HOUSE OF LORDS

SESSION 1996–97
3rd REPORT

SELECT COMMITTEE ON
SCIENCE AND TECHNOLOGY

THE INNOVATION-EXPLOITATION BARRIER

REPORT

Ordered to be printed 11 March 1997

LONDON: THE STATIONERY OFFICE
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TABLE OF CONTENTS

REFERENCES IN THE TEXT ARE AS FOLLOWS:

(Q) refers to a Question in oral evidence
(p) refers to a page in HL Paper 62-I of this Session

THIRD REPORT

11 March 1997

By the Select Committee appointed to consider Science and Technology.

ORDERED TO REPORT

THE INNOVATION-EXPLOITATION BARRIER

CHAPTER 1 INTRODUCTION

1.1 This report on the Innovation-Exploitation Barrier follows from our report on "*Innovation in Manufacturing Industry*" in 1991[1]. That report identified a series of broad issues that were, and still are, crucial to the competitiveness of UK manufacturing industry. Amongst the most urgent were the need for a change of national attitude towards manufacturing and wealth creation; the need to adopt best practice and learn from our competitors overseas, in terms of both business practice and marketing; and the need to fund long-term investment in innovation to counteract "short-termism". In this report we have not re-visited all these broad issues but have instead focused on one critical part of the process—the point at which new ideas become the basis for a viable business enterprise. And we deal only with the interface between universities and small business—we do not explore any barriers to exploitation that may exist within established companies, for example between the research department and management. Nonetheless we should record straightaway that during the course of our enquiry we detected in many of the areas examined earlier, particularly those relating to national attitudes, welcome signs of changes for the better.

1.2 In the past six months a number of new studies have addressed issues at the interface between the innovator and the commercial exploitation of ideas. These include the Bank of England's "*The Financing of Technology-Based Small Firms*" (October 1996) and the CBI study "*The Barriers to Start-up: the Growth of Technology-Based SMEs*" (February 1997). We greatly welcome these developments. The Bank's report concentrates primarily on issues of finance and we look at this in more detail in Chapter 2 where we examine issues affecting the availability of seed capital. The CBI report tends to complement that from the Bank and looks in particular at the management issues faced by small firms. It deals with building management teams, developing entrepreneurship and market focus together with the potential of corporate alliances. On 3 March 1997, both of these organisations joined with the Royal Society to organise a conference "*Partners in Business*" to discuss how the ideas in their respective reports might be carried forward.

1.3 We have been guided and greatly helped by these studies and by the sessions at the conference. Together they deal with issues very relevant to the innovation-exploitation barrier and develop further many of the lines of thought that ran through our 1991 report on manufacturing. However with our more limited objectives this time we have not examined all the aspects covered in that report in detail. Indeed, even some of the issues we have considered, for example those relating to legislation covering limited partnerships and the operation of due diligence (cf paragraph 2.12), we would have preferred to examine more closely had time allowed. All these matters are linked and would be a very worthwhile topic for a future report unconstrained by an impending General Election.

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[1] 1st Report (1990–91), *Innovation in Manufacturing Industry*, HL Paper 18, ISBN 0 10 481491 8.

1.4 In examining the innovation-exploitation interface we have taken evidence on the strength of the science base from which new innovative ideas emerge; looked at the impact that Foresight might have on the transition from innovation to exploitation; taken note of the constraints and difficulties that the would-be entrepreneur faces in creating viable technology-based enterprises; and examined some of the factors such as business schools and science parks that facilitate the creation of new enterprises. But the report is not intended as a complete list of all the factors, nor is it an exhaustive treatment of the subjects we have chosen. Rather, we have confined ourselves to a few topics and focused on some of the key aspects of each.

1.5 This enquiry was conducted by Sub-Committee II, whose members are listed in Appendix 1. They issued a call for evidence, which is set out in Appendix 2. We wish to thank all of the witnesses who gave oral evidence during the course of this enquiry and for the time and effort of those who contributed to the written evidence. A full list of contributors is printed in Appendix 3 and a list of acronyms appears in Appendix 4. We are particularly grateful to those witnesses who gave evidence to us at very short notice. All the evidence is printed in a separate volume, HL Paper 62–I.

CHAPTER 2 SEED CAPITAL

"There is a kind of market failure, and that market failure is the provision of start up and seed capital to small high tech firms" (Mr Pendarell Kent, Bank of England, Q 108).

BACKGROUND

2.1 In its recommendations relating to the financing of research and development (R&D), the 1991 report called for an R&D tax allowance, suggesting that 150 per cent of industrial expenditure on R&D should be exempt and that companies should be allowed to choose for themselves the rate of depreciation against tax for plant and machinery. Although many of the measures proposed were intended to encourage more R&D by reducing its cost they were not specifically addressed to the problems of the interface between research and its commercial exploitation. Nonetheless recommendations called on the Department of Trade and Industry (DTI) to make its schemes more readily understood and there was support in particular for the Small Firms Merit Award for Research and Technology (SMART) and the Support for Products Under Research (SPUR) initiatives.

2.2 In their reponse (Cm 1575), the Government did not accept that there was conclusive evidence that the cost of borrowing is consistently and significantly higher in the United Kingdom than our competitors. They rejected the Committee's findings in this area together with the proposal for tax relief for R&D, arguing that to single out R&D for special treatment would run counter to the policy of ensuring that investment decisions should be based on companies' commercial judgement and not distorted by tax subsidies.

2.3 However, the Government argued that a range of current and forthcoming measures would help to stimulate innovation. They responded to the Committee's call for simplification by describing two initiatives, "Technology and Change—Help for Business" and the "Innovation Enquiry Line", that went towards those ends. Other schemes identified by the DTI in support of innovation in 1991 are described in Box 1.

2.4 Since June 1991, there have been two significant milestones in Government's support for science and technology. In May 1993 the Government published a White Paper on Science, Engineering and Technology (SET)[2] which focused Government policy in this area on the creation of wealth and improved quality of life. In parallel, DTI re-focused its SET activities to concentrate more on improving technology transfer and less on supporting technology development. In June 1996, the Government announced a radical new approach to support for business and a simplification of existing schemes. The outcome of this is currently in the process of being implemented.

RECENT EVENTS

2.5 The Bank of England report "*The Financing of Technology-Based Small Firms*" provides an excellent analysis of the reasons why technology-based firms are significant to the economy and why not all the potential benefits that might flow from the exploitation of research, much of which is Government funded, can be captured by the private investor (or at least not directly in the short term). It makes a number of suggestions to address these issues. It considered that successful "serial entrepreneurs" are important role models, and can help to motivate future generations of entrepreneurs by passing on their expertise and enthusiasm. But more work is needed to understand how the number and role of "Business Angels" can be enhanced. The Bank also endorsed the approach taken in the DTI's *Biotechnology Means Business* programme, in which mentors, business incubators (see Box 6) and sector-specific finance advisers play a key role. Indeed, the report stressed the importance of promoting better awareness of the benefits of business incubation, particularly for technology-based firms at a very early stage of development.

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[2] *Realising our Potential: A Strategy for Science, Engineering and Technology* (1993), Cm 2250, ISBN 0 10 122502 4.

Box 1: Some of the main measures identified by DTI in 1991 in support of innovation

Training and Enterprise Councils (TECs): Established in 1990 by the then Employment Department to stimulate employer investment in skills, foster economic growth and contribute to the regeneration of their communities. Transferred to DTI in 1992 and now the main vehicle for delivering that Department's business support services. A recent document "TEC Achievements" sets out details of what has been achieved since the establishment of TECs.

The Education Business Partnership Initiative (EBP): Launched in December 1990 by the then Employment Department to provide more coherence and co-ordination to, and increase the quality and quantity of, links between education and business. Government funding to enable them to operate ended in March 1995 but most EBPs continue with financial support from other sources. A national EBP network was launched in December 1996 aimed to promote EBPs as organisations with support from the Department for Education and Employment amongst others.

The Innovation Advisory Board (IAB): Set up in November 1988 to provide a forum for industrial advice to DTI on innovation. It was formally disbanded in September 1993. Most of its activities were taken on by DTI's own Innovation Unit.

Scientific Research Allowance (SRA): Allows companies immediate 100 per cent tax relief on capital investment for activities directed at the extension of knowledge in the fields of natural or applied science. It still operates with little change and covers all manufacturing R&D to the same extent as with the OECD's Frascati definition.

The Teaching Company Scheme (TCS): In operation for over 20 years and regarded by Government as one of its most successful schemes for facilitating technology transfer by promoting partnerships between academia and industry. It currently supports over 1000 graduates in over 620 projects.

"Industrial Units" in HEIs: Announced in May 1991 to improve the commercial activities at HEIs and to help them established industrial units. It is now entering its final year.

LINK: Initially launched in 1987 to support research partnerships between industry and the science base. Government and industry fund LINK projects on a 50:50 basis. There are currently 54 individual programmes open of which 26 are accepting new project proposals. A major review was undertaken in 1994 and the scheme subsequently relaunched in March 1995 with changes to the eligibility constraints, in particular, allowing stand alone projects to be considered. LINK now also has a new strategic direction in responding to priorities identified by the Foresight exercise.

SMART and SPUR (see Box 2): SMART launched in 1986 has supported over 1600 projects and SPUR almost 800 since its launch in February 1991. Both schemes continue.

The Manufacturing Planning and Implementation Studies Programme (MPI): Launched in February 1991 to encourage manufacturing SMEs to employ third party advisers to help them undertake a strategic review of their capabilities and markets. It was closed for applications in December 1994.

Technical Action Line (TAL): Launched in February 1991 to help SMEs solve technical problems concerned with the use and application of new technology, and to encourage them to use academia, research organisations and industry. It was absorbed into the new one-stop-shop structure which later became known as the business links network.

Box 2: Some of the current DTI sponsored schemes supporting innovation and small business

SMART—Small Firms Merit Award for Research and Technology: SMART is an annual competition run by the DTI. Project proposals are judged against each other by a group of experts with technological and financial backgrounds. SMART is open to individuals or business in the UK with up to 50 employees and either total assets of less than £1.5 million (ECU 2 million) or a turnover of less than c. £3.5 million (ECU 5 million). The maximum grant is £45,000 and the awards are made for up to 75 per cent of costs to carry out feasibility studies on innovative technology projects. One third of the grant is paid at the start of the contract with the rest to be claimed in arrears at three month intervals. The DTI told us that 20 per cent of projects funded by SMART which achieved at least one year of actual sales went on to have a third year turnover of more than £0.5 million.

SPUR—Support for Products Under Research: These grants are often taken as a follow-up to a successful SMART award. SPUR is open all year round to UK companies with up to 250 employees and either total assets of less than approximately £8 million (ECU 10 million) or a turnover of less than £15 million (ECU 20 million). Eligible projects must involve a significant technological advance for the industry and must not be defence related. Each project proposal is judged on its own merit and good proposals will receive funding if money is available. Awards of up to 30 per cent of project costs are usually made and the maximum value of a SPUR grant is £150,000 (claims are paid every three months in arrears). So far, over 500 projects have shared £46 million of SPUR grants. The DTI told us that 63 per cent of small companies receiving a SPUR grant had established an on-going R&D capability as a direct result.

SPUR-plus: This is a higher-level version of SPUR with similar eligibility criteria etc., but for projects which would lead to a technological step forward for the whole of the United Kingdom. The maximum grant is £450,000.

Amalgamation of DTI schemes: Later this year SMART, SPUR, and SPUR-plus are to be amalgamated with other innovation grants available from the Government. Inter-Departmental discussions are in progress as to the name of this new programme (although the SMART branding may be retained), the eligibility criteria (more competition is likely), and the size of grants that will be available. The original budget for the programme announced in the 1995 White Paper *Competitiveness Forging Ahead* (Cm 2867) was £76 million over three years, including £7 million of new funding, although this is now under review.

