Patterns in business R&D

A series of working papers prepared for
the Scottish Science Advisory Committee
in support of its study
R&D: Science Base to Business

October 2006

Contents

1: Introduction

1.1 This report brings together the contents of a series of working papers prepared by SQW Limited[1] in the course of a study into business R&D conducted on behalf of the Scottish Science Advisory Committee (SSAC).

Background

1.2 The SSAC currently has a Working Group convened by Professor Steve Beaumont, University of Glasgow, that is considering the strengths of the business R&D base in Scotland, with a view to developing recommendations on how it might be enhanced and better supported, including by the science base.

1.3 The emphasis in the Group's work has been on the business perspective: its work aims to complement the substantial body of prior research into science base (largely Higher Education) to business interactions, research that has often viewed the interaction from a supply-side or HE perspective.

1.4 As one key input to its deliberations, the Working Group held a workshop in November 2005 entitled *Research and Development: Science Base to Business*.

1.5 This report provides additional input to the Working Group. Steered by regular discussion with Group members, it address the following topics:

- the pattern of business R&D expenditure in Scotland
- the significance of R&D for the financial services sector
- the nature of public sector support for business R&D in Scotland
- constraints on the growth of business R&D in Scotland
- measuring quality of business R&D
- internationalisation of business R&D, and
- international policy comparisons for support of business R&D.

1.6 This report concludes with its authors' views of the main issues to emerge.

Methods

1.7 This report was prepared largely from desk research, complemented by consultations with a number of individuals in the public and private sectors, whose inputs are gratefully acknowledged. These include consultees drawn from the Scottish Executive's Enterprise Department; Scottish Enterprise; the Scottish Funding

[1] SQW Limited wishes to acknowledge its collaboration with Dr Geoff Gregson, University of Edinburgh in the conduct of the research and in the preparation of this report.

Council's Knowledge Transfer and Innovation Task Group; the commercialisation function within a university research school; the technology and innovation functions within major Scottish banks, as well as companies in the supply chain of the banks.

1.8 However, the views expressed in this report are those of its authors and not those of the consultees or of the SSAC.

2: Concepts and definitions

2.1 This paper describes concepts and sets out definitions relevant to the study of business R&D and to the papers which follow.

Definitions of R&D

2.2 Research and development, and related concepts, follow internationally agreed standards defined by the Organisation for Economic Cooperation and Development (OECD) and published in the 'Frascati' Manual[2]. R&D is defined as "*creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of the stock of knowledge to devise new applications*". The definition excludes activities such as market research, most software development, routine testing, quality control and artistic design work.

2.3 In keeping with the industry-focused approach to this study, it is appropriate to summarise below the definitions used by the Department of Trade and Industry and HM Revenue & Customs, the latter relating to the definition of R&D for the purpose of providing R&D Tax Credits to UK businesses.

2.4 The DTI guidelines for defining R&D refer to activity which seeks to:

- extend overall knowledge or capability in the field of science or technology; or
- create a process, material, device, product or service which incorporates or represents an increase in overall knowledge or capability in a field of science or technology; or
- make an appreciable improvement to an existing process, material, device, product or service through scientific or technological change; or
- use science or technology to duplicate the effect of an existing process, material, device, product or service in a new or appreciably improved way.

2.5 HM Revenue & Customs further states that such activity will be deemed R&D for tax purposes if the project seeks to achieve an advance in overall knowledge or capability in a field of science or technology, rather than just in a company's own state of knowledge or capability alone.

2.6 The focus on science and technology is evident. The inclusion of R&D to "appreciably" improve on what already exists is also notable.

2.7 Statistics on Business Enterprise Research and Development (BERD)[3] expenditure in the UK limits R&D to that undertaken within business enterprises (intra-mural

[2] National Statistics (2004) *Research and Development in UK Businesses*
[3] The Scottish Executive (2005) *Business Enterprise Research & Development in Scotland 2003*

research, irrespective of the source of funding) and excludes R&D undertaken in higher education institutions or government establishments (even if funded by business).

R&D and value added

2.8 An increasingly important concept in economic development in Scotland and across the UK is that of Gross Value Added (GVA). Gross Value Added is being used by regional economic development agencies in their appraisal and evaluation of interventions and other contributions to economic or wider sustainable development.

