5 | nr |
| Innovation | 3.3 | 5.0 | 5.0 | 4.0 | 3.5 | 5.0 |
| Relationship with suppliers | 4.3 | 5.0 | 4.3 | 4.5 | 4.5 | nr |
| Tariff barriers | 2.3 | 3.3 | 1.7 | 3.0 | 3.5 | 1.0 |
| Non-tariff barriers | 2.7 | 2.3 | 2.0 | 3.0 | 3.0 | 2.5 |
| Regulatory requirements abroad | 3.3 | 4.3 | 2.3 | 3.0 | 3.0 | 5.0 |

nr=not relevant

**A2.5: Do you have an explicitly stated technology strategy?**
Yes: 13, No: 4.

**A2.7: How does your management of design compare with your competitors?**

| Better | Worse | Don't know |
|---|---|---|
| 9 | 2 | 4 |

No answer: 2.

**Q2.9** (B2.1): **Do you employ integrated (multi-functional) teams during product development?**
Yes: 73, No: 4 (No answer: 2) [Yes: 17, No: 0]

**Q2.11** (B2.3): **Is the notion of the "product champion" or "project champion" one which your company . . .**

| | Per cent |
|---|---|
| Utilises on a regular basis | 53 (68) |
| Occasionally uses | 17 (22) |
| Does not use | 4 ( 5) |
| Is not familiar with | 4 ( 5) |

Not relevant: 1.

**Sectoral Analysis**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Uses regularly | 10 | 14 | 7 | 6 | 7 | 9 |
| Occasionally uses | 2 | 3 | 3 | 3 | 1 | 5 |
| Do not use | 1 | — | 1 | — | — | 2 |
| Not familiar with | — | — | 1 | 2 | 1 | — |

**Q2.12** (B2.5): **Do you utilise a formal, quantitative project appraisal system to help you decide on new projects and chose between alternative products?**
Yes: 59, No: 19, (No answer: 1) [Yes: 16, No: 1]

**Sectoral (Y/All):** Aero 12/13, Auto 14/17, F: 8/12, M/Tool 5/11, Office 7/9, Pharm 13/16

**Q2.13** (B2.6): **If "yes", does the system have inputs?**

| | |
|---|---|
| Only from R&D, Design, or | 1[ 0] |
| Other technical functions, or | 3[ 1] |
| From all company functions | 54[15] |

1 Other [1 Other].

**Q2.17** (B2.10): **Do you engage in joint ventures or partnerships to develop new products?**
Yes: 69, No: 10, [Yes: 15, No: 2]

**Sectoral (Y/All):** Aero 13/13, Auto 15/17, F: 7/12, M/Tool 11/11, Office 8/10, Pharm 15/16

**Q2.17b** (B2.10b): **If "yes", does this arise from:**

| | |
|---|---|
| Free choice | 46[10] |
| Customer requirements | 31[ 9] |
| Other | 12[ 1] |

Some respondents gave more than one reason.

**A2.18: During the past five years, which percentage of: A. new products, and B. improved products, have derived from ideas put to you by your customers?**

| New Products Per cent | No. |
|---|---|
| 0 (none) | 3 |
| 1-10 | 5 |
| 11-50 | 2 |
| 51-99 | 0 |
| 100 | 2 |

No details: 5.

| Improved Products Per cent | No. |
|---|---|
| 0 (none) | 2 |
| 1-10 | 4 |
| 11-50 | 3 |
| 51-99 | 1 |
| 100 | 1 |

No details: 6.

## 3: Research & Technology, Design and Development Activities (RTDD)

**Q3.1: Turnover devoted to RTDD:**

| Per cent | 1981-82 (Per cent) | 1986-87 (Per cent) | 1991-92 (Per cent) |
|---|---|---|---|
| 0-2.0 | 13 (27) [4] | 10 (18) [3] | 13 (20) [3] |
| 2.1-5.0 | 11 (23) [3] | 16 (28) [3] | 17 (27) [5] |
| 5.1-10.0 | 10 (21) [2] | 14 (25) [4] | 12 (18) [2] |
| 10.1-50.0 | 10 (21) [4] | 12 (21) [4] | 15 (23) [4] |
| 50.1-100.0 | 4 (8) [0] | 5 (9) [1] | 7 (11) [2] |
| Not given | 31 [4] | 22 [2] | 15 [1] |

**Sectoral Analysis, 1991-92**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-2.0 | — | — | 8 | 2 | 3 | — |
| 2.1-5.0 | 3 | 8 | 2 | 2 | — | 2 |
| 5.1-10.0 | 3 | 2 | — | 2 | 1 | 4 |
| 10.1-50.0 | 3 | 2 | — | 2 | 2 | 6 |
| 50.1-100.0 | 2 | 1 | 1 | — | 1 | 2 |

**Change in proportion of turnover devoted to RTDD 1981-82 to 1991-92**

| Increased | Same | Reduced |
|---|---|---|
| 26 [8] | 14 [4] | 8 [1] |

Insufficient data: 31 [4].

**Sectoral Analysis, 1991-92**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Increased | 4 | 7 | 1 | 3 | 2 | 9 |
| Same | 0 | 2 | 6 | 3 | 2 | 1 |
| Reduced | 3 | 1 | 0 | 1 | 2 | 1 |

**Q3.2: Is the head of any of these functions a main Board member?**
Yes: 50, No: 29, [Yes: 11, No: 6]

**Sectoral (Y/All):** Aero 8/13, Auto 9/17, Food 1/12, M/Tool 9/11, Office 8/10, Pharm 15/16

**Q3.3: Do you have a separate R&D lab?**
Yes: 55, No: 24, [Yes: 14, No: 3]

**Q3.3b: Where is it located?**

| UK | Overseas | Both |
|---|---|---|
| 27[8] | 13[3] | 15[3] |

**A3.4: If you are a multi-divisional company/part of a group, does the group have a central R&D lab?**
Yes: 9, No: 5, Not relevant: 3.