SFLGS—Small Firms Loan Guarantee Scheme: The SFLGS allows small firms without security or a track record to obtain conventional business loans from banks. The DTI provides security for up to 70 per cent of the loan value for new businesses and up to 85 per cent for existing businesses. In return, the borrowers pay a premium to the DTI which is 1.5 per cent of the loan if it is taken at a variable rate and 0.5 per cent if it is fixed. Eligibility criteria for companies were simplified in September 1996 and the main factor is now turnover: businesses involved in manufacturing must have a turnover of less than £3 million, and non-manufacturers less than £1.5 million. The maximum size of loans is £100,000 for new businesses and £250,000 for existing businesses. The maximum term of the loan has recently been increased from seven to ten years. Over 5000 guarantees were made in 1995-96 and two thirds of them were for loans of less than £30,000. The value of guarantees issued in 1995-96 was £275 million (£30 million up from the previous year) and the DTI has set no limit on the number or value of guarantees that it will issue in any year.

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2.6 The Bank considered it important that universities and colleges develop better links between their science and technology departments and their business schools. The entrepreneurs starting small technology-based firms need to improve their management skills and competence, and the business schools and networks of business support agencies can play an important role in this.

2.7 The Bank considered the SMART/SPUR (see Box 2) scheme had been highly effective and should be continued; it also considered that some of the US programmes to increase funding for technology-based firms could be appropriate in the UK. The Bank recommended that the operation of Venture Capital Trusts and the Enterprise Investment Scheme should be reviewed on a regular basis to ensure they remain appropriate vehicles for the financing of technology-based firms. Finally, the Bank considered that some adjustments to capital taxation could help to encourage entrepreneurship and investment in technology-based firms.

2.8 The figure in Box 3 below (derived from Chart 2.1 in the Bank of England report) summarises the typical sources and scale of finance over the life cycle of the firm:

— In the earliest stage (the period of conception) finance requirements are low and are often met from personal or family savings.

— In the start-up stage (when the firm is launched) finance requirements are growing, and are met by private investors or seed funds, or in some cases by SMART and the Small Firms Loan Guarantee Scheme (SFLGS) (see Box 2).

— In the early growth stage, the firm may be operating at a profit, but these profits are probably insufficient to meet the firm's capital requirements, and finance is obtained in the form of classic venture capital and commercial banks.

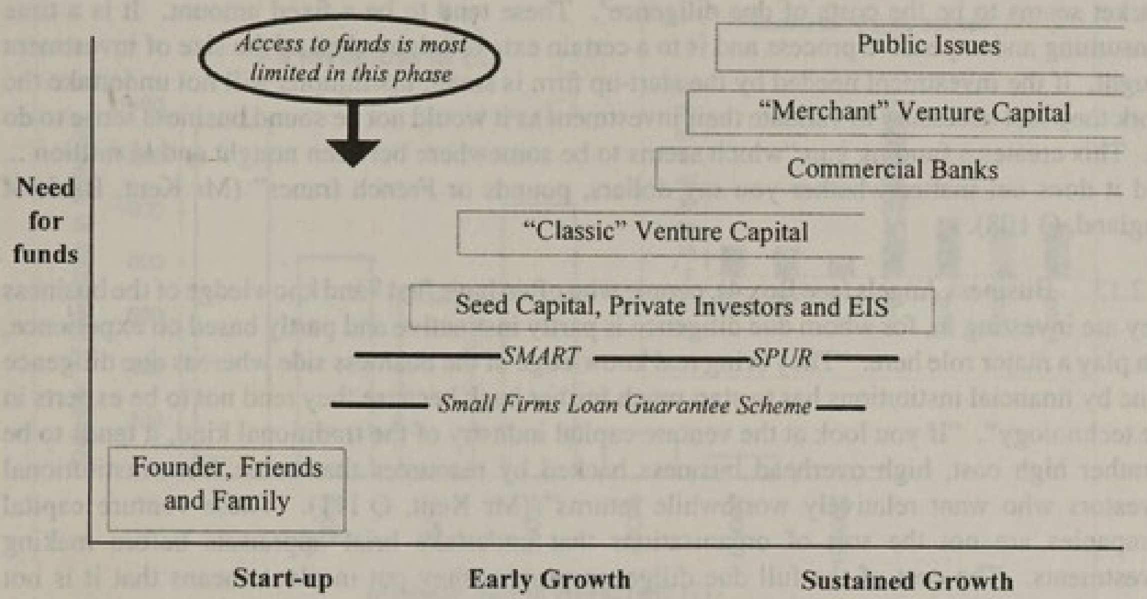
By the time the firm reaches the sustained growth stage, the majority of financial needs are satisfied through retained profits, but public share issues may be needed in some cases.

EVIDENCE TO THE COMMITTEE

2.9 The written and oral evidence to the Committee confirmed the importance of issues affecting the provision of early start-up or seed capital for innovators. For many small "life-style" enterprises, which have no objective of becoming larger organisations, very slow growth is compatible with the founder's aims to maintain control and remain independent. The distinguishing feature of technology-based start-ups, particularly the so-called "hard starts" characterised by a higher initial capital requirement, is that speed of exploitation is of the essence. If it is to succeed the enterprise must expand rapidly and capitalise on the innovation. At this stage a commercially viable product does not exist, the size of the potential market is extremely difficult to assess, investment may be needed for a long period and the technological risks are difficult to evaluate, particularly by people unfamiliar with the technology. The risks are high and "the success rate may be in the less than 20 per cent area" (Mr Quysner, British Venture Capital Association, Q 201) (a rate which is however not dissimilar to the average rate for start-ups). But in this category in particular, the rewards from the successful may more than make up for the losers.

2.10 There is no shortage of ideas: "Our concern with the state of innovation is therefore less a concern about new ideas themselves and more a concern about the ability to create valuable business from what we broadly see as an existing wealth of ideas" (memorandum from 3i, paragraph 2.1). In principle there is no shortage of funds: "the venture capital industry invests approximately £2.5 billion" per year in the United Kingdom (Mr Quysner, Q 190). But this includes everything from small amounts of money as seed capital for nascent technology-based companies right through to management buy-outs and privatisation share issues involving existing very large companies. There is a clear distinction between areas of activity at either end of this scale and in effect there are two very different venture capital industries: one supplying "merchant"

Box 3: Sources of funding during the growth of a firm



Although routes of funding do exist to transform ideas into start-up companies, finding suitable finance which is acceptable to both the innovator and the investor can be a major stumbling block. The availability of funding sources increases as the firm develops a track record or receives a stamp of approval such as a SMART award.

Seed Capital is finance targeted at firms in the early and start-up phases of development. Seed capital firms tend to take a "hands-on" approach to investment in the formative years of a technology-based firm.

"Classic" Venture Capital is risk finance for the start-up and development of small and medium sized unquoted companies with significant growth potential.

"Merchant" Venture Capital is finance for investment in management buy-outs and management buy-ins, and has come to dominate the overall market for venture capital in the United Kingdom.

Public Issue of shares takes place on the primary Stock Exchange, or in secondary markets such as AIM (the Alternative Investment Market).

The Enterprise Investment Scheme (EIS), Small Firms Loan Guarantee Scheme (SFLGS), Support for Products Under Research (SPUR) and Small Firms Merit Award for Research and Technology (SMART) are discussed elsewhere in this chapter.

venture capital which is used to refinance existing industries, and the other "classic" venture capital which focuses on early stage financing.

2.11 In the United Kingdom the industry is dominated by merchant venture capital which now accounts for 96 per cent of activity. The average annual investment in classic venture capital has been around £100 million per year over the last ten years, with about half of this going to technology-based firms. Looking more closely at equity investments in seed and early stage businesses (not necessarily solely technology-based) suggests that the proportion of investment here has fallen recently and now accounts for only about 1 per cent of total venture capital activity (Bank of England report p 19).

2.12 The key reason for the venture capital industry's concentration on the larger end of the market seems to be the costs of due diligence[3]. These tend to be a fixed amount. It is a time consuming and expensive process and is to a certain extent independent of the size of investment sought. If the investment needed by the start-up firm is small, institutions will not undertake the work they feel necessary to validate their investment as it would not be sound business sense to do so. This creates a funding gap "which seems to be somewhere between nought and ¼ million ... and it does not matter whether you say dollars, pounds or French francs" (Mr Kent, Bank of England, Q 108).

2.13 Business Angels (see Box 4), people who often have first hand knowledge of the business they are investing in, for whom due diligence is partly instinctive and partly based on experience, can play a major role here. "They bring real knowledge of the business side whereas due diligence done by financial institutions has to start much further back because they tend not to be experts in the technology". "If you look at the venture capital industry of the traditional kind, it tends to be a rather high cost, high overhead business backed by resources that come from institutional investors who want relatively worthwhile returns" (Mr Kent, Q 111). These venture capital companies are not the sort of organisations that undertake brief appraisals before making investments. The cost of the full due diligence process they put in place means that it is not economic to make small investments. Large investments and management buy-outs are far more cost effective.

2.14 There are also problems created by the cultural differences between the management structure of a large venture capital company and a new start-up, often with only rudimentary knowledge of management practice. In contrast a lot of Angels in the US have an entirely different attitude to risk—they "gamble" (Mr Ian Harvey, BTG, Q 274) and invest in small companies because they have a personal attraction to the industry, or the technology, or detailed inside knowledge of its operations: they back a hunch. Without this knowledge there is a mismatch between entrepreneur and investor and, as the Bank of England report states, "Asymmetry of information and interest between provider and user of finance are common sources of market imperfections".

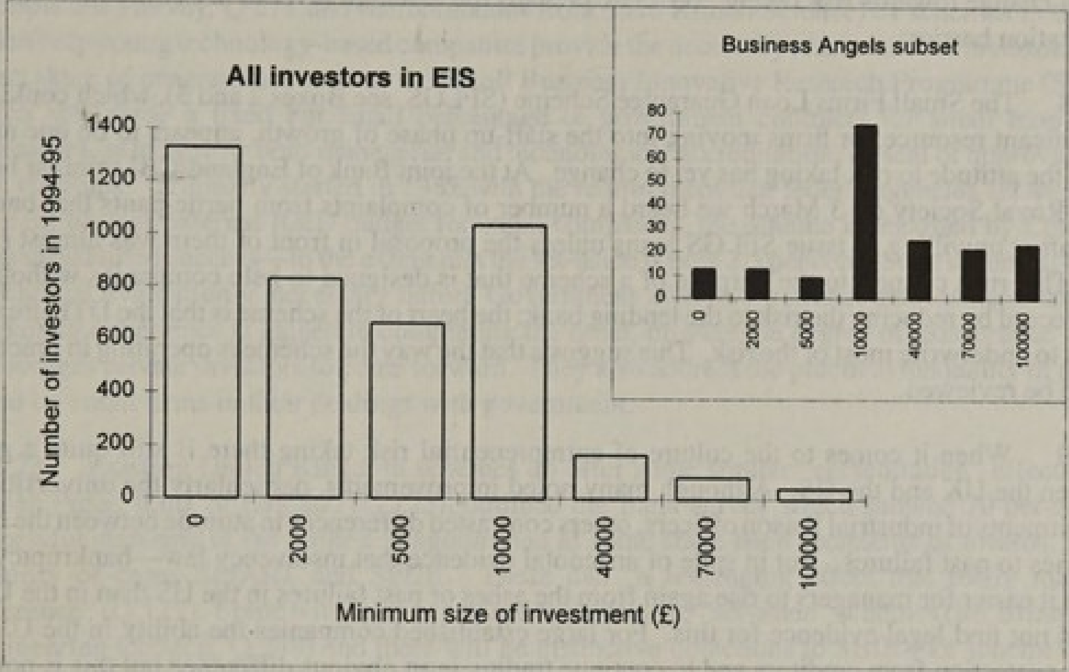
2.15 Mr Hugh Thomson, Director of Research and Consultancy Services, Strathclyde University, told us that they had used Business Angels alongside entrepreneurs from their academic community on start-up companies. The Business Angels were investing their money for the tax advantages, but they were also interested in getting involved in new ideas and the academic staff were a very useful source for them (Q 328). A significant feature of investment by Business Angels can be their contribution of experience to the management of the start-up company. In recognition of this steps have been taken recently by the Government to attract more individuals to become Business Angels, for example through changes to the rules of the Enterprise Investment Scheme (EIS) (see Box 4).