2.9 Value Added (VA) is also being used by the Small Business Service of UK Government as a diagnostic and assessment tool at the level of the industry sector and the individual firm. It is instructive to consider how expenditure on R&D is treated in its assessment of Value Added.

2.10 The DTI Value Added Scorecard[4] defines VA as a firm's sales less the cost of bought-in materials, components and services. The value created by a company is used variously to reward its stakeholders and/or to sustain and develop its business. The Value Added Scorecard identifies six different ways in which VA can be used by a company:

- payments to the providers of capital – i.e. cost of funds
- payments to staff - total operating employee costs
- corporation taxes paid to government
- investment - in R&D and the depreciation of capital equipment
- amortisation - a charge against a balance sheet item (mainly acquisition goodwill in most cases) that has already been purchased and is thus not normally a recurring cash outflow
- retained value added - what remains after the first five items have been deducted from the total. It will be negative if value added is insufficient to cover the other five.

2.11 It is notable that the relative proportions of these six elements may vary substantially between companies, even for those in the same sector. It is also notable that R&D as an investment is grouped together with a measure of investment in capital equipment.

2.12 Scoreboard findings indicate that a high level of value added can only be sustained over the longer term if a proportion is re-invested. This investment may be made in different ways: in R&D; via CAPEX (measured in the Scoreboard as depreciation); in a brand or in a related acquisition that can be developed further (amortisation); or in the other ways such as design, new processes, market development and other

[4] http://www.innovation.gov.uk/value_added/home.asp?p=home

intangibles. Innovative, growing businesses may choose to sustain high levels of Value Added in different ways at different times.

Innovation

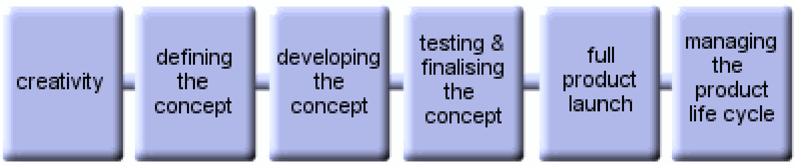
2.13 Innovation may be defined simply as *the commercial exploitation of new ideas*.

2.14 The European Commission's Green Paper on Innovation (1995) defined it as "*the renewal and enlargement of the range of products and services and the associated markets, the establishment of new methods of production, supply and distribution, the introduction of changes in management, work organisation, and the working conditions and skills of the workforce".*

2.15 Innovation therefore is not restricted in terms of process or of outcome to science and technology matters, and not to R&D. R&D is but one possible input to innovation.

2.16 The Scottish Enterprise web site (www.scotent.co.uk) offers insights to businesses on "ideas and innovation" as part of a product development process. It draws attention to the successes of innovative companies such as 3M, Sony, Black & Decker and Polaroid. It introduces a staged development process, illustrated below, relevant to both products and services. There is no explicit reference to the possible role for business R&D in this process.

The process



Invention and innovation

2.17 Invention may be a pre-requisite for certain types of innovation, but it is only when the invention is exploited commercially that it results in "innovation" and starts to yield economic benefits.

2.18 Research may be a precursor to invention, but it is not necessarily so. Innovation is neither an immediate nor an inevitable outcome of either research-based or other invention.

Degrees of innovation

2.19 There is an important distinction to be drawn between *radical* and *incremental* innovation. The former represents something new: the latter represents an improvement to something that already exists. Radical innovations have the potential to cause very significant and rapid transformations in markets whereas the effects of incremental innovation may be felt more slowly: the cumulative business and economic impact over time of the incremental may be just as significant.

2.20 Linked to the above, innovation may be wholly novel, new to an industry, new to a market or new to a firm. Degree of novelty can be an important eligibility criterion for businesses seeking public sector grants and other incentives to support R&D and related innovation.

Diffusion

2.21 This distinction between innovations that are new to the market and those are simply new to a firm, is important in the context of *diffusion*. One leads to the other through the process of diffusion whereby the novel innovation is taken up by imitators or followers.

2.22 The economic benefits of innovation are influenced by the speed and scope of diffusion. The business and the economic benefits from an innovation commonly accrue from diffusion throughout its market, not its introduction – this is especially the case with product innovation.