**If "yes", where is this located?**

| UK | Overseas | Both |
|---|---|---|
| 4 | 2 | 3 |

**A3.5: If "yes", what percentage of R&D is expended in the central lab?**

| Per cent | No. |
|---|---|
| 0-5 | 3 |
| 6-50 | 3 |
| 51-60 | 2 |

No details: 1.

**Q3.6a (B3.4a): How many of the following do you employ full time in your technical function?**

| | Graduate scientists/ engineers | Postgraduate scientists/ engineers | Technicians | Other support staff |
|---|---|---|---|---|
| 0-10 | 18[2] | 34[5] | 19[2] | 28[3] |
| 11-50 | 13[1] | 12[2] | 20[4] | 11[3] |
| 51-500 | 23[7] | 13[5] | 10[3] | 16[5] |
| 501-2,500 | 9[4] | 4[2] | 14[5] | 8[3] |

Insufficient or no details: 16[3].

**Q3.6b (B3.4b): Proportion of employees that are graduates or post graduates in the technical function**

| Per cent | Number (Per cent) |
|---|---|
| 0-1.0 | 15(23)[3] |
| 1.1-5.0 | 17(27)[2] |
| 5.1-10.0 | 13(20)[4] |
| 10.1-50.0 | 14(22)[4] |
| 50.1-100 | 5( 8)[1] |

No details: 15[3].

**Sectoral Analysis**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-1.0 | 1 | 3 | 9 | 1 | 1 | — |
| 1.1-5.0 | 2 | 7 | — | 3 | 3 | 2 |
| 5.1-10.0 | 3 | 2 | — | 1 | 1 | 6 |
| 10.1-50.0 | 6 | 1 | — | 2 | 2 | 3 |
| 50.1-100 | — | 2 | 1 | — | — | 2 |

**Q3.6c (B3.4c): Proportion of employees in the technical function.**

| Per cent | No. (per cent) |
|---|---|
| 0-5.0 | 18 (28)[4] |
| 5.1-20.0 | 24 (37)[5] |
| 20.1-50.0 | 13 (20)[2] |
| 50.1-99.9 | 6 (9)[3] |
| 100 | 4 (6)[0] |

No details: 14[3].

**Sectoral Analysis**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-5.0 | 1 | 6 | 9 | 1 | 1 | — |
| 5.1-20.0 | 4 | 5 | 1 | 4 | 3 | 7 |
| 20.1-50.0 | 4 | 2 | — | 2 | 2 | 3 |
| 50.1-99.9 | 2 | — | — | — | 1 | 3 |
| 100 | 1 | 2 | 1 | — | — | — |

**Q3.9** (B3.6): **Is technology and innovation becoming more or less important to the firm?**

| | |
|---|---|
| More | 74[14] |
| Same | 3[ 3] |
| Less | 0[ 0] |

No details: 2.

**Q3.10** (B3.7): **What percentage of R&D expenditure is devoted to:**

1. Basic Research
2. Applied Research
3. New Product Development
4. Product Improvement
5. Quality Enhancement
6. Cost Reduction
7. Other

| Per cent | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 0 (none) | 28 | 19 | 1 | 8 | 21 | 24 | 42 |
| 0.1-10.0 | 28 | 21 | 2 | 17 | 24 | 27 | 15 |
| 10.1-50.0 | 5 | 20 | 30 | 34 | 16 | 10 | 3 |
| 50.1-100 | 0 | 1 | 28 | 2 | 0 | 0 | 1 |

No details: 18.

**Sectoral Analysis: Basic Research**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0 (none) | 2 | 5 | 4 | 7 | 2 | 8 |
| 0.1-10.0 | 8 | 6 | 5 | — | 5 | 4 |
| 10.1-50.0 | — | 2 | — | — | — | 3 |
| 50.1-100 | — | — | — | — | — | — |

**Sectoral Analysis: Applied Research**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0 (none) | — | 2 | 2 | 5 | 2 | 8 |
| 0.1-10.0 | 6 | 8 | 2 | 2 | 2 | 1 |
| 10.1-50.0 | 3 | 3 | 5 | — | 3 | 6 |
| 50.1-100 | 1 | — | — | — | — | — |

**Sectoral Analysis: New Product Development**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0 (none) | — | — | — | — | 2 | — |
| 0.1-10.0 | — | — | — | 1 | — | 1 |
| 10.1-50.0 | 4 | 7 | 9 | 2 | 2 | 5 |
| 50.1-100 | 6 | 6 | — | 4 | 3 | 9 |

**Sectoral Analysis: Product Improvement**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0 (none) | 1 | — | — | — | 1 | 7 |
| 0.1-10.0 | 3 | 3 | 3 | 4 | 3 | 2 |
| 10.1-50.0 | 6 | 10 | 6 | 3 | 2 | 6 |
| 50.1-100 | 1 | — | — | — | 1 | — |

**Sectoral Analysis: Quality Enhancement**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0 (none) | 6 | 2 | — | 1 | 3 | 10 |
| 0.1-10.0 | 4 | 6 | 4 | 4 | 2 | 4 |
| 10.1-50.0 | — | 5 | 5 | 2 | 2 | 1 |
| 50.1-100 | — | — | — | — | — | — |