2.16 Although the Committee heard evidence that the introduction of the EIS has attracted purely tax-based Angels, some of whom did not become actively involved in the company they invest in (Mr Quysner, Q 195), nevertheless from others there was evidence of the value of EIS. Figures from the Inland Revenue indicate that the scheme attracted over 7,000 individual investors in its first three years of operation and that over £75 million had been raised for over 675 companies. Around two thirds of investors had committed less than £10,000 to the EIS, but Business Angels (defined for this purpose as investors who also become paid directors of the company) typically invested larger sums. Their pattern of investment also appears to have changed

[3] The due diligence process is the technical and financial feasibility assessments a prospective investor will undertake before making a commitment. It can involve chartered accountants reporting on financial projections and external consultants examining technical feasibility and market projections. References will be taken up on the company.

Box 4: Enterprise Investment Scheme and Business Angels

Participation in the EIS. Data from the Inland Revenue Company Tax Division.



EIS: The Enterprise Investment Scheme provides tax incentives for individuals to invest in unquoted companies, thus providing typically small companies with a source of equity finance. EIS investors benefit from relief at the lower rate of income tax on investments of up to £100,000 a year, are exempt from capital gains tax if the shares are held for at least five years, and can claim relief against capital gains tax or income tax if the shares are disposed of at a loss. To qualify, investors must not already be connected with the company (although they can subsequently become a paid director), and the investor must not buy more than 30 per cent of the share capital. The company must trade wholly or mainly in the UK, and carry on a qualifying activity for a minimum of three years, and the amount that a company can raise in a year on which relief will be given is £1 million (or £5 million for some shipping activities). The scheme was introduced in 1993 as the successor to the Business Expansion Scheme.

Business Angels: Business Angels are individuals, usually acting separately but often as part of a syndicate, who provide equity capital direct to new and growing unquoted businesses and play a part in their direction and development. They most usually take an equity stake but may provide other long term finance and frequently, but not always, have some prior connection with or knowledge of the sector in which they invest. They invest smaller amounts, generally less than £100K, and at an earlier stage than most venture capital firms: indeed they help to make the transition from the funds of the founders, friends and family to those of the venture capitalist. In the figure above Business Angels are defined as those investors who become paid directors on or after the date of buying shares in the company.

with time: now 40 per cent of Business Angel investment is at levels over £70,000 (14 per cent investing the maximum of £100,000), whereas there were no investments in this range in 1993–94.

2.17 Although we found a broad consensus that there was a funding gap for equity investment in seed and early start-up companies there was also much evidence (for example Mr Langston, Mr Quysner QQ 106, 197) that the situation was improving. (University industrial liaison officers also told us of increasing involvement of Business Angels, with banks and accountants acting as the centres of informal networks.) Although the United Kingdom lagged far behind the US, it was, said

Mr Harvey, ahead of Europe in addressing this funding requirement. "I think the United Kingdom does extremely well, certainly compared with Germany, France, Spain or Italy" (Q 299) (a view reinforced by the university industrial liaison officers); further, "The UK is in the middle of a culture change towards risk taking" (Q 271), perhaps the essential lever to lower the innovation-exploitation barrier.

2.18 The Small Firms Loan Guarantee Scheme (SFLGS, see Boxes 2 and 3), which could be a significant resource for firms moving into the start-up phase of growth, appears to be one area where the attitude to risk taking has yet to change. At the joint Bank of England/CBI seminar held at the Royal Society on 3 March we heard a number of complaints from participants that banks were often unwilling to issue SFLGS loans unless the proposal in front of them was almost risk free. This runs counter to the purpose of a scheme that is designed to help companies without a track record by reducing the risk to the lending bank: the heart of the scheme is that the DTI already agrees to underwrite most of the risk. This suggests that the way the scheme is operating in practice should be reviewed.

2.19 When it comes to the culture of entrepreneurial risk taking there is still quite a gulf between the UK and the US. Although many noted improvements, particularly the universities' appointments of industrial liaison officers, others contrasted differences in attitude between the two countries to past failures. But in spite of anecdotal evidence that insolvency law—bankruptcy—makes it easier for managers to rise again from the ashes of past failures in the US than in the UK, we did not find legal evidence for this. For large established companies the ability in the US to obtain protection from creditors and to continue trading is an obvious difference but this is not so relevant to new start-ups. In the seeming absence of institutional reasons for any difference of attitude to past failures this may reflect part of our culture that has yet to change.

OPINION OF THE COMMITTEE

2.20 Since our last report there have been many very welcome changes in both the availability of finance for small start-up companies and the willingness of individuals to form these companies. This latter change in attitude is particularly encouraging. Nonetheless there is evidence of a market failure in the provision of seed capital to technology-based start-up firms, due in part to an asymmetry of information (or understanding) between suppliers and users of finance leading to different assessments of the risk/reward ratio for such enterprises. However, while we go on to recommend some specific changes to help correct this assymetry, our first objective is to ensure that existing schemes fulfil their original aim. Financial stability is itself an important objective. All concerned with the formation of new companies need to feel confident that the decisions they make are not likely to be rendered nugatory by dramatic changes in the business environment.

2.21 The role of Business Angels is widely recognised (for example, DTI, Q 36) and supported by the tax incentives supplied by the EIS. However, although there is recent research[4] which emphasises the importance of their role, there are more anecdotes than firm information. Some universities and budding entrepreneurs seem to have little difficulty gaining access to angel networks, others seem unaware of the opportunities available. Existing efforts to create a national network of Business Angels are supported by the charitable donations of a few benefactors. To increase the number and scope of Business Angel activities we need to know more about the extent of their present involvement and any constraints that prevent expansion of their role. EIS data provides a new and potentially revealing source of information on the characteristics and interests of these individuals. **We recommend that the role of Business Angels be examined further by Government, universities and leading financial institutions to determine the extent of their present involvement and the conditions that influence their activities, and to identify ways of expanding their role. We believe particular attention should be paid to the potential value of Business Angel networks and ways of supporting a national network.**

[4] *Business Angels: Tapping the Potential*, Coveney, Moore and Nahapiet, Templeton College.

2.22 The perceived risk/reward ratio can be reduced if understanding of the technology and the business can be improved. "Second tier" or "serial" Angels, who are reinvesting in the area of their own entrepreneurial success, have this instinctively but we have received evidence (for example Mr Harvey, Q 271 and memorandum from Save British Science) of schemes in the US which help young technology-based companies provide the necessary reassurance to investors. The effect there of programmes such as the Small Business Innovative Research Programme (SBIR), which sets aside a fixed but small percentage of government contracts for small innovative companies, is to bestow both managerial and technological accreditation, a "seal of approval", for new start-ups. Originally started in 1982 with the requirement that federal agencies set aside 0.2 per cent of their external R&D budget for small companies, the scheme is regarded by Congress as an unqualified success—to the extent that the set-aside is now 2.5 per cent. Such schemes, where a technical evaluation is necessary before Government awards a contract and management and marketing experience is gained in completing the order, provide the degree of reassurance which encourages private investors to come forward. They also address the practical inequality of access faced by small firms in their dealings with government.

2.23 Existing United Kingdom schemes do offer some similar "accreditation" effects. Mr Adrian Piper, Bank of England (Q 125), outlined the Bank survey which showed 70 per cent of successful start-ups in the United Kingdom had at some stage been recipients of awards, in the majority of cases SMART and SPUR. These had "a leveraging effect that really makes a difference" (Q 127). Some witnesses expressed opposition to "set-aside" schemes (Mr Brian Kent, Engineering Council, Q 248) and there will be instinctive objections to SBIR-like schemes from those whose budgets would be pre-empted in this way. Nonetheless, although there was considerable scepticism about the operation of such schemes in practice **we recommend that the Government examines ways in which its own existing programmes might be used to underpin the innovation process, following the example of SBIR in the US.**

2.24 We identified two other potential obstacles to the provision of seed capital. Firstly the reluctance of some entrepreneurs to accept equity investment with voting rights owing to the perceived loss of control, and secondly the reluctance of venture capitalists to invest small seed capital amounts, typically from £100K to £500K, owing to the relatively high setting up costs (due diligence) of such small investments. Reducing these obstacles would contribute to overcoming the innovation-exploitation barrier and would also deter companies from over-reliance on bank loans with resulting high gearing. In practice, an initial reluctance to cede equity can often be overcome by good advice, particularly when successful examples of those who have followed this route are at hand. But **we recommend that the DTI should examine how the disincentive of disproportionately high costs of due diligence with respect to the small investments needed by start-up companies could be reduced.**

2.25 Our concern over the cost of due diligence and the inhibiting effect this has on the ability of start-up firms to raise funds is heightened by the report we have received that the "Big Six" accountancy firms are acting together to impose standard terms on venture capital firms to limit their liability on venture capital due diligence work. This action could result in fundamental changes in current practice which would restrict the venture capital available to UK companies. We did not take evidence on this issue and we are not in a position to comment on the merits of the representations being made by the venture capital industry but we draw it to the reader's attention.

2.26 Although we have received some suggestions that income tax relief on investments in technology-based companies could be used to stimulate investment in various chosen sectors (eg ABPI, Q 245), we are not in favour of any such sector-specific approach. Nonetheless the treatment of capital gains can have a profound influence on the investment decisions of the individual investor and here we heard evidence (Mr Quysner, Q 206) that there is an apparent inequality of treatment between the individual entrepreneur who has just founded an organisation and the co-investor institutions. **We recommend that the Government considers equality of CGT treatment between the individual founding shareholders and the institutional shareholders.**

2.27 We share the views expressed in the Bank of England's report that the operation of EIS and Venture Capital Trust (VCT) Schemes should be kept under close review. These two schemes do not appear to have achieved in practice their potential for funding technology-based start-ups and there are signs that the VCTs are drifting towards a risk averse strategy. The announcement of Venture Capital Trusts in November 1994 said "the aim, in particular, is to help provide more funds where they are most needed, among dynamic, innovative growing businesses" (Treasury statement 29 November 1994). Speaking to the Association of Investment Trust Companies in May 1995 the Financial Secretary to the Treasury spoke of the "general thrust of the legislation to encourage risk". The initial intent of this innovative scheme, which is explicitly aimed at the funding gap experienced by start-up companies and therefore of prime significance to new entrepreneurial technology based companies, would seem to go a long way towards meeting many of our concerns in this area. It is perhaps inevitable that any such novel scheme will undergo change as it develops, but we were concerned to hear, for example from Sir David Cooksey at the Royal Society conference on 3 May, that these trusts are now being used to fund asset backed schemes with significant investments in property. This completely diverts the intent of VCTs and by so doing reduces the availability of funds to the intended sector. **We recommend that the Government re-examines the VCT scheme to see if the present direction is consistent with the original intent. If there are indications that changes are needed to ensure these trusts do not become risk averse those changes should be made promptly. The EIS should also be kept under review to ensure that the final economic impact of this scheme fulfils the original aims.**

2.28 Other measures can be taken that, if they do not increase the availability of start-up capital, can reduce the need for it. We cover in particular the role of incubators and science parks in Chapter 5. None of these measures alone can make a dramatic breach in the innovation-exploitation barrier but each can make a valuable contribution to increasing the number of entrepreneurs starting up new companies.

CHAPTER 3 THE SCIENCE BASE

INTRODUCTION

3.1 "The science base" is a loose expression often used to mean the nation's common stock of scientific talent and resources. It embraces publicly-funded science in universities and Research Council units; depending on the context, it may be meant to include the resources of Government research institutes, research charities (mainly medical) and industrial research organisations; it is distinguished from the research capabilities of individual commercial firms. Much of the activity of the science base consists of "basic science", i.e. research with no specific application in mind; the two expressions are not synonymous but to avoid any impression that they are synonymous the expression "science and engineering base" is sometimes used. Many of the ideas which lead to innovation originate in the science base, and, if barriers to exploitation exist, they may be found within the science base or at its interface with industry. In this chapter we examine the factors which affect the ability of the science base to bring forward ideas, the way the key issue of intellectual property rights (IPR) are handled, mechanisms for handling technology-transfer at the interface and the steps taken overall to reduce the barriers to innovation.