Measuring innovation

2.23 Two measures commonly used to measure innovation, especially by policy makers, are patents and R&D expenditure[5]. Neither are perfect metrics.

- patents do not capture the innovation by firms that are imitators
- not all innovations new to the market are patented
- propensity to patent varies across industry sectors
- patents are often registered at the HQ of a business, giving regional distortions
- similarly, intra- regional R&D figures may be reported on by part of an organisation located in another region.
- R&D is an input rather than an output measure
- R&D spend is sensitive to industrial structure or mix – differences in R&D intensities across countries/regions will reflect differences in industrial structure and not necessarily innovative behaviours and performance
- the extent to which R&D spend is a good proxy for novel innovation depends on how much "unsuccessful" R&D expenditure there is i.e. R&D that fails to result in an invention; the extent that successful inventions are commercialised; and the degree of spillover effects
- part of an organisation's R&D expenditure is acquired technology or embodied R&D – the knowledge/R&D embodied in new capital equipment.

[5] See Frenz and Oughton (2005) Innovation in the UK regions and devolved administrations: a review of the literature. Report to the DTI and ODPM.

2.24 The Community Innovation Survey[6] (CIS3) attempts to capture the wider range of factors relevant to innovation activity. This includes an assessment of new products and processes introduced by a firm that are new to the market or new to the firm. However, it is important to note that the statistics on these product/process introductions are based on binary data (introduced/not introduced) and not on numbers of introductions per firm. The CIS3 survey is restricted to firms with 10 or more employees.

2.25 Nevertheless, the CIS is probably the most comprehensive firm-level innovation database available. It also provides measures of organisational innovation, co-operation and absorptive capacity, all of which are regarded as important parts of the innovation process.

2.26 A summary of an analysis of the CIS3 results for Scotland is provided in Section 5. The data for the fourth Community Innovation Survey (CIS4) have been released recently and it is likely that an analysis of the results for Scotland will be published by the Scottish Executive in due course.

Absorptive capacity

2.27 The concept of *absorptive capacity* is prominent in the innovation literature. It appears in subsequent papers in this report. It has been proposed that absorptive capacity, the "*ability to recognize the value of new external information, assimilate it, and apply it to commercial ends*"[7], is a significant determinant of innovative capability.

2.28 The concept of absorptive capacity has been used as a key concept for understanding the conditions for effective learning. Cohen and Levinthal assumed the existence of a current knowledge-base as a necessary, but not a sufficient condition for the ability to absorb new knowledge: "*absorptive capacity is more likely to be developed and maintained as a by-product of routine activity when the knowledge domain that the firm wishes to exploit is closely related to its current knowledge base*".

2.29 For some authors, absorptive capacity has been treated as a cognitive barrier to knowledge transfer. Motivational factors associated with the parties involved have been viewed as a separate group of factors influencing knowledge transfers[8]. Others argue[9], based on evidence gathered from subsidiaries of multinational companies, that absorptive capacity is a function of both competency/ability and motivation, i.e. it has two dimensions.

[6] Conducted by the Office of National Statistics on behalf of the Department of Trade and Industry

[7] Cohen, W.and Levinthal, D. (1990) Absorptive Capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* 35:128–152

[8] Gupta, A. and Govindarajan, V. (2000) Knowledge Flows within MNCs. *Strategic Management Journal*, 21: 473-496

[9] Minbaeva *et al* (2001) *MNC knowledge transfer, subsidiary absorptive capacity and HRM.* Copenhagen Business School WP 14-2001

2.30 Taking this view, absorptive capacity must include both the ability to acquire knowledge and the motivation to do so, since ability without motivation and *vice versa* are likely to result in poor performance.

2.31 A dictionary definition of "ability" includes certain human attributes like prior achievement, initial skills, aptitudes, etc. The ability/ "*can do*" factor usually denotes "*a potential for performing some task which may or may not be utilized*" while the motivation/ "*will do*" factor of course reflects drive[10].