**Sectoral Analysis: Cost Reduction**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0 (none) | 4 | 2 | 3 | 1 | 5 | 9 |
| 0.1-10.0 | 5 | 7 | 4 | 5 | 1 | 5 |
| 10.1-50.0 | 1 | 4 | 2 | 1 | 1 | 1 |
| 50.1-100 | — | — | — | — | — | — |

**Q3.11 (B3.8): Do you have a deliberate policy of using external technological expertise?**
Yes: 57, No: 20, (No answer: 2) [Yes: 13, No: 4]

**A3.12 a: Do you undertake contract R&D?**
Yes: 8, No: 9.

**b: What proportion of total R&D does this represent?**
1=5 per cent, 1=22 per cent, 1=29 per cent, 1=52 per cent, 4—No details

**Q3.13 (B3.9): What percentage of your RTDD budget is spent externally?**

| Per cent | No. (Per cent) |
|---|---|
| 0 (none) | 8 (12) |
| 0.1-5.0 | 12 (18) |
| 5.1-10.0 | 15 (22) |
| 10.1-20.0 | 21 (32) |
| 20.1-100 | 10 (15) |

No details: 13.

**Q3.14a: If you undertake RTDD externally, what percentage of external RTDD is spent with:**

1. Suppliers
2. Customers
3. Universities/polytechnics
4. Government laboratories
5. Independent R&D organisations
6. Joint ventures
7. Other

**UK+Overseas=100**

**In the UK:**

| Per cent | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 0 (none) | 24 | 40 | 8 | 36 | 12 | 42 | 39 |
| 0.1-10.0 | 7 | 5 | 16 | 9 | 12 | 6 | 3 |
| 10.1-25.0 | 3 | 3 | 10 | 2 | 8 | 1 | 4 |
| 25.1-50.0 | 7 | 1 | 7 | 2 | 10 | 0 | 2 |
| 50.1-100 | 8 | 0 | 8 | 0 | 7 | 0 | 1 |

Insufficient or no data: 30.

**Overseas:**

| Per cent | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 0 (none) | 36 | 45 | 36 | 46 | 40 | 44 | 38 |
| 0.1-10.0 | 5 | 3 | 11 | 3 | 5 | 3 | 4 |
| 10.1-25.0 | 5 | 1 | 2 | 0 | 2 | 0 | 2 |
| 25.1-50.0 | 1 | 0 | 0 | 0 | 1 | 2 | 1 |
| 50.1-100 | 2 | 0 | 0 | 0 | 1 | 0 | 4 |

Insufficient or no data: 30.

**Q3.14b: Proportion of external RTDD spent in the UK.**

| | No. |
|---|---|
| 0-20.0 | 3 |
| 20.1-50.0 | 9 |
| 50.1-80.0 | 8 |
| 80.1-99.9 | 8 |
| 100 | 24 |

No data: 27.

**A3.15: How many joint ventures have you in RTDD?**

| | No. |
|---|---|
| None | 2 |
| 1-5 | 7 |
| 6-20 | 2 |
| 30 | 1 |

No details: 5.

**A3.16: How important have external sources of science and technology been in facilitating your own R&D activities? (Rank 1 to 5, 1=unimportant, 5=crucially important.)**

| 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|
| 3 | 3 | 6 | 2 | 3 | 2.9 |

**A3.17: Is external scientific and technological expertise becoming more or less important to your long-term competitiveness? (Rank 1 to 5, 1=much less important, 3=same, 5=much more important.)**

| 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|
| 1 | 1 | 6 | 6 | 3 | 3.5 |

**A3.18: Have you encountered significant problems in attempting to access external scientific or technological advice?**

Yes: 5, No: 12.

**A3.20: What were the main difficulties experienced?**

| | Yes | No |
|---|---|---|
| Difficult to identify appropriate source | 3 | 2 |
| Too expensive | 0 | 5 |
| Difficult to access | 3 | 2 |
| Inappropriate technical solution | 1 | 4 |
| Took too long | 3 | 2 |
| Solution too theoretical | 1 | 4 |
| Communications difficulties | 3 | 2 |
| Other | 1 | 4 |

**A3.21: During the past five years have you enjoyed regular contact with . . .?**

| | Yes | No |
|---|---|---|
| Universities | 15 | 1 |
| Polytechnics | 14 | 2 |
| Government laboratories | 12 | 4 |
| Independent R&D organisations | 13 | 3 |
| Other | 4 | 12 |

No details: 1.

## 4: Training and Skills

**Q4.1: Does your company have a formal training and professional development policy?**

Yes: 73[17], No: 6[0].

**Q4.2: Does this include training for:**

| | Yes | Positive Per cent |
|---|---|---|
| Senior Managers | 70[17] | 96 |
| Middle Managers | 71[17] | 97 |
| Junior Managers | 71[17] | 97 |
| Functional Specialists | 68[16] | 93 |
| Technicians | 69[16] | 95 |
| Line Workers | 60[15] | 87* |

*Four companies have no line workers.

**A4.3: What proportion of your senior managers have, during their careers, spent at least five years in a research, technology, design or development activity?**

| Per cent | No. |
|---|---|
| 0-20 | 5 |
| 21-50 | 7 |
| 51-70 | 2 |
| 100 | 1 |

No details: 2.

**Q4.4 (B4.3): What percentage of turnover do you devote to training and personnel development?**

| Per cent | |
|---|---|
| 0 (none) | 2[1] |
| 0.1-0.9 | 16[5] |
| 1.0-1.9 | 26[5] |
| 2.0-5.0 | 20[5] |

No details: 15[1].

**A4.6: Do you mount special induction training courses for new . . . ?**

| | Yes | No |
|---|---|---|
| Graduates | 17 | 0 |
| Managers/Management trainees | 16 | 1* |
| Functional specialists | 17 | 0 |
| Technicians | 16 | 1 |
| Line workers | 15 | 2 |

* Not recruited externally.