BACKGROUND

3.2 In its report of 1991, the Committee considered the university-industry interface, and said:

> "We welcome the closer relations between industry and the science base which have been forged in recent years. We regret that British companies are often slow to take advantage of improved technology transfer from Research Councils and HEIs (higher education institutions, which then included polytechnics as well as universities) and urge them to improve their responsiveness. Greater interaction in policy formation between industry and academia would be advantageous. More staff of HEIs should be involved on the boards of companies. Further improvements in the links between industry and academia should not be perceived by Government as an excuse for reducing support to HEIs and Research Councils" (paragraphs 10.20–23).

3.3 The Government agreed with the Committee. Their response offered nothing new, but drew attention to various existing policies: the expansion of higher education and the ending of the "binary line" between polytechnics and universities; money available to HEIs at that time from the DTI "to strengthen the marketing and commercial skills of their 'Industrial Units'" and for "institution-wide technology audits to identify research results for exploitation"; LINK and the Teaching Company Scheme (TCS); the new Interdisciplinary Research Centres (IRCs); and new statutory provision to encourage representation of industry in the governance of polytechnics. This response referred approvingly to the rapid growth in the number of United Kingdom science parks, from two in 1979 to 39 in 1991; and to the rise in the research grant and contract income of universities from industry from £27 million in 1982–83 to £105 million in 1989–90. It said,

> "The Government is committed to maintaining a healthy science base and will continue to fund the Research Councils and HEIs accordingly ... the Government stands by its commitment not to reduce public support in response to institutions' continuing success in generating income from other sources".

3.4 The milestone White Paper "*Realising our Potential*", published by the Government in May 1993, set out a series of reforms intended to build on the country's existing strengths in science, engineering and technology. It maintained the commitment to support the science and engineering base and said Government schemes for technology transfer would be developed to re-emphasise the importance of the interchange of ideas, skills, know-how and knowledge between the science and engineering base and industry. It also gave the commitment to easier access, especially for small and medium sized enterprises (SMEs), to the innovation support programmes run by the DTI and the equivalent offices in Scotland, Wales and Northern Ireland.

3.5 The Bank of England's recent report notes the significance of the university-industry interface without making it a major theme. It acknowledges that, at the "seed stage", a technology-based firm often consists of a full-time academic researcher developing an innovation either at work, in his own or his employer's time, or at home.

> "This situation, although an advantage initially (since the innovator has an income and access to facilities), can lead to important problems later when the product is to be launched: technology-based firms which spin-off from a university or other research establishment often face difficulties involving intellectual property rights" (paragraph 2.2 of BoE report).

3.6 The report repeats the familiar refrain: strong in invention, weak in innovation. It cites a study (by PRISM in 1996) of human genetic technology patents: United Kingdom scientists wrote 6.5 per cent of papers cited, but only 2.8 per cent of the patents were owned in the United Kingdom; Japan produced only 4.8 per cent of the papers, but owned 12.3 per cent of the patents. It notes that an increasing number of universities have a technology transfer department, some with their own venture funds; and that the Medical Research Council (MRC) has set up spin-out firms, or fostered them by incubation, and plans to set up its own seed investment fund.

> "However, there are still cultural barriers to commercialisation. It is generally believed that UK universities are not yet as commercially-minded as their US counterparts" (paragraph 3.57 of BoE report).

To improve the culture, the report recommends that universities use successful graduate innovators as role models, and we endorse that recommendation.

EVIDENCE TO THE COMMITTEE

Threats to the science base

3.7 Many witnesses stressed the importance of maintaining the science base, as well as supporting the innovation process. Witnesses from the Association of the British Pharmaceutical Industry (ABPI) told us that "We rely very heavily now on our colleagues in academia to do a lot of the really fundamental and underpinning research for us" (Q 228). The DTI restated its total commitment to maintaining the science base. Dr David Evans, Director of Technology and Standards at the DTI, assured us that the Government and the Research Councils are still trying to maintain the balance between "bedrock" science and applied research set out in *Realising our Potential* (Q 10). However, the ABPI argued that British companies are increasingly looking abroad for new research partners because they consider the UK science base is declining through under-investment (Q 237). The pharmaceutical industry also looks to universities to produce skilled scientists to staff the industry's laboratories. Here, too, the ABPI says that it finds the UK science base increasingly wanting.

3.8 But although it is very significant, the pharmaceutical industry is hardly typical of United Kingdom industry. The big firms are global in operation; the market is large and highly regulated; development takes a very long time, but a new patented medicine can command large returns; and academic and commercial researchers communicate with relative ease because they work in substantially the same ways (Mr Langston and Dr Garnsey, QQ 93–97). At the same time, moreover, the industry's specialist research relies on a level of capital equipment in its laboratories that can rarely be duplicated in universities; and it must expect to carry some of the burden of training its own scientific staff. More disturbing were the comments of Professor Gareth Roberts, Chairman of the Committee of Vice-Chancellors and Principals (CVCP), that "if the UK economy is to remain internationally competitive, it is essential that our universities are adequately funded to maintain the international excellence and standing of their research. However we believe that there is growing evidence that some multi-national companies based in this country are re-siting collaborative research overseas in the light of concern about the research infrastructure in the United Kingdom". "It is clear that the money allocated by our Higher Education Funding Councils is now grossly inadequate to meet all the objectives". "Greater attention must be given to the replacement costs of research facilities and equipment". "Infrastructure funding is falling between the cracks in the system and none of the stake-holders is taking full responsibility for it" (Q 337).

3.9 Professor Roberts drew our attention to the importance of recognising that employers are not a homogeneous group and that large multi-national companies have very different needs from small businesses. He reminded us that it is the small companies which are critical to the innovation process. Similarly the organisation of research in the more than 100 universities in the United Kingdom varies considerably from the large strongly research-focused institutions to those that are small and teaching-focused. Within this research environment activities range from "blue sky" basic research to near-market applied research. There is a balance between the need to carry out work at the very leading edge of technology and the need to form links at local and regional level with SMEs and local business advisory services. Even more important is the need to maintain the very delicate balance between investigator-driven basic research and the more focused applied research where commercially successful exploitation is more readily apparent.

3.10 Professor Roberts pointed out that although it was not explicit Government policy to divert more public sector funding into applied research, the attractiveness of schemes designed to bring university and industry together tended to push research programmes in that direction. "I suspect that the overall balance is now about right", he told us (Q 358). "But with all the momentum it could soon be out of bounds" (Q 359).

Interaction with the science base

3.11 Dr John Forrest, Chairman of the Brewton Group of small and medium-sized IT companies, voiced two familiar criticisms concerning interaction with the United Kingdom science base: too many of its best brains are business-illiterate; and inventors did not wish to relinquish equity in their inventions (Q 166). We found much truth in this generalisation, but a lot of evidence suggests things are changing.

3.12 Dr David Evans (DTI) told us his assessment of the present United Kingdom position was positive: "there has been a steady growth in the interaction between industry and the universities" (Q 2). This bodes well for competitiveness, since DTI surveys show that firms which grow fastest tend to exhibit good connections with the science base (Q 7).

3.13 Dr Garnsey described the interface between the science base and industry by emphasising that innovation is not always a linear process, proceeding from the university to the company and out to the market. It is an interactive process where innovations in, for example, software or scientific instruments may feed back into the science base and trigger new research (Q 86). The significance of partnerships between industry and the science base was mentioned by many of our witnesses.

3.14 William Castell, the Chief Executive of Amersham International plc, told us the key to innovation is partnerships involving the best scientists around the world (Q 143). Although in the global market, he regards Amersham as a relatively small company, he believes that big firms will also be forced increasingly to make research partnerships, partly because in many situations innovation requires more disciplines than any one firm could have in-house. Amongst Amersham's strategies for finding the right partners were university "listening posts", an international high-level advisory board, and interfaces as informal as dinner in college halls (QQ 154–6).

3.15 The ABPI spoke of partnerships with university science that are close: "The barriers between us are now largely removed, or at least minimised" (Q 228). Mr Harvey emphasised that it was important for universities to forge links with industry (Q 278); however, this should be done on a one to one basis. "When universities go it alone", he argued, rather than forming university consortia to manage the university/industry interface, "they do better because they are motivated to work in their own self-interest" (Q 280).

3.16 Representatives from the Association of University Research and Industry Liaison Officers reinforced the view that a significant change in culture is under way. "Academics are interested in commercialisation of their ideas" (Mr Thomson, Q 303). Our witnesses emphasised the importance of integrating the technology transfer function within the universities' affairs: "licensing is part of the business" (Q 303). They emphasised both the timescale of the process, given that it might be 20 years before an initial breakthrough led to an exploitable product, and the need to look at the "portfolio" of ideas within an establishment, not one or two isolated examples. Professor Roberts emphasised the top-level strategic role of the technology transfer function. These were issues that needed to handled by the top management within academic institutions. Licences also gave rise to one of the few sources of funds that were not earmarked, and could be spent how the university chose.

Innovation

3.17 Innovation is widely recognised as the key to industrial success. The White Paper "*Realising our Potential*" points out that "firms which are skilful at innovation will secure competitive advantage in a rapidly changing world; those which are not will be overtaken". Madame Edith Cresson, the European Commissioner responsible for research and education, has spoken of an "innovation deficit" in Europe and the need to foster a genuine innovation culture. Dr David Evans explained that the DTI has moved away from support for industrial R&D itself in favour of actions to improve the "infrastructure" for innovation (Q 9). He mentioned some of the many schemes including the Teaching Company Scheme (Q 7), Postgraduate Training Partnerships to support both postgraduates to work for their degrees in industrial research organisations (Q 9) and LINK (see Box 1).

3.18 Dr Elizabeth Garnsey (a lecturer in Management Studies) told us of the work at Cambridge University that has created "a culture that is open to enterprising activities" (Q 98). "There is an opening up of awareness that it is not necessary to go into the large company with large laboratories, but there are now opportunities for starting up your own business" (Q 92).

3.19 The Chief Executive of BTG plc[5], Ian Harvey, was in general optimistic about innovation in the UK. He produced figures to show that the United Kingdom is five times more successful at generating royalties from patents and licences than the USA. In his experience, United Kingdom universities have become much more "creative" in innovation over the last ten years, and more keen to spin-out new companies. A lack of receptivity to new ideas in United Kingdom industry was at the root of any failure to innovate (Q 271). Evidence from the industrial liaison officers tended to confirm the view that there was no lack of ideas inhibiting the innovation process: "the problem is to identify the opportunities" (Mr Thomson Q 303).

Intellectual property rights

3.20 University research may lead to patentable ideas. If a patent is taken out it may be licensed to an existing firm, perhaps a large multi-national company, or it may form the basis of a local start-up enterprise. Whichever route is followed, IPR are key to both the generation of income to the university from licensing and the spin-out of new business enterprises. One of our early witnesses, Dr Elizabeth Garnsey, told us that Cambridge, unlike other universities, does not claim IPR in inventions of its staff. This is an unusual policy. Strathclyde was more typical, taking the IPR and sharing royalties 50:50 with the principal investigator. Most witnesses felt the expertise, both technical and legal, required to take out and uphold a patent meant this could not be left to individuals. DTI suggested that some universities might be keen, "sometimes too keen", to protect their IPR with patents which are expensive to acquire and much more expensive to defend (Q 8). Although there was little support for the idea that IPR should be ceded to industry, it was acknowledged that it was a chronic problem: universities had limited funds with which to support

[5] BTG exists on the academic-industrial interface; it acquires IPR from universities and licenses it on. Formerly the British Technology Group, BTG was privatised in July 1995 and now operates internationally; but it still files about a third of all patents generated by United Kingdom universities.

a technology transfer office and apply for patents; even deciding what to patent was "extraordinarily difficult" (Mr Quysner, Q 205).

Box 5: Intellectual Property Rights

The Research Councils have adopted a consistent approach on intellectual property rights (IPR) and the commercial exploitation of research arising from their grants. It is expected that valuable results obtained in the course of research will be exploited to the benefit of the institution (usually a university) and its researchers. Initially the ownership of IPR rests with the institution and IPR may be retained or assigned to individuals or industrial partners under exploitation arrangements. Where more than one institution is involved, the IPR rests with the institution employing the inventor. Agreements on IPR and revenue sharing are supposed to be made prior to starting to draw down research grants on projects that involve collaboration with industry.