2.32 It is commonly accepted that organisational learning is closely linked with how an organisation manages its human resources[11]. For instance, limited investments in training and development may result in low levels of employee knowledge and skills, thereby inhibiting learning. However, it appears that knowledge of how human resource management (HRM) influences absorptive capacity remains fairly rudimentary.

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[10] In Minbaeva *et al* ibid.
[11] Lado, A. and Wilson, M. (1994) "Human Resource Systems and Sustained Competitive Advantage: a competency-based perspective". *Academy of Management Review* 19: 699-727

3: Reflections on the Scottish R&D "condition"

3.1 This Paper offers insights into the Scottish "condition" concerning business R&D. It is not intended to be a comprehensive treatment. Rather it summarises useful/interesting perspectives offered by recent commentators and by some recent policy-related research.

3.2 Baumal[12] in his reflections on the challenges facing the Scottish economy in The Allander Series of papers, referred to the role of R&D and innovation. He emphasised the important differences, but also the complementarities, between the characteristic innovative contributions of large and smaller firms - arguably a key issue given the profile of the Scottish business base. From international evidence, he argues that major breakthroughs tend to come from small, new enterprises while incremental contributions, of no less economic significance, tend to come from larger firms.

3.3 Two additional groups "outside the market sector" are included in Baumal's "four sources of innovation" – namely, government and the universities. There is a call for full understanding of the roles of these four key sectors and of what is required, including incentives, to ensure all four participate effectively in a policy for growth. This appears to chime well with the Scottish Executive's current interest in innovation systems (of which more later).

3.4 A full analysis of Baumal's contribution is beyond the scope of this working paper, however a number of additional points are worthy of note:

- rivalry amongst large firms in industries with relatively few players is a major driver of innovation in order to sustain competitiveness – delivering a constant stream of innovations
- 70% of R&D expenditure in the USA is by private business, most provided by larger firms[13]
- the attempts by large firms to free employees to engage in freer, entrepreneurial activity in pursuit of innovation is often, according to Baumal, unsuccessful - *i.e. the "skunk works" is no silver bullet*
- small firm innovation is twice as closely linked to scientific research as large firm innovation, on average –- *therefore the need for effective engagement between small firms and the wider research-base in Scotland*

[12] Baumol, WJ (2003) *Four sources of innovation and the stimulation of growth in the Scottish economy.* The Allander Series.
[13] US statistics quoted by Baumal indicate that in 2000 15% of total R&D spend by US businesses was by companies with fewer than 500 employees. Scottish statistics (for 2001) are, as Baumal concludes, not too dissimilar: 24% of business R&D was spent by firms of less than 399 employees.

- the critical factor for growth is the speed with which improved products and production techniques become widespread, including widespread adoption by others besides the innovator

- Baumol emphasises the key role played by licensing of technology in the dissemination and adoption of innovations, including licensing by large firms that can afford R&D to smaller firms that cannot and, furthermore, do not have the people qualified to do it

- to reduce costs and/or share risks in the conduct of R&D, the role of sharing consortia is introduced amongst larger firms.

3.5 Baumol argues that most of the innovation achieved in Scotland cannot be expected to come from the country's own R&D, but from R&D activities conducted elsewhere. He argues for a re-examination of the potential for technology transfer from those willing to make inward investments in Scotland and, more broadly, the development of capabilities for organised "imitation".

3.6 He quotes Ashcroft (1996)[14] who states that in addition to being less likely to invest in R&D than companies elsewhere in the UK, Ireland and Germany, firms in Scotland appear to be much less willing to "*formalise the innovation process; to involve key employee groups, such as designers, market/sales and engineering/technical staff, in all phases of the innovation process; and to collaborate with other companies and organisations*". If this is indeed a fair description, then increasing investment in R&D is a secondary challenge: investment in R&D without the rest would, intuitively, be wrong-headed from a business perspective and likely to lead to poor returns from the R&D investment.

3.7 Ashcroft (2002)[15] states that Scotland's R&D and innovation performance remains relatively weak, especially in firms with between 10-29 employees, and also that dissemination and adoption of new technology tends to be slow in Scotland, especially in locally-owned firms

3.8 It appears that that low or weak capability may play a role here as incentives are broadly comparable with other UK regions:

- with the paucity of headquarters in Scotland restricting the amount of R&D conducted in the country

- with requirements for capability and capacity in key knowledge areas – business personnel with appropriate training in pertinent fields including science/engineering and marketing; informed on patent laws, tax, safety, environmental regulation.