**A4.7: Do you regularly provide training in management (e.g., finance, marketing, human relations, project management) for your scientific and technical staff?**

Yes: 15, No: 2.

**A4.8: Do you participate in government sponsored training schemes?**

Yes: 13, No: 3, (No answer: 1)

**A4.10: Have, A. the availability, or B. the quality, of technical personnel presented difficulties during the past five years? C. Do you anticipate there being a problem in the future?**

| | Yes | No |
|---|---|---|
| A: Availability | 9 | 8 |
| B: Quality | 8 | 8 |
| C: Future problem | 11 | 6 |

No answer: B 1.

**A4.13: Do you have quality related training schemes?**

Yes: 17, No: 0.

**A4.14: Do you have any secondments of technical staff to or from academia?**

Yes: 11, No: 6.

## 5: Manufacturing

**Q5.1: What percentage of turnover is devoted to the purchase of new manufacturing equipment?**

| Per cent | 1981-82 | 1986-87 | 1991-92 |
|---|---|---|---|
| 0 (none) | 1 | 1 | 3[1] |
| 0.1-2.5 | 14 | 14 | 16[5] |
| 2.6-5.0 | 13 | 16 | 21[6] |
| 5.1-12.5 | 12 | 17 | 15[3] |
| 12.6+ | 3 | 3 | 4[0] |
| Not applicable/not given | 36 | 28 | 20[2] |

Fourteen companies are not engaged in manufacturing.

**Q5.2: How old would you estimate the vintage of your manufacturing equipment is in relation to: A, your main foreign competitors; B, your main UK competitors.**

1. Sixty per cent or more of your equipment is older than the average of your competitors'.
2. Between 20 per cent and 60 per cent is older than the average competitors'.
3. About the same general vintage as the average competitors'.
4. Between 20 per cent and 60 per cent is more modern than the average competitors'.
5. Sixty per cent or above is more modern than the average competitors'.

| | A: Foreign (Per cent) | B: UK (Per cent) |
|---|---|---|
| 1 | 1( 2)[0] | 1( 2)[0] |
| 2 | 12(20)[1] | 2( 4)[0] |
| 3 | 19(32)[5] | 22(40)[7] |
| 4 | 19(32)[6] | 19(35)[5] |
| 5 | 8(14)[3] | 11(20)[3] |

No details/not applicable: A 20[1], B 24[2].

**Sectoral Analysis: A, Compared with Foreign Competitors**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1 | — | — | — | 1 | — | — |
| 2 | 3 | 5 | — | 1 | 1 | 2 |
| 3 | 4 | 5 | 1 | 4 | 1 | 4 |
| 4 | 3 | 2 | 5 | 4 | 1 | 4 |
| 5 | 1 | 3 | — | — | 1 | 3 |
| Average | 3.2 | 3.2 | 3.8 | 3.1 | 3.5 | 3.6 |

**Sectoral Analysis: B, Compared with UK Competitors**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 1 | — | 1 | — | — | — | — |
| 2 | — | — | — | — | — | 2 |
| 3 | 5 | 5 | 3 | 3 | 2 | 4 |
| 4 | 4 | 3 | 4 | 5 | — | 3 |
| 5 | 1 | 3 | — | 1 | 2 | 4 |
| Average | 3.6 | 3.6 | 3.6 | 3.8 | 4.0 | 3.7 |

**Q5.4: Are your main equipment suppliers UK based or overseas?**

| | |
|---|---|
| In the UK | 13[ 2] |
| Overseas | 39[11] |
| Both | 11[ 3] |

No details: 17[1].

**Q5.5: If "overseas", does this disadvantage you in any way?**
Yes: 12, No: 38, [Yes: 4, No: 10]

**A5.6: Do you have a separate production engineering department?**
Yes: 12, No: 3, Not relevant: 2.

**A5.7: What percentage of turnover do you devote to production engineering activities?**

| Per cent | No. |
|---|---|
| 0.1-1.0 | 4 |
| 1.1-2.0 | 3 |
| 2.1-4.0 | 5 |
| 10.0 | 2 |

No details: 3.

**A5.8: How many graduate production engineers do you employ?**

| | No. |
|---|---|
| 0 (none) | 1 |
| 1-10 | 4 |
| 11-20 | 4 |
| 21-100 | 4 |
| 100+ | 2 |

No details: 2.

**A5.9: Is the head of manufacturing a member of the main board?**
Yes: 8, No: 7, Not relevant: 1, No answer: 1.

**A5.10: Are you accredited for BS5750 or equivalent, or are you aiming for accreditation?**
Yes: 15, No: 2.

**A5.11: What percentage of manufacturing is sub-contracted to other companies?**

| Per cent | No. |
|---|---|
| 0.1-1.0 | 1 |
| 1.1-5.0 | 5 |
| 5.1-25.0 | 4 |
| 25.1-50.0 | 4 |

No answer: 2, Not relevant: 1.

**A5.12: If you do sub-contract out manufacturing, has this presented you with significant disadvantages?**
Yes: 2, No: 13. (No answer: 2)

**A5.14: During the past five years, have you: increased/kept about the same/reduced, the number of suppliers you use?**

| Increased | Same | Reduced |
|---|---|---|
| 3 | 2 | 12 |

**A5.15: Are you making deliberate attempts to forge closer relationships with your main suppliers?**
Yes: 16, No: 1.

**A5.16: During the past five years have you sourced: more/about the same/less, of your supplier input from UK based companies?**

| More | Same | Less |
|---|---|---|
| 4 | 7 | 6 |

**A5.17: If you are sourcing increasingly from abroad, specify your main reasons for doing so? (Answers from "same" or "more").**

| | Yes | No |
|---|---|---|
| No UK suppliers | 4 | 7 |
| Poor UK quality control | 1 | 10 |
| Foreign parts/components cheaper | 2 | 9 |
| Inadequate UK supply volume | 1 | 10 |
| Problems in meeting supply schedule | 1 | 10 |
| Foreign parts more technically advanced | 3 | 8 |
| Other | 5 | 6 |

Not relevant: 6.