The Office of Science and Technology (OST) has similar rules for IPR resulting from research that it funds directly (e.g. through the Foresight Challenge fund): it is up to research consortia to negotiate the ownership of IPR themselves; and exploitation is expected in a manner that brings maximum benefit back to the United Kingdom.

The OST and most of the Research Councils do not expect to receive royalties as a result of the exploitation of external research that they have funded. However, the ESRC retains the right to 50 per cent of the income from IPR royalties and copyright. The Medical Research Council (MRC) funds a large amount of internal research by its own staff, and in its own institutions, and in this case the IPR, and any revenues, are retained by the MRC.

In general for the United Kingdom, if an invention (in the widest sense of the term) is developed in the normal course of work then the rights to it belong to the employer. If it is made outside the bounds of work then it belongs to the individual. If the invention is made within work and it is of profound importance to the employer (e.g. transforming a small company into a high value world leader), then it is possible for the individual to get compensation. However, the Patent Office has said that no one in the UK has yet been awarded compensation under this clause.

In some European countries the law on IPR is rather different. In Germany, for example, an individual is automatically entitled to remuneration from inventions made during the normal course of work. Individuals can also claim compensation if the company does not do enough to exploit the invention.

3.21 The significance of IPR to universities with large research programmes and its importance as one of the few unconstrained sources of income raised the question whether IPR work was adequately funded. Numbers provided by David Thomas, Chief Executive, Imperial Exploitation Ltd (Q 303) for his organisation showed that five technology transfer specialists were examining the IPR opportunities that arise from the work of around 2,000 academics. This, he argued, indicated that even the more enlightened organisations could do more to fund and protect their IPR. But, as Professor Gareth Roberts explained, any Vice-Chancellor acting in the role of a chief executive who had seen the funding of his organisation from Government drop from over 80 per cent to under half recognised what had to be done—and had the powers to do it. The remedy was in the hands of the universities.

The balance between spin-off and licensing

3.22 The complexity of the relationship between innovation and exploitation is indicated by the discussion in the Bank of England report. This notes (paragraph 3.60) that United Kingdom universities with IPR to exploit usually license it, for immediate gain, rather than set up a spin-out company. If the licence goes overseas there may be a loss of United Kingdom competitiveness which a spin-out would have prevented. Douglas Robertson, Secretary of the Association of University Research and Industry Liaison Officers, confirmed that he "approaches IPR licences globally and it is often easier to get a licence overseas than in the United Kingdom" (Q 304). But whereas the larger research universities might find it easier to seek markets for their IPR overseas, Jay Mitra, Head of Economic Development at the University of North London, explained that IPR was less of a concern for the ex-polytechnic sector. They looked at what their universities could do to meet the needs of small, mainly local, companies. Only a less specialised multi-disciplinary approach could bridge the gap between what small companies needed and what universities can provide. He outlined collaborative work where the University of North London drew on the expertise of the University of Bologna in its linkages with local business. This collaboration, where the university acted as the intermediary between local industry and the research worker, contrasted with collaborative work described by Professor Gareth Roberts between the universities in York, Leeds and Sheffield where different research centres at the forefront of science worked together.

OPINION OF THE COMMITTEE

3.23 Our witnesses are agreed that the entrepreneurial qualities of science base researchers appears to be improving. This is very much to be welcomed. But pressure to innovate can retard new ideas. So while we welcome the statements from DTI about its commitment to basic science we were concerned by evidence from the Chairman of the CVCP about the shift in the balance of funding. Changes made at individual universities to shift their balance from investigator driven research to applied research and development could, on aggregate, lead to a major shift away from the national effort devoted to basic science which industry relies on them to undertake. **We recommend that the universities and the Funding Councils should monitor the overall balance of effort and if necessary put in place mechanisms to prevent short-term work squeezing out the longer-term basic research.**

3.24 A reason given for the very welcome improvement in entrepreneurial qualities at United Kingdom universities is that they have been forced to innovate and compete in their quest for more funds. Some of the university researchers who contribute the most to industrial innovation are also world leaders in science and technology, and most of these researchers consider that their industry-funded research complements their government-funded research[6]. However, as the proportion of funding provided by the Government has fallen we have received a number of warnings[7] from industry that our science base is slipping below world-class standards in its level of equipment and thus in the training which it provides. This has implications for the distribution of funding. Resources cannot be spread evenly if the best laboratories are to be equipped to the standards necessary to undertake research at the forefront of their chosen discipline. This implies a focused approach, concentrating highly specialised resources in a way that is already familiar to the users of large science facilities such as particle physicists and astronomers. The corollary is access must be given to researchers of high calibre from other institutions. **We recommend that the Funding Councils should ensure that a higher proportion of available funds be channelled into creating centres of excellence, which should be accessible to researchers of high calibre irrespective of their university.**

3.25 However, the contribution of smaller, less research intensive institutions also deserves attention. Large organisations have a certain rapport: global companies, large research intensive

[6] E. Mansfield, Academic Research Underlying Industrial Innovation: Sources, Characteristics and Financing, *Review of Economics and Statistics*, 76(1) 55–65, 1995.

[7] Paragraph 3.7; see also this Committee's 2nd Report (1993–94), *Priorities for the Science Base*, HL Paper 12, ISBN 0 10 48109 4.

universities and government find it easy to talk together. It is by no means clear that these large organisations find it easy to deal with small entrepreneurial companies. We were impressed by what we heard of the role of the ex-polytechnic sector in acting as a bridge between small local businesses and the research base, both national and international. We suspect this work is not as widely recognised and valued as it should be. **We recommend that the DTI consider an enhanced role for its small firms programme in support of this bridging work between the ex-polytechnic sector and small, local businesses.**

3.26 Within universities we welcome initiatives that seek to provide management training for science and engineering students. Some of those who are so trained may, of course, leave research behind and become managers. But this is not a bad outcome: scientist-managers are likely to be more open to science-based innovations than managers with no technical background. We were impressed by steps taken by some sectors of the venture capital and banking industry to explain to universities the workings of their industry and the opportunities for finance. **We recommend those universities that are not taking advantage of the work of the capital providers in explaining financial issues to researchers to follow the example of those who do.**

3.27 We endorse the views expressed by Professor Roberts that universities should be able to manage their own IPR. **We recommend that universities recognise the importance of IPR management and devote the necessary resources to it.**

CHAPTER 4 TECHNOLOGY FORESIGHT

BACKGROUND

4.1 The Technology Foresight exercise (now often abbreviated to "Foresight") resulted from an announcement in the 1993 White Paper on Science, Engineering and Technology. The first part of the exercise was a wide-ranging survey involving industry, commerce, the public sector and academia from March 1994 to March 1995. The results of that survey were published by the Office of Science and Technology in 15 sector reports (April 1995) and one overall report from the Foresight Steering Group (May 1995). Sectors ranged from transport to financial services and from agriculture to materials. The exercise evaluated the current state of United Kingdom research capabilities, highlighted priority areas of research over the next 5 to 20 years, and sought to evaluate areas for research on the basis of their potential for improving wealth creation or the quality of life.

4.2 The second stage of the exercise, which is in progress now, is to take forward the findings of Foresight and apply them to the benefit of the United Kingdom. This has involved maintaining the networks of contacts already created during the exercise, influencing Government policy on research spending, and taking the messages about priorities back to the academic, industrial and commercial sectors. During this stage a number of schemes have been introduced by the Government to provide funding for Foresight priority areas (e.g. the Foresight Challenge, and new LINK programmes for collaborative research between academia and industry).

4.3 The Foresight exercise identified many areas for priority research and these in turn could be translated into opportunities for innovation. The nature of the Foresight exercise with its emphasis on both academic and industrial research makes it of particular interest to this enquiry because it is at the interface between academia and industry that much innovation takes place.

4.4 A review of Foresight has already been conducted by the House of Commons Committee on Science and Technology[8] and so we have not attempted to re-examine the whole of the exercise in this report.

EVIDENCE TO THE COMMITTEE

4.5 Most of our witnesses agreed that the Foresight exercise had had little or no impact on them, their suppliers, or on how research and development funds have been allocated (Mr Quysner, Q 182, and memoranda from eg, The Engineering Council, ABPI, Glaxo, St. John's Innovation Centre and BVCA). In part this may be because it is too soon after the exercise for such an assessment to be made (e.g. Dr Keddie, DTI, Q 18 and Royal Academy of Engineering, paragraph 8) and because, in particular, it would take some time for the information to reach small companies via the "trickle-down effect" (Mr Quysner, Q 182). The level of awareness of the Foresight exercise in small businesses was thought to be particularly low. The NatWest Innovation and Growth Unit said: "For many SMEs, Technology Foresight appears to be irrelevant, and many are unaware of it altogether". The following data from the *CBI/NatWest Innovation Trends Survey 1996* highlights the extent of the awareness problem:

Percentage of companies aware of the Technology Foresight exercise

Company type	Unaware	Aware but not involved	Involved
Manufacturing	52	20	28
Non-manufacturing	72	14	14

Based on a sample of 687 companies drawn from CBI members and those in receipt of NatWest's *Innovation Business* newsletter. Survey conducted in February and March 1996.

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[8] House of Commons Science and Technology Committee: 1st Report (1995–96), *Technology Foresight* (HC 49), ISBN 0 10 204396 5.

4.6 Of those companies that were involved in the Foresight exercise, 13 per cent of manufacturers had attended a regional workshop, 18 per cent had completed a "Delphi" questionnaire and five per cent had contributed as a sector panel member (figures for non-manufacturers were five, nine and nine per cent respectively). The DTI accepted that the Research Councils and public sector had been enthusiastic followers of Foresight and the opportunities it had identified but that the broad mass of industry had paid insufficient attention (Q 9). This was despite the fact that over 600 Foresight "events" had been held, over 130,000 copies of the panel findings had been distributed and 12,000 people receive a Foresight newsletter every six weeks[9]. The DTI re-launched the Foresight programme on 4 December 1996 in an attempt to rectify this.

4.7 Dr Forrest said that more publicity for Foresight through the World Wide Web would be an ideal way of spreading awareness to many small companies[10]. However, a lot of effort would be required, "more than you might think is necessary", to get the message of Foresight across and how it might translate into meaningful business benefits (QQ 183–84 and memorandum from the NatWest Innovation Growth Unit)[11]. If Foresight is to enhance innovation and competitiveness then it is essential that it reach the key business decision makers and opinion formers and not just those people directly involved in R&D.

4.8 We asked the DTI whether the Foresight exercise had been too focused on specific sectors and had thus not given a fair representation to the many innovative ideas that arise outside of traditional sector boundaries (e.g. nanotechnology). The DTI said that the approach had been necessary to make the exercise manageable (Q 31) and that LINK programmes (such as the one for nanotechnology that had now closed) often covered the gaps between sectors. However, the DTI added that "we cannot carry on forever with LINK programmes ... If we can get them going, we can then withdraw and they go on without government support" (Q 32). In the report on Technology Foresight from the House of Commons Science and Technology Committee it was suggested that the scale of the exercise was such that new connections between otherwise unrelated fields had already been made. As a result the need for generic research into sensor technology had been identified.

4.9 Witnesses argued that it was difficult to identify whether the money allocated to support initiatives arising from the Foresight exercise was new or just redistributed from elsewhere (thus affecting other schemes and areas of research). They were concerned that critical but lower priority areas including technology development and demonstration projects should not be forgotten (memoranda from NatWest Innovation Unit, Royal Academcy of Engineering, ABPI and Glaxo Wellcome).

4.10 One witness told us that the follow-up initiatives to the original Technology Foresight exercise had been established without first considering the effects on those companies which would be likely to take part. The ABPI said that they had not been consulted prior to the setting up of the Foresight Challenge Fund initiative which involves academics securing matched funds from industry: "the first we knew about it was when we started getting applications from other academic colleagues to partner them in such applications. We had to turn the majority of them down and that again sours the relationships that were pretty good" (Q 234). The rapid timescale for introducing such schemes (leaving little time for companies to plan their budgets) and the changing rules that alter how existing schemes operate were also criticised by the ABPI (Q 234).