## 6: Finance and Corporate Control

**Q6.1: Has the company raised significant amounts of external finance (i.e., other than retained earnings) during the last seven years?**

Yes: 52, No: 21, (No answer: 6) [Yes: 13, No: 3, No answer: 1]

**Sectoral (Y/All):** Aero 11/12, Auto 12/15, Food 5/10, M/Tools 8/11, Office 4/9, Pharm 12/16

**Q6.2: If "yes", which of these was the source of finance?**

| | Yes (of 36) | Positive Per cent |
|---|---|---|
| Venture Capital | 2[1] | 6 |
| Bank Loan | 31[9] | 71 |
| Bond Finance | 16[5] | 44 |
| Loan Finance | 17[5] | 47 |
| Private Placement of Shares | 8[1] | 9 |
| Public Issues of Shares | 18[4] | 32 |
| Investment by Corporate Partner | 9[3] | 26 |
| Other | 10[3] | 24 |

No details: 16.

**Q6.3: If the answer to 6.1 was "yes" was the finance of innovation an important (e.g., more than one-third) part of the company's needs?**

Yes: 15, No: 34, (No details: 9) [Yes: 5, No: 7, No details 1]

**Sectoral (Y/All):** Aero 3/9, Auto 5/12, Food 0/5, M/Tools 3/8, Office 0/4, Pharm 4/11

**Q6.4: From your company's experience, how would you rate the following sources of finance?**

| | Fully satisfactory | Moderately satisfactory | Unsatisfactory | No opinion | Index* |
|---|---|---|---|---|---|
| Venture Capital | 3 | 2 | 10 | 42 | –47 |
| Bank Loan | 23 | 24 | 3 | 7 | +40 |
| Bond Finance | 17 | 10 | 0 | 30 | +63 |
| Loan Finance | 10 | 14 | 2 | 31 | +31 |
| Private Placement of Shares | 6 | 1 | 4 | 46 | +18 |
| Public Issue of Shares | 16 | 4 | 0 | 37 | +80 |
| Investment by Corporate Partner | 7 | 6 | 1 | 43 | +43 |
| Other | 4 | 2 | 2 | 49 | +25 |

*Index scores: Value of +1 given for "fully satisfactory" answers, –1 for "unsatisfactory" answers, 0 for "moderately satisfactory" answers. Sum of answers is multiplied by 100, and divided by the number of responses, excluding "no opinion", e.g., Venture Capital: [(3-10)×100]/15=–47.

**Q6.5: If you have found bank loan finance less than a fully satisfactory source, is this due to:**

| | Yes | No |
|---|---|---|
| High interest rates | 21 | 6 |
| Terms for securing the loan | 12 | 15 |
| Absence of long-term finance | 12 | 15 |
| Lack of understanding of your business by the bank | 4 | 23 |
| Lack of commitment by the bank | 6 | 21 |
| Other | 3 | 24 |

**Q6.6: If you have found raising finance by issue of shares a less than fully satisfactory source, is this due to:**

| | Yes | No |
|---|---|---|
| "Short termism" on the part of investors | 3 | 3 |
| Cost of accessing the market | 2 | 4 |
| Changes in gearing | 0 | 6 |
| Instability in the market | 1 | 5 |
| Threat of takeover of your company | 1 | 5 |
| Burdens imposed by increased demands for information | 0 | 6 |
| Lack of understanding of your business by investors | 1 | 5 |
| Other | 2 | 4 |

**Q6.7: If you have found raising finance from a corporate partner less than fully satisfactory, is this due to:**

| | Yes | No |
|---|---|---|
| Conflict between the Partner's and your business objectives | 4 | 2 |
| Threat of takeover | 0 | 6 |
| Insufficient finance available from this source | 3 | 3 |
| Other | 0 | 6 |

**Q6.8: What has been the effect of external financing on:**

| | Increased | No effect | Reduced | Both inc. and red. |
|---|---|---|---|---|
| The level of profits retained | 9 | 32 | 7 | 1 |
| The level of R&D spending | 7 | 43 | 2 | 0 |

**Sectoral Analysis, level of profits retained:**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Increased | 2 | 1 | 1 | 1 | 1 | 3 |
| No effect | 4 | 7 | 4 | 6 | 3 | 8 |
| Reduced | 4 | 2 | — | — | 1 | — |

One company claimed external finance reduced profits in the short-term but raised profits in the long run.

**Sectoral Analysis, level of R&D spending:**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| Increased | 1 | 1 | — | — | — | 5 |
| No effect | 8 | 11 | 5 | 7 | 5 | 7 |
| Reduced | 2 | — | — | — | — | — |

## 7: Marketing and Sales

**Q7.1: Percentage of turnover devoted to Marketing and Sales:**

| Per cent | 1986-87 | 1991-92 |
|---|---|---|
| 0-2.5 | 13 | 14[3] |
| 2.6-5.0 | 15 | 15[1] |
| 5.1-15.0 | 16 | 22[5] |
| 15.1+ | 6 | 9[3] |

No details: 1986-87 29, 1991-92 19[5].

**Sectoral Analysis, 1991-92**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-2.5 | 4 | 4 | 2 | 1 | 2 | 1 |
| 2.6-5.0 | 8 | 1 | — | 4 | — | 2 |
| 5.1-15.0 | 1 | 5 | 4 | 4 | 2 | 6 |
| 15.1+ | — | — | 1 | 1 | 2 | 5 |

**Q7.2: Is the head of M&S a main board member?**

Yes: 47, No: 26, (No answer: 6) [Yes: 10, No: 6]

**Sectoral (Y/All):** Aero 7/13, Auto 8/15, Food 8/11, M/Tools 9/10, Office 5/9, Pharm 10/15

**Q7.3a: Number of personnel in M&S:**

| | Number |
|---|---|
| 0-10 | 17[1] |
| 11-100 | 19[4] |
| 101-1,000 | 19[6] |
| 1,001+ | 12[3] |

No details: 12[3].

**Q7.3b: Percentage of personnel in M&S:**

| (Per cent) | Number (Per cent) |
|---|---|
| 0-2.0 | 14(21)[4] |
| 2.1-5.0 | 18(27)[4] |
| 5.1-20.0 | 18(27)[3] |
| 20.1+ | 17(25)[3] |

**Sectoral Analysis**

| Per cent | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| 0-2.0 | 6 | 5 | 1 | — | — | 2 |
| 2.1-5.0 | 6 | 6 | 1 | 1 | 2 | 2 |
| 5.1-20.0 | — | 2 | 4 | 8 | 2 | 2 |
| 20.1+ | 1 | — | 2 | 1 | 5 | 8 |

**Commitment to R&D as compared to commitment to M&S**

A: Expenditure/employment in R&D is less than half that for M&S.
B: Expenditure/employment in R&D is between half and the same as M&S.
C: Expenditure/employment in R&D is up to four times that for M&S.
D: Expenditure/employment in R&D is between four and 10 times that for M&S.
E: Expenditure/employment in R&D is over 10 times that for M&S.

| Expenditure on R&D/M&S | No. (Per cent) |
|---|---|
| A | 12(23) |
| B | 13(25) |
| C | 11(21) |
| D | 8(15) |
| E | 8(15) |

No details: 27.

| Employment in R&D/M&S | No. (Per cent) |
|---|---|
| A | 15(26) |
| B | 6(10) |
| C | 16(28) |
| D | 13(22) |
| E | 8(14) |

No details: 21.

**Sectoral Analysis: A, Expenditure on R&D/Expenditure on M&S**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| A | — | 2 | 4 | 2 | 1 | 3 |
| B | 2 | — | 2 | 2 | 2 | 5 |
| C | 2 | 3 | — | 3 | — | 3 |
| D | 4 | 3 | — | — | 1 | — |
| E | 3 | 1 | — | — | 2 | 2 |

**Sectoral Analysis: A, Employment in R&D/Employment in M&S**

| | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|
| A | — | 1 | 6 | 1 | 3 | 4 |
| B | — | 1 | 1 | — | 1 | 3 |
| C | 2 | 5 | 1 | 6 | 1 | 1 |
| D | 8 | 3 | — | — | 1 | 1 |
| E | 2 | 2 | — | — | 1 | 3 |

**A7.5: If you are a multi-divisional company/part of a group, do you have central . . . ?**

| | Yes | No |
|---|---|---|
| Marketing | 8 | 7 |
| Sales | 3 | 11 |
| Distribution | 3 | 12 |

No answer: 2, 3, 2.

**A7.7: Are any of your M&S personnel technically qualified?**

Yes: 17, No: 0.

**A7.8 If "yes", what percentage have: A. Graduate level qualifications, B. Technician level qualifications, C. Graduate or Technician level qualifications.**

| Per cent | A: Graduate | B: Technician | C: Either |
|---|---|---|---|
| 0 (none) | 0 | 5 | 0 |
| 1-25 | 4 | 2 | 2 |
| 26-50 | 4 | 4 | 0 |
| 51-99 | 2 | 1 | 8 |
| 100 | 2 | 0 | 2 |

No answer: 5.

**A7.9: Is opening markets abroad a significant problem for your company?**

Yes: 3, Sometimes: 1, No: 10. (No answer: 3)

## 8: Role of Public Policy as it Relates to Innovation

**Q8.2: What was your opinion of the scheme(s) usefulness?**

| | No. | Per cent |
|---|---|---|
| Highly useful | 9[1] | 20 |
| Useful | 28[9] | 58 |
| Made no difference | 4[2] | 9 |
| Unsatisfactory | 4[2] | 9 |
| Very unsatisfactory | 2[0] | 4 |

**Q8.6: Have you had any assistance from government actions (other than that specified above) which you believe has enhanced your competitiveness during the past five years?**

Yes: 24, No: 50, (No answer: 5) [Yes: 5, No: 11, No answer: 1]

## 9: Overall Environment; UK and Abroad

**Q9.1: Do you consider that the general environment for innovation in the UK is more or less favourable than in:**

| | More | Equal To | Less | No Opinion | Index scores* |
|---|---|---|---|---|---|
| Japan | 3[0] | 6[3] | 62[14] | 1[0] | −83[−82] |
| USA | 1[0] | 18[3] | 53[14] | 0[0] | −72[−82] |
| Germany | 12[5] | 20[2] | 39[ 9] | 1[1] | −38[−25] |
| France | 14[3] | 26[4] | 30[ 9] | 2[1] | −22[−38] |
| Taiwan | 14[2] | 7[1] | 32[10] | 19[4] | −33[−61] |

*Index scores: Value of +1 given for "more" answers, −1 for "less" answers, 0 for "equal to" answers. Sum of answers is multiplied by 100, and divided by the number of responses (excluding "no opinion") e.g., Japan: [(3-62) × 100]/71=−83.1.
No answers: 7.