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9 DTI press release, 4 December 1996, and *CBI/NatWest Innovation Trends Survey 1996*.

10 Background information on Foresight, key recommendations made in each sector report, and details of the Foresight Challenge etc. are already available on the Office of Science and Technology home page—*http://www.open.gov.uk/ost/osthome.htm*

11 The Institute of Physics have a programme called "the SME Club" to provide help to small companies including access to Foresight developments and details of the range of products and services on offer from the DTI and other sources.

OPINION OF THE COMMITTEE

4.11 The Technology Foresight exercise is a useful mechanism for identifying broad research priorities in the United Kingdom and for widening the network of contacts between academia and industry. Foresight has had and will have a significant influence on Government funding of research. This can be seen directly through initiatives including the Foresight Challenge Fund, but also indirectly for example by the inclusion of Foresight-related activities in the evaluation criteria of the recent university Research Assessment Exercise (which is used to allocate research money by the Higher Education Funding Councils). We are concerned, therefore, about the continuing lack of awareness of Foresight, in particular in small firms, and the apparent lack of consultation on initiatives designed to support research in areas identified as priorities. In our enquiry into OST[12] we discussed the problem that although in companies with an R&D base there is an awareness of Foresight there are also a large number of companies in which there is nobody who can even identify areas of science that would be of value to them. **We recommend that the Government and industry take more effective action to make innovators both within and outside universities aware of the opportunities (including funding initiatives) that result from Foresight. Subsequent Foresight reports should be made more accessible to small businesses.**

4.12 We welcome initiatives such as the "Business Mentoring and Incubator Challenge" which resulted from the findings of the Health and Life Sciences Foresight report[13]: this will provide targeted business support to start-up biotechnology companies and it should be a direct help to those people wishing to take innovative ideas out of the university or research institute laboratories and into new companies. However, the question of where the funding will come from for such schemes could be made much clearer. **Whilst we do not wish to divert more money towards Foresight, the Government should conduct an audit of all research spending by Departments, the Research Councils and the Higher Education Funding Councils in an attempt to clarify the impact that Foresight has had on the allocation of public research funds.**

4.13 Foresight could and should have a major impact on improving innovation and competitiveness in the United Kingdom. It should not, however, be used to restrict creative research in universities which does not yet have a perceived application. Nor should areas of research that have been defined as important but of lower immediate priority be abandoned as a result. It is also all too easy for innovative lines of research to fall between two sectors. We are not convinced that the existing measures are adequate to ensure that support is available for ideas falling across sectors and, in particular, for those that fall outside traditional sectors. **We recommend that the Government establish a clear policy, in the context of Foresight, of seeking out "misfit" lines of research which fall across or between sectors and evaluate them separately if necessary.**

4.14 We wish to see Foresight used as a force for driving innovation forward in the United Kingdom. We recognise that large companies will always play a major role at least in the earlier stages of an exercise such as Foresight, and that they are important to the innovation process not merely in their relationship with actual and potential suppliers. However, **we recommend that the Government refocus its efforts to ensure, as far as possible, that Foresight is not entirely dominated by large companies and is recognised by small and non-science based businesses as relevant to their needs.**

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12 1st Report (1995–96), *Office of Science and Technology*, HL Paper 11, ISBN 0 10 401196 3.

13 Results of the Business Mentoring and Incubator Challenge were announced by the DTI on 22 January 1997. The eight winning groups will share £970,000.

CHAPTER 5 CLUSTERS, SCIENCE PARKS, INCUBATORS AND MANAGEMENT EDUCATION

BACKGROUND

5.1 The tendency of firms in the same or related industries to cluster together is well known. It happens when there are economies of agglomeration (or co-location). These benefits can derive from strong local customers, from infrastructure, local suppliers, and availability of skilled labour and risk capital. While the rapid development of communications technologies is reducing some types of agglomeration economy, enough remain to mean that the cluster is still a potent force in economic development (see Box 6). Industrial clusters can grow of their own accord, but they often result from development activity by national government or regional development agencies. In high technology clusters—at least during their formative years—it is common to find universities or public research laboratories at the centre of the cluster.

5.2 There is evidence that firms located in these clusters perform better than average. Firms located in strong clusters tend to grow faster than average. Firms in clusters tend also to be more innovative. In addition, strong clusters encourage higher than average rates of new firm formation.

5.3 Specialised clusters—where all firms are from the same industrial sector—often grow fastest in their formative years, but the long-term survival of a cluster, which is dependent on new firm entry, will be best secured if there is adequate diversity in the cluster.

5.4 Clusters may have to reach a certain size, or critical mass, before they start to grow rapidly. Below a certain size, entry of new start-up firms can be limited, but beyond that size, entry takes off rapidly. This critical mass is not the same for all sectors, and it depends on how the cluster is organised. Moreover, few studies have been able to estimate this critical mass with any precision. However, for the US computer industry, for example, it is estimated to occur when total computer industry employment in a State reaches around 10,000. British industry cannot enjoy the same scale advantages as are found in the United States, but within the computer industry a few regions of the United Kingdom have reached this level of employment, and thus can be said to have achieved critical mass.

5.5 There are two polar approaches to creating industrial clusters. The most frequently cited example, Silicon Valley in Santa Clara County in California, is perhaps the classic case of a market-generated cluster of science based industries, though it is sometimes forgotten that government activity was instrumental in the early growth of Silicon Valley during the 1950s. The second is the planned science park, science city or "technopole", of which Tsukuba Science City north-east of Tokyo is often taken as the classic example, where central or regional government plays an essential role.

5.6 The experience of science parks (see Box 6) in Britain has been mixed. Some have been very successful, most notably the Cambridge Science Park, while others—there are now, according to the United Kingdom Science Parks Association, a total in the United Kingdom of 51—have remained too small to achieve critical mass[14]. While university science parks were designed to encourage interaction between host university and the companies on the park, this interaction has been hard to achieve in practice and can be a major problem.

5.7 The Enterprise Panel Report of 1996[15] has emphasised the importance and potential of incubators (see Box 6) in developing new businesses, and the application of incubator principles more generally. Business incubators select firms best able to benefit from support, give access to

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14 Grayson L. (1993) *Science Parks: An Experiment in High Technology Transfer* London: British Library Science Reference Information Service.

15 *Growing Success: helping companies to generate wealth and create jobs through Business Incubation*, The Enterprise Panel (1996). The Enterprise Panel was set up by HM Treasury in 1995 to look at business incubation in the UK and to consider whether action was required to increase it.

Box 6: Clusters, Science Parks and Incubators

A **cluster** is a loose term referring to a strong concentration of companies, often in the same or related industries, sharing a common geographical location, and often in close proximity to important parts of the science base. The strongest clusters usually have a well developed infrastructure of transport and communications, providers of specialist finance and legal services, and environmental or cultural features which makes the cluster a pleasant place in which to live. The geographical size of a cluster is variable: it may contain just one large city and its environs, or can extend to cover a number of smaller towns and cities. A cluster may encompass one or more science parks.

A **science park** offers good quality accommodation and business support services to companies which are commercialising new and existing technologies, with the aim of wealth creation and employment generation. Some science parks are built on new "green field" sites on the periphery of a city, while others are redevelopments of "brown field" inner city land. Science parks often have links with a local university and may be located on or near to the campus, though this need not be the case. A science park frequently contains an incubator.

An **incubator** is a property with small work units providing a supportive environment for entrepreneurs and investors during the start-up stage of their business. But the incubator is more than just the premises: it seeks to build a culture for entrepreneurship by providing access to a wide variety of facilities, equipment and expertise. The incubator aims to maximise the formation and development of businesses with growth potential. Incubators select businesses with growth potential, and the incubator director has a close hands-on relationship with client businesses. The businesses are encouraged to leave the incubator when they have established sufficient market strength, and frequently relocate to a science park. (See also Box 7.)

a range of business skills and training to help businesses grow, provide access to finance and enable enterprises to stand on their own feet more quickly.

EVIDENCE TO THE COMMITTEE

Clusters

5.8 Our witnesses stressed the importance of strong science based clusters to the United Kingdom's economic development, and the importance of a strong science base at the heart of these clusters. While some interaction between the science base and companies can use new communications technologies, the role of the face-to-face meeting is as important as ever. Mr Castell of Amersham International affirmed that "We have in the United Kingdom internationally respected academic establishments. Those establishments are vital if one is to succeed in the clustering effect ... relationships come only because of personal contact ... it cannot all be remote work" (Q 143).

5.9 Many witnesses recognised that science-based clusters have to reach a critical mass to be successful, and that it may be important that these clusters are highly diversified. Mr Castell proposed a European Science Park, a very large cluster around Cambridge, London and Oxford. This would aim to attract "a great number of multinationals whether they be in engineering, the motor industry, the aerospace industry, the IT industry or the chemical industry ... the cluster has to be rather like Research Triangle Park [in North Carolina, USA], across a number of universities, because no one university is likely to have the capacity ..." (Q 158). Other witnesses recognised that critical mass can be important, but considered that a venture on this scale was unnecessary, and it would overshadow successful existing clusters. Professor Gareth Roberts of CVCP argued that small science parks can be successful so long as they are clearly focused (QQ 368, 372).

5.10 Chapter 2 of this report identified a gap in the provision of seed capital which can arise because investors face high costs in appraising technology based investments. It appears that this gap in provision of risk capital is less serious in the strongest high-technology clusters, such as those in California, because investors have lower overheads. The frequent informal interchange of technological knowledge within clusters means that investors are better informed about technology investments, and therefore face lower costs of appraisal.

5.11 Many of those who gave evidence referred to the virtuous circle that acts to generate and sustain the best industrial clusters. Mr Harvey of BTG also referred to "a mutually sustaining co-existence" between applied and basic research. "I think the researchers find that the two sorts of input aid and abet each other, and they are not in conflict at all" (Q 279). Mr Hugh Thomson of Strathclyde University and Dr David Thomas of Imperial Exploitation Ltd also referred to a virtuous circle between the exploitation of research and further basic research (QQ 306–7).

5.12 The entry of new firms to clusters is essential to sustain the innovativeness and vibrancy of a cluster. Dr Garnsey said "there is a different sort of culture in Silicon Valley where graduates find it positively embarrassing to work for a big company" (Q 85). While the Engineering Council were keen to point out that innovation is not the exclusive preserve of small firms (Q 264), many major innovations (for example, the microcomputer and the photocopier) did not start with large firms. It often requires the start-up of a small entrepreneurial firm to initiate innovation even if the innovations were subsequently taken up and more successfully marketed by large firms. New start-up firms are often better placed to exploit opportunities that emerge across sectoral boundaries, while existing companies are better placed to exploit opportunities emerging within their own sector.

Clusters, the Science Base and Infrastructure

5.13 Many successful clusters are based around a strong part of the science base. Strong research teams in research intensive universities are obviously an important part of that science base, but for companies to benefit from that research expertise, they must be able to gain access to it. This has traditionally been much harder for small and medium sized companies than for large companies (Bank of England, QQ 250, 258). Some of the new universities have particular expertise in working with small and medium enterprises, and have played an important role in helping these companies access research in the most research-intensive universities (Mr Jay Mitra, Head of Economic Development, University of North London, Q 302).

5.14 Often the most successful clusters are self-organising. The Massachusetts corridor was described as "a natural clustering around academic units which left their doors open ... not a planned environment, but it reflects the culture of North America" (Mr Castell, Q 147). Many consider this model of cluster development more successful than the science park because of the latter's small scale.

5.15 Research Triangle Park in North Carolina, by contrast, is "an engineered environment ... where the State fathers wisely saw that if they put within the triangle three universities in a research grouping, and brought in mixed skills, chemistry, engineering, IT and pharmaceuticals, that they could create wealth in North Carolina" (Mr Castell, Q 147). A number of largely self-organising clusters have originally been stimulated by investment in science and technology. For example, the introduction of a computer-aided design centre in Cambridge (UK) has helped to create a large number of start-up firms in computer aided design and geographic information systems companies (Dr Garnsey, Q 79). Over the last 20 years 1,200 new businesses have been created in the Cambridge area, many of them in telecommunications, software, biotechnology, and the total turnover of these new businesses is around £1.5–2 billion per annum. The only comparable development elsewhere in Europe is at Sophia Antipolis near Nice, which is similar in terms of new business development, but this "*technopole*" has been created as a result of government investment in the region. Our Report of 1994 on *International Investment in UK*

Science[16] studied in depth the question of what encourages overseas companies to locate R&D in the United Kingdom.

5.16 Some witnesses argued that the Japanese Science City has been less successful as a way of creating clusters. The best known of these, Tsukuba, has deliberately been located some distance away from Tokyo. It appears not to have attracted the best scientific talent, and because of its isolation it has not really functioned effectively as a cluster (Mr Castell, Q 147). Unlike the European model which is generally based on an existing and strong concentration of leading research centres, the Japanese *technopole* is a purpose-built new development and may be located in areas that are industrially underdeveloped. It must be remembered of course that the rationale for Japanese Science Cities is rather different from the rationale for cluster promotion in the United Kingdom: the Science City was one of the chosen instruments to bring about the central policy objective of greater industrial decentralisation, by trying to establish countervailing clusters.

5.17 Some of our witnesses argued that science parks had been less useful in promoting technology transfer than had originally been expected. Mr Hugh Thompson of Strathclyde University argued that some science parks did not have the critical mass to attract the companies that would contribute to a virtuous circle (Q 318). It was suggested that some science parks are really *business* parks, and were managed as a real estate investment (Q 321). There was general agreement that the incubator was a more effective mechanism for achieving technology transfer from the science base to technology-based companies, and this is discussed further below.

5.18 A strong infrastructure with good transport and communications is essential to the success of an industrial cluster. Indeed, if this infrastructure is good enough, then the cluster need not be tightly confined to a small geographical area. Dr Michael Elves of Glaxo Wellcome, speaking for the ABPI, said that "the concept of a virtual centre of excellence has a lot to commend it" and this was possible in the United Kingdom because of our excellent IT and communications (Q 240). Mr Jay Mitra of the University of North London also recognised that clusters of industries in and around a university science park could be connected by "virtual links" (Q 321). In some clusters, notably Research Triangle Park in North Carolina, the infrastructure has grown up after the cluster started to grow, rather than the other way around (Mr Castell, Q 147).

Skills and Education for Innovation and Exploitation

5.19 One of the most important features of the strong cluster is the ease with which multi-skilled teams can be formed. Mr Philip Langston of Cambridge Quantum Fund Limited stressed that in high technology business, "there is a need for teams who are multi-skilled and in those teams business awareness and a very good understanding of technology are equally important. You need the technical skills all the way through because only the technologists can understand the potential of their products and hence what problems they can solve for users. You also need the business acumen from the start" (Q 80). Mr Langston considered that venture capitalists can perform an important role in ensuring that teams are multi-skilled (Q 80). Mr Thomson of Strathclyde University noted that Business Angels can be as important to the incubator for their management skills as for their money (Q 326).

5.20 The Bank of England Report[17] stressed that innovators need to acquire better business and management skills, and this point was also made in much other evidence to us. Equally the Report[18] noted that, in the opinion of the technology-based firms surveyed, "finance providers did not normally have an understanding of the technology they were being asked to finance", and other evidence suggested that investors needed to acquire a better understanding of the technologies in which they invest. In this respect, the movement of scientists and engineers into financial institutions may be beneficial, so long as they are encouraged to make active use of their scientific

16 4th Report (1993–94), HL Paper 36-I, ISBN 0 10 477795 8.

17 Recommendation 10, p 69.

18 Paragraph 4, p 36.

and technological expertise (Mr Quysner, Q 214). We learned of some initiatives to train financial managers in technology awareness (see Save British Science evidence), and such initiatives are to be welcomed. Mutual understanding between innovators and investors is most common in well developed clusters, partly because of the more frequent social interaction between innovators and investors, and as already noted this can help to overcome some of the gaps in the market for seed capital.

5.21 This Committee's report of 1991 welcomed the introduction of postgraduate courses in innovation management (paragraph 10.32), and recommended that "business schools and other higher education institutions providing management training should ensure that the importance of technological innovation to enterprise is fully reflected in the courses they offer" (paragraph 10.33). Following on from this lead, the 1993 Science White Paper recommended that the Economic and Social Research Council should fund the development of modules for the teaching of innovation on Masters' degree courses and continuing education programmes in British business schools. The ESRC set up a programme to produce packages of training materials covering different aspects of innovation management. These packages have been widely disseminated by the ESRC Postgraduate Training Division and are available on the World Wide Web[19]. They have been tested in a number of teaching settings, and the general response has been good. The programme has also produced a directory of all courses focusing specifically on innovation management in British business schools. The importance of innovation is now more widely recognised in business schools. There have been a number of other ventures in this direction, including the growth of entrepreneurship courses and projects, which Mr David Quysner of the BVCA indicated were very popular (Q 202), and courses on venture capital. The BVCA have also been active in visiting universities to talk about their work.

5.22 Our evidence stressed that there is a need for further collaboration between business schools and university science and technology departments, and for business schools to provide business and management expertise to innovators. This is emphasised in the Bank of England Report (Recommendations 4, 10) and in evidence from Mr Harvey of BTG (Q 271). Some business schools have been active in developing entrepreneurship projects, but further developments in this direction would be welcome. The CBI Report *Tech Stars* argued that the Engineering and Physical Sciences Research Council should extend its Total Technology Studentships and Engineering Doctorates to include more emphasis on business and management. That report also recommends that universities should consider a business club for collaboration between students in their science and technology departments and those in business schools. The students would collaborate on developing business plans for the commercialisation of new technological developments (Tech Stars, p 26).

5.23 In some universities and business schools, Business Angels (see chapter 2) are playing an important role as tutors for such projects (Mr Mitra, QQ 333-4). It is recognised that one of the obstacles to placing innovation more prominently on the business school curriculum and equally to placing business and management teaching on the science and engineering curriculum is the fact that most curricula already suffer from severe congestion (ABPI, Q 244), a point also stressed by the Engineering Council (Q 265). It is also recognised that the demand for innovation courses in business schools depends on the degree to which management see it as a priority to acquire such expertise, and this is not always a top priority for management.

5.24 This Committee's Report of 1991 also recommended greater interaction in policy formation between industry and academia (paragraph 10.22). There has been continued collaboration between research councils and industry in helping to frame some of the research priorities of the Research Councils. Written evidence from the EPSRC refers to initiatives such as the Postgraduate Training Partnerships, Engineering Doctorates, Research Masters and Teaching Company Schemes, and most recently to the Faraday Partnerships. Dr Fiona Steele, Director of the

19 http://bprc.warwick.ac.uk/rc-inn.html

ESRC's Innovation Research Programme, notes that this programme was the first in the ESRC where the traditional method of calling for proposals was accompanied by a "wish list" of questions of concern to the business people involved in the programme.

Incubators

5.25 One of the most exciting recent developments in this field has been the emergence of incubators as an instrument of technology transfer from the science base to technology-based companies. In the words of the Enterprise Panel, business incubation "provides firms with intensive hands-on support to combat the most common reasons for failure". Evidence on the success of incubators in the United Kingdom is limited so far, although many more incubator projects are now being developed, and early indications are very promising. Experience in the USA, where there are over 900 incubators, suggests that business incubation is a system that can overcome some of the most common problems faced by small and new companies. Dr Sarah Eccles of Therexsys, speaking for the ABPI, said that "the availability of more technology incubators for the early stages of the company would be of enormous advantage" (Q 245).

Box 7: Types of incubator

The Enterprise Panel Report identifies four sorts of incubator:

(a) The sector-specific incubator which develops businesses in a specific sector (for example Oxford Trust, Campus Ventures in Manchester, Cardiff Medicentre and the Manchester Bioscience Incubator);

(b) The incubator that is developed as an integral part of the science park (for example Aston and Warwick Science Parks, Aberdeen Science and Technology Park, Cranfield Technology Park);

(c) The general incubator with a mix of different businesses (for example New Work Trust in Bristol, Preston Technology Management Centre);

(d) The incubator which concentrates on building businesses by creating management teams to develop specific commercial ideas (Lanarkshire Development Agency, Univentures in Wakefield).

5.26 Save British Science reported that universities can provide a very effective first stage incubator by providing a stable operating base and technical support for the development of ideas which may eventually become the basis for formation of a start-up company. Such university-based incubators are usually joint ventures, where a university provides the buildings on their campus and where a company or financial institution provides the external investment (Q 323), and several witnesses stressed the value of this public-private partnership in establishing incubators. Dr Douglas Robertson of the University of Nottingham said that this partnership was the best way of bringing together scientific expertise and knowledge of the market place (Q 324).

5.27 The Enterprise Panel concludes that the key factors in the success of incubators are:

(a) links with universities and/or large companies which are interested in commercialising their own or others' research;

(b) links with venture capital companies, both from local Angel networks and venture funds;

(c) strong local authority or regional involvement;

(d) involvement of local educational institutions (at all levels) to provide training in essential skills;

(e) access to a local science park where companies can move after graduating from the incubator.

The Enterprise Panel have recommended that a Business Incubator Centre be established to act as a catalyst and facilitator in extracting maximum benefit from the business incubation process. It is recognised that there are some economies of scale in the establishment of incubators: the fixed costs for facilities and incubator management cannot be covered in a small scale incubator. Moreover, it is recognised that there has to be a "not for profit" element in the establishment of incubators, and that re-emphasises the importance of the public-private partnership.

Customers and Marketing

5.28 Much of the discussion of the success of new technology-based firms has focused on technology transfer and the financing of innovation. Another very important factor in the growth of such firms is their strategy for marketing and interacting with customers. This Committee's Report of 1991 concluded that companies should be prepared to work in partnership with customers and suppliers. One of the great benefits available to firms located in strong clusters is the opportunity to work with strong and demanding customers in developing world-beating products and services. Mr Michael Goulette of Rolls Royce, speaking for the Engineering Council, stressed the importance of developing strong and responsive supply chains to "connect the market requirement to the technological opportunity or the business opportunity", and argued that this was as important as the more traditional concern with technology transfer (Q 256). Mr Brian Kent, Chairman of the Board for the Engineering Profession, said that businesses "make money when market pull equals technology push" (Q 258). Nevertheless it was also recognised that some of the most exciting examples of new and responsive supply chains relied on chance meetings between senior staff from organisations that had formerly had very little contact. An active dialogue between design, R&D and marketing is required to match innovations to market needs, and ensure a market pull to overcome the innovation-exploitation barrier.

5.29 The CBI Report *Tech Stars* suggests that some new technology-based firms pay insufficient attention to marketing, citing evidence that such companies spend on average about 16 per cent of their turnover on R&D but only 10 per cent on sales and marketing. "Significantly, those companies that do commit most resources to sales and marketing show the highest growth rates" (Tech Stars, p 15). And although sales and marketing are essential functions in the growth and profitability of new technology-based firms, many neglect these functions. The CBI report refers to a "marketing skills gap" (Tech Stars, p 16) and recommends that to overcome this gap, Business Links and incubators should aim to provide marketing advice and support, Training and Enterprise Councils (TECs) should encourage the provision of marketing training, and business schools could target new technology-based firms through the Teaching Company Scheme.

OPINION OF THE COMMITTEE

5.30 The Japanese experience demonstrates that it is very hard to establish clusters to rival existing centres of industrial concentration. Accordingly, initiatives to develop new science-based clusters should work to build on the strengths of existing centres, and not work against them. Clusters may have to reach a certain critical mass before they attract new firms in significant numbers, but this critical mass varies from sector to sector, and depends on how the cluster is organised. It is believed that the same considerations apply to science parks. While competition between science parks is healthy, we are concerned that some science parks may fail to achieve critical mass. **We recommend that a study of science parks should be undertaken by the Government to determine the elements critical to success, whether these be a matter of size, focus or the framework of collaboration with one or more universities.**

5.31 The key to developing strong industrial clusters lies in the steady improvement of all those interactions in the virtuous circle that lead to clustering. This involves a large number of policy actions on a small scale rather than one or two grand measures. This includes, for example, investment in TECs, Business Links, education and training for innovators and investors, infrastructure, regional enterprise agencies, IT networks—though it is recognised that some of these initiatives overlap, causing confusion.