### Sectoral Analysis

| Index scores | All | Aero | Auto | Food | M/Tools | Office | Pharm |
|---|---|---|---|---|---|---|---|
| Japan | −83 | −100 | −88 | −80 | −100 | −100 | −47 |
| USA | −72 | −91 | −41 | −60 | −78 | −100 | −81 |
| Germany | −38 | −91 | −69 | −30 | −66 | +11 | +12 |
| France | −22 | −100 | −50 | −30 | −33 | +22 | +38 |
| Taiwan | −33 | −100 | −50 | −75 | −43 | −63 | +62 |

No answers: 15.

**Q9.3: Do you consider your company to be more or less innovative than your counterparts in:**

| | More | Equal to | Less | No opinion | Index scores |
|---|---|---|---|---|---|
| Japan | 25[ 8] | 19[4] | 14[3] | 6[2] | +19[ +33] |
| USA | 27[ 7] | 29[6] | 7[4] | 1[0] | +32[ +17] |
| Germany | 34[ 9] | 21[7] | 8[0] | 1[1] | +41[ +56] |
| France | 38[12] | 21[4] | 3[1] | 2[0] | +56[ +65] |
| Taiwan | 29[11] | 12[0] | 0[0] | 23[6] | +71[+100] |

## Sectoral Analysis

| Index scores | All | Aero | Auto | Food | M/Tool | Office | Pharm |
|---|---|---|---|---|---|---|---|
| Japan | +19 | +25 | −62 | 0 | +40 | +28 | +79 |
| USA | +32 | 0 | +43 | +50 | +60 | +33 | +14 |
| Germany | +41 | +36 | −15 | +50 | +40 | +100 | +64 |
| France | +56 | +27 | +15 | +38 | +100 | +100 | +79 |
| Taiwan | +71 | +40 | +28 | +50* | +80 | +67 | +83 |

* Based on three or fewer opinions.

**Q9.4: Do you consider your UK customers to be more or less innovation demanding than customers in:**

| | More | Equal to | Less | No opinion | Index scores |
|---|---|---|---|---|---|
| Japan | 5[3] | 17[3] | 29[8] | 6[1] | −47[−35] |
| USA | 8[3] | 31[6] | 18[6] | 0[0] | −18[−20] |
| Germany | 7[3] | 32[8] | 18[4] | 0[0] | −19[ −6] |
| France | 6[3] | 40[8] | 11[4] | 0[0] | −9[ −6] |
| Taiwan | 7[2] | 19[5] | 6[1] | 25[7] | +3[+12] |

No answers: 22.

## Sectoral Analysis

| Index scores | All | Aero | Auto | Food | M/Tools | Office | Pharm |
|---|---|---|---|---|---|---|---|
| Japan | −47 | −33 | −71 | 0 | −30 | −100 | −50 |
| USA | −18 | −44 | +7 | +38 | −10 | −60 | −64 |
| Germany | −19 | −33 | −36 | +50 | −50 | +40 | −45 |
| France | −9 | −33 | −21 | +38 | −10 | +40 | −36 |
| Taiwan | +3 | 0 | +17 | +50* | −12 | −40 | +17 |

* Based on three or fewer opinions.

## APPENDIX 3

## LIST OF VISITS MADE IN CONNECTION WITH THE INQUIRY

### Visit to Germany 9-11 March 1993

1. The Committee had discussions with the following during its visit:

(1) The Federal Ministry of Research and Technology, including the Minister for Research, Herr Wissman

(2) The Bundestag Research and Technology Committee

(3) The Federal Ministry of Economics

(4) Officials of the Kreditbank fur Wiederaufbau, the Bundesverband der Deutschen Industrie and the Arbeitsgemeinschaft industrieller Forschungsvereinigungen

(5) Fraunhofer Institute (fur Produktionstechnik und Automatisievring)

(6) The Steinbeis Foundation

(7) Baden-Wurttemberg Ministry of Economics

(8) A Max Planck Institute (Institut fur Metallforschung)

(9) Institute for Micro Electronics

(10) Trumpf GmbH

### Visit to Japan - 23-30 October 1993

2. The Committee had discussions with the following during its visit:

(1) The Japan Key-Tech Centre

(2) Sankyo Pharmaceuticals

(3) The Science and Technology Agency

(4) Mitsubishi Heavy Industries Co.

(5) Nagoya Municipal Industrial Research Intitute

(6) Yamazaki Mazak Co (Minokamo Plant)

(7) Toyota Central Research and Development Laboratory

(8) Toyota Technical Institute

(9) Toyota factory (The Tsutsumi Plant)

(10) Japan Development Bank

(11) Keidanren (CBI equivalent)

(12) Sharp Corporation (Makuhari)

(13) Japan Industrial Technology Association

(14) Research Centre for Advanced Science and Technology at Tokyo University

(15) Members of the Committee on Science and Technology of the House of Representatives

(16) Japan Research and Development Corporation

(17) Ministry of International Trade and Industry and the Agency of Industrial Science and Technology

## UK Visits

(1) Cambridge University and St John's Innovation Centre — 17.2.93.

(2) Ricardo Consulting Engineers Ltd, Shoreham-by-Sea — 3.3.93.

(3) AEA Technology, Didcot, Oxfordshire — 31.3.93.

(4) Thrombosis Research Institute, London — 21.4.93.

(5) Merck, Sharpe & Dohme's Research Laboratory, Harlow — 30.6.93.

(6) Warwick University — 2.3.94.