5.32 It is important to promote education for the management of innovation and exploitation. This involves increasing scientific and technological understanding amongst the financial community and general management, as well as increasing business, management and entrepreneurship skills amongst scientists and technologists. We cannot stress too strongly that mutual understanding is a two-way process. Universities and business schools could benefit by organising joint projects in which students of science and technology collaborate with students of business to develop business plans for new technology based firms. **We recommend that business schools should play a greater role in teaching the management of innovation and exploitation to students of science and engineering. The Committee also considers it is in the interests of banks and other financial institutions to invest in developing management awareness of science and technology, and putting it to good use.**

5.33 We are impressed by the promise of incubators. While evidence from the United Kingdom is limited, indications are that the incubator is a very effective way to foster the initial growth and survival of new technology-based firms. **We recommend that further research is required into the effectiveness of incubators, and their role in promoting the growth of new technology-based firms and in promoting industry-university relations.**

CHAPTER 6 SUMMARY OF RECOMMENDATIONS

6.1 We were greatly encouraged by the amount of both oral and written evidence which reported overall improvement in the relationships between industry and academia. Academics are becoming more interested in commercialising their ideas, research partnerships between industry and academia are increasing and business incubation is underway in many universities. However, there is no room for complacency: relationships in the United Kingdom seem better than those in the rest of Europe but we still have further to go before we can match the close working relationships of the United States. And it is apparent that in spite of—or perhaps because of—the many initiatives from DTI, small businesses are still unaware of the importance of the science base to their survival and growth. In 1991 we called for a simplification of DTI schemes yet further initiatives and "challenges" have followed. Simplification is now underway but experienced and knowledgeable people still report "it is an awful mess out there—a bit of a shambles". If this is the view of knowledgeable observers, it is entirely understandable that small business has difficulty in recognising and realising the opportunities presented by our excellent science base.

6.2 A cause for unease in all aspects of our study was the paucity of hard data in areas many acknowledged to be important. This came to the fore in our discussion of the roles played by Business Angels where, although there were many examples of their significance to new enterprises, there seemed no coherent overall picture from which one could learn. But a similar lack of data seemed to pervade many of our discussions of the merits of various initiatives. Beyond more data, there is also a need for evaluation of the factors critical to success in the many developments at the interface between academia and industry.

6.3 Our recommendations therefore, from what has necessarily been a brief and hurried look at only a small number of the issues, are focused on the need for vigorous appraisal, in order to encourage best practice, build on what is good and reverse any trends that might lead to harm. Rigour is also, we believe, needed in the distribution of research funds, to ensure that the UK science base maintains centres of excellence on a par with any in the world. Our recommendations are as follows.

6.4 We recommend that the role of Business Angels be examined further by Government, universities and leading financial institutions to determine the extent of their present involvement and the conditions that influence their activities, and to identify ways of expanding their role. We believe particular attention should be paid to the potential value of Business Angel networks and ways of supporting a national network. (paragraph 2.21)

6.5 We recommend that the Government examines ways in which its own existing programmes might be used to underpin the innovation process, following the example of SBIR in the US. (paragraph 2.23)

6.6 We recommend that the DTI should examine how the disincentive of disproportionately high costs of due diligence with respect to the small investments needed by start-up companies could be reduced. (paragraph 2.24)

6.7 We recommend that the Government considers equality of CGT treatment between the individual founding shareholders and the institutional shareholders. (paragraph 2.26)

6.8 We recommend that the Government re-examines the VCT scheme to see if the present direction is consistent with the original intent. If there are indications that changes are needed to ensure these trusts do not become risk averse those changes should be made promptly. The EIS should also be kept under review to ensure that the final economic impact of this scheme fulfils the original aims. (paragraph 2.27)

6.9 We recommend that the universities and the Funding Councils should monitor the overall balance of effort and if necessary put in place mechanisms to prevent short-term work squeezing out the longer-term basic research. (paragraph 3.23)

6.10 We recommend that the Funding Councils should ensure that a higher proportion of available funds be channelled into creating centres of excellence, which should be accessible to researchers of high calibre irrespective of their university. (paragraph 3.24)

6.11 We recommend that the DTI consider an enhanced role for its small firms programme in support of bridging work between the ex-polytechnic sector and small, local businesses. (paragraph 3.25)

6.12 We recommend those universities that are not taking advantage of the work of the capital providers in explaining financial issues to researchers to follow the example of those who do. (paragraph 3.26)

6.13 We recommend that universities recognise the importance of IPR management and devote the necessary resources to it. (paragraph 3.27)

6.14 We recommend that the Government and industry take more effective action to make innovators both within and outside universities aware of the opportunities (including funding initiatives) that result from Foresight. Subsequent Foresight reports should be made more accessible to small businesses. (paragraph 4.11)

6.15 Whilst we do not wish to divert more money towards Foresight, the Government should conduct an audit of all research spending by Departments, the Research Councils and the Higher Education Funding Councils in an attempt to clarify the impact that Foresight has had on the allocation of public research funds. (paragraph 4.12)

6.16 We recommend that the Government establish a clear policy, in the context of Foresight, of seeking out "misfit" lines of research which fall across or between sectors and evaluate them separately if necessary. (paragraph 4.13)

6.17 We recommend that the Government should refocus its efforts to ensure, as far as possible, that Foresight is not entirely dominated by large companies and is recognised by small and non-science based businesses as relevant to their needs. (paragraph 4.14)

6.18 We recommend that a study of science parks should be undertaken by the Government to determine the elements critical to success, whether these be a matter of size, focus or the framework of collaboration with one or more universities. (paragraph 5.30)

6.19 We recommend that business schools should play a greater role in teaching the management of innovation and exploitation to students of science and engineering. The Committee also considers it is in the interests of banks and other financial institutions to invest in developing management awareness of science and technology, and putting it to good use. (paragraph 5.32)

6.20 We recommend that further research is required into the effectiveness of incubators, and their role in promoting the growth of new technology-based firms and in promoting industry-university relations. (paragraph 5.33)

APPENDIX 1

Sub-Committee II: The Innovation-Exploitation Barrier

The members of Sub-Committee II were:

V. Caldecote
L. Cuckney
L. Currie of Marylebone
L. Dainton
L. Dixon-Smith
L. Flowers
B. Hogg (Chairman)
L. Hollick *(until 22 January 1997)*
L. Kirkwood
L. Redesdale
L. Tombs
L. Winston

The Sub-Committee appointed as its Specialist Adviser Professor the Hon. Peter Swann of the Business Economic Group, Manchester Business School.

APPENDIX 2

Call for Evidence

The House of Lords Science and Technology Committee has appointed Sub-Committee II, under the chairmanship of Baroness Hogg, to conduct an enquiry into the Innovation-Exploitation Barrier. This will be a follow-up enquiry to our earlier report on Innovation in Manufacturing Industry, published in 1991. It is being carried out in the context of the Bank of England report on *The Financing of Technology-Based Small Firms* (October 1996) and the conference on this subject to be organised by the Bank of England, the CBI and the Royal Society in early 1997. We will receive evidence in writing and in person, with a view to making a report to the House of Lords in 1997.

The Sub-Committee invites written submissions on matters of relevance to this topic, but in particular on the questions listed below. The enquiry will focus on how innovative ideas from our science and technology base are turned into exploitable products or processes for the United Kingdom. We wish to assess the effectiveness of the innovation initiatives promoted by the Department of Trade and Industry and their impact on start-up companies. One of the main areas on which we wish to concentrate is the early phase of development of technology-based firms, including their access to funds and management support. We ask the question, to what extent does the United Kingdom suffer from an inability to exploit its own developments in science and technology and what can be done to address this problem?

1. What is the current state of innovation in the United Kingdom?

2. How successful have the Department of Trade and Industry (DTI) and other Government Departments been with their range of initiatives designed to stimulate innovation?

3. How effective in terms of product or process innovation and other exploitable outcomes are initiatives which encourage collaboration between industry and academia?

4. Does financing need to be improved for technology-based small firms during their crucial start-up and early development phases?

5. What other support systems could be introduced to ensure that the maximum advantage is taken of innovative ideas that originate with individuals or, for example, in academia?

6. Is there institutional inertia towards the funding of technology-based small companies? If so, to what extent may this be due to financiers' unfamiliarity with science and technology concepts and what should be done to address this?

7. The Committee recommended tax credits for research and development in our previous enquiry. Would this still be an effective way of fostering innovation and how should they be introduced to ensure that they are roughly cost-neutral?

8. How has the Technology Foresight Exercise influenced the availability of development funds for innovative ideas that were not given short-term high priority status?

9. Has the tax relief introduced in 1992–93 for individuals' expenditure on vocational training had any impact on the status of continuing professional development, in particular for employees in small firms?

APPENDIX 3

List of Witnesses

Those marked * gave oral evidence.

3i plc
* Amersham International
Apax Partners & Co
* Association of the British Pharmaceutical Industry
Association of Electricity Producers
* Bank of England
Barclays Bank
* Brewton Group
Bristows, Cooke and Carpmael
* BTG plc
* British Venture Capital Association
Cambridge Research and Innovation Ltd
Confederation of British Industry
Construction Industry Council
CRISP Secretariat
Department of Trade and Industry
Economic and Social Research Council
* Engineering Council
Engineering Employers' Federation
Engineering and Physical Sciences Research Council
Engineers' and Managers' Association
Enterprise Panel
Environment Agency
Dr Elizabeth Garnsey, University of Cambridge
Glaxo Wellcome plc
Institute of Physics
Lord Kennet
* Mr Jay Mitra, University of North London
National Westminster Bank plc
Mr Norman Nunn-Price
Pax Technology Transfer
Pilkington Optronics
John Van Reenen, University College London
* Professor Gareth Roberts, University of Sheffield
* Mr Douglas Robertson, University of Nottingham
Royal Academy of Engineering
Royal Society for the encouragement of Arts, Manufactures and Commerce
Royal Society of Edinburgh
Save British Science Society
Science Policy Research Unit, University of Sussex
Scottish Enterprise
SmithKline Beecham
St John's Innovation Centre
Dr Fiona Steele
* Dr David Thomas, Chief Executive, IMPEL
* Mr Hugh Thomson, University of Strathclyde
University of Cambridge Programme for Industry

APPENDIX 4

Acronyms

ABPI	Asssociation of the British Pharmaceutical Industry
AIM	Alternative Investment Market
BoE	Bank of England
BVCA	British Venture Capital Association
CBI	Confederation of British Industry
CVCP	Committee of Vice-Chancellors and Principals
DTI	Department of Trade and Industry
EASDAQ	European Association of Securities Dealers Automatic Quotation System
EBP	Education Business Partnership Initiative
EIS	Enterprise Investment Scheme
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
HEI	Higher education institution
IAB	Innovation Advisory Board
ILO	Industrial Liaison Officer
IPR	Intellectual Property Rights
IRC	Interdisciplinary Research Centre
MPI	Manufacturing Planning and Implementation Studies Programme
MRC	Medical Research Council
NASDAQ	National Association of Securities Dealers Automatic Quotation System
OST	Office of Science and Technology
PRISM	Wellcome Trust Unit for Policy Research in Science & Medicine
PTP	Postgraduate Training Partnership
R&D	Research and development
SBIR	Small Business Innovative Research Programme
SET	Science, engineering and technology
SFLGS	Small Firms Loan Guarantee Scheme
SMART	Small Firms Merit Award for Research and Technology
SME	Small or medium-sized enterprise
SPUR	Support for Products Under Research
SRA	Scientific Research Allowance
TAL	Technical Action Line
TCS	Teaching Company Scheme
TEC	Training and Enterprise Council
VCT	Venture Capital Trust

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