## List of those who gave informal advice to the Committee during the course of the Inquiry

Mr G Cameron

Dr A Graves

Dr M Hobday

Professor C Mayer

Dr J Meullbauer

Professor H Newby

Professor K Pavitt

# PROCEEDINGS OF THE COMMITTEE RELATING TO THE REPORT

## WEDNESDAY, 13 APRIL, 1994

Members present:

Sir Giles Shaw, in the Chair

| | |
|---|---|
| Mr Spencer Batiste | Mr Andrew Miller |
| Dr Jeremy Bray | Sir Trevor Skeet |
| Mrs Anne Campbell | Sir Gerard Vaughan |
| Dr Lynne Jones | Dr Alan Williams |

The Committee deliberated.

Draft Report (The Routes through which the Science Base is Translated into Innovative and Competitive Technology), proposed by the Chairman, brought up and read.

*Ordered,* That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 4 read and agreed to.
Paragraph 5 read, amended, and agreed to.
Paragaphs 6 to 14 read and agreed to.
Paragraph 15 read, amended, and agreed to.
Paragaphs 16 to 36 read and agreed to.
Paragraph 37 read and agreed to.
Paragraphs 38 to 54 read and agreed to.
Paragraph 55 read, amended, and agreed to.
Paragraph 56 to 71 read and agreed to.
Paragraphs 72 and 73 read, amended, and agreed to.
Paragraphs 74 to 76 read and agreed to.
Paragraph 77 read, amended, and agreed to.
Paragraphs 78 to 81 read and agreed to.
Paragraph 82 read, amended, and agreed to.
Paragraphs 83 to 86 read and agreed to.
Paragraph 87 read, amended, and agreed to.
Paragraphs 88 to 95 read and agreed to.
Paragraph 96 read, amended, and agreed to.
Paragaphs 97 to 100 read and agreed to.
Paragraph 101 read, amended, and agreed to.
Paragraphs 102 to 106 read and agreed to.
Paragraph 107 read, amended, and agreed to.
Paragaphs 108 to 111 read and agreed to.
Paragraph 112 read, amended, and agreed to.
Paragraphs 113 to 125 read and agreed to.
Paragraph 126 read, as follows:

> The Warwick Manufacturing Group makes sufficiently high profits to enable it to pay its Teaching Fellows, who are responsible for courses directed at industry, a higher stipend than would normally be the case. Salford University encourages its staff to work with industry by including success in technology transfer and entrepreneurial activity among the criteria for promotion. Not all universities will be able to use such methods, but they are a good example of encouraging interaction with industry through increased rewards.

Amendment proposed, in line 3, after the word "case" to insert the words "The fact that it is necessary to do this highlights the gap between university salary scales and the pay levels that can be commanded in the private sector." — (*Dr Lynne Jones.*)

Question put, That the Amendment be made.

The Committee divided.

| Ayes, 5 | Noes, 2 |
|---|---|
| Dr Jeremy Bray | Mr Spencer Batiste |
| Mrs Anne Campbell | Sir Trevor Skeet |
| Lynne Jones | |
| Mr Andrew Miller | |
| Dr Alan W Williams | |

Paragaph, as amended, agreed to.
Paragraphs 127 to 153 read and agreed to.
Paragraph 154 read, amended, and agreed to.
Paragraph 155 read and agreed to.
Paragraph 156 read, amended, and agreed to.
Paragraphs 157 to 164 read and agreed to.
Paragraph 165 read, amended, and agreed to.
Paragraphs 166 to 185 read and agreed to.
Paragraph 186 read, amended, and agreed to.
Paragraphs 187 to 215 read and agreed to.
Paragraph 216 read, amended, and agreed to.
Paragaphs 217 to 222 read and agreed to.
Paragraph 223 read, amended, and agreed to.
Paragraphs 224 to 247 read and agreed to.
Paragraph 248 read, amended, and agreed to.
Paragraphs 249 to 255 read and agreed to.
Paragraph 256 read, amended, and agreed to.
Paragraphs 257 and 258 read and agreed to.
Paragraph 259 read, amended, and agreed to.
Paragaphs 260 to 271 read and agreed to.
Paragraph 272 read, amended, and agreed to.
Paragraph 273 to 276 read and agreed to.
Paragraph 277 read, amended, and agreed to.
Paragraphs 278 to 280 read and agreed to.
Paragraph 281 read, amended, and agreed to.
Paragraphs 282 to 305 read and agreed to.
Paragraph 306 read, amended, and agreed to.
Paragraph 307 read and agreed to.
Paragraph 308 read, amended, and agreed to.
Paragraphs 309 and 310 read and agreed to.
Paragraph 311 read, amended, and agreed to.
Paragraphs 312 to 334 read and agreed to.
Paragraphs 335 and 336 read, amended, and agreed to.
Paragraphs 337 to 352 read and agreed to.
Paragraph 353 read, amended, and agreed to.

*Ordered,* That a list of abbreviations be annexed to the Report. — *(The Chairman.)*

*Ordered,* That the following papers be appended to the Report:

Questionnaire commentary
Questionnaire statistical analysis
List of visits made in connection with the inquiry. — *(The Chairman.)*

*Resolved,* That the Report, as amended, be the First Report of the Committee to the House.

*Ordered,* That the Chairman do make the Report to the House.

*Ordered,* That the provisions of Standing Order No. 116 (Select committees (reports)) be applied to the Report.

Several papers were ordered to be appended to the Minutes of Evidence.

*Ordered,* That the Appendices to the Minutes of Evidence taken before the Committee be reported to the House. — *(The Chairman.)*

[Adjourned till Wednesday 20th April at Four o'clock.

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