[14] Ashcroft, B. (1996) Scotland's Economic Problem: too few entrepreneurs, too little enterprise? University of Strathclyde, Inaugural Lecture, December 10, 1996.
[15] Ashcroft, B (2002) Chapter 1: The Scottish Economy," Scots Economy – 2020

Other recent research

3.9 Recent thinking on business R&D in Scotland can also be found in the following pieces of research:

- the report by DTZ Pieda[16] for the Scottish Executive on business attitudes in Scotland to R&D and innovation
- the report by Roper *et al*[17] for the Scottish Executive on the Scottish Innovation System.

Scottish Business attitudes

3.10 The DTZ Pieda study included a large scale postal survey of businesses, together with 29 in-depth case studies of both R&D performers and non-performers. The study adopted a definition of R&D that is wider than that usually adopted: it included an assessment of so-called "innovative behaviour". With careful review, the research remains relevant and useful in the present context.

3.11 This report recommended a number of actions to improve R&D performance in Scotland targeted at different segments of the Scottish business base:

Scottish business target group	Proposed actions
No R&D experience/ no future intentions	Not a priority as for most the product/service is not considered to require R&D / innovation
No R&D experience but open to future R&D	Promote an action plan approach to R&D Provide assistance to identify areas in which R&D might be possible and profitable Provide advice and information of technical opportunities Provide training General support to improve the financial position of the business
Intermittent performers of R&D	As above
Performers of continuous R&D in Scotland	Focus on younger, smaller high growth businesses Provide business support Provide financial support
Performers of continuous R&D outside Scotland	Focus on key clusters Market success and local skills

3.12 Of those firms undertaking R&D, the main difficulties being faced included: accessing external funds (88%), recruiting skilled staff (75%) and financial risk (50%).

[16] DTZ Pieda (2005) *Scottish business attitudes to research, development and innovation*. Report to the Scottish Executive
[17] Roper et al (2006) *The Scottish Innovation System: actors, roles and actions*. Report to the Scottish Executive

3.13 The study found that c.13% of non-R&D performing companies is open to future involvement in R&D/ innovation. Barriers/ inhibitors or alternatively factors that would encourage participation include:

- barrier: lack of confidence in good financial returns to R&D
- barrier: inability to find areas where innovation would be possible and profitable
- need to see improved business and market conditions
- wish to see improvements in government grants and tax incentives
- wish to see improvements in business information, advice and training.

3.14 Of companies that had conducted R&D in the past, but were no longer R&D performers, the reasons for no longer investing in R&D include:

- prohibitive cost of R&D as it could not be passed on to customers
- working in a market with limited competition and therefore did not require continuous R&D
- lack of internal funds
- R&D is undertaken on a project-by-project basis as deemed necessary.

3.15 Among those non-R&D companies that are not being deterred by finance, the issue appears to be more a lack of knowledge of target markets – an absence of skills to research a potential market or to promote a product to a target market.

3.16 Among the characteristics of R&D/ innovative companies in the survey and case studies, the following factors are noted:

- a lack of technological opportunity is seen as a main obstacle to innovation – interpreted at the company level as a knowledge gap within the firm to detect or identify areas where innovation could become possible and profitable
- size is not a significant determinant of innovative behaviour – both large and small companies are as likely to be involved
- younger companies (less that 11 years old) are more likely to undertake R&D
- grants and tax incentives are seen as the most effective means of government support, although the process of obtaining grants was often seen to be laborious: c. 25% of respondents also regarded loans as an effective support mechanism
- the means of channelling information on business opportunities and links with HEIs were seen as important, especially by more traditional manufacturers.

3.17 However, there were only weak links identified between single site manufacturers and universities. Those firms that expressed an interest in linking with a university still lacked knowledge of what expertise is available and how to go about making links.

3.18 The study sought to find out how those firms performing R&D on a continuous basis or on a project-by-project basis as required could be encouraged to spend more on this activity. The findings are summarised below:

- for the intermittent performers, lack of finance was a key factor in limiting their activities
- for the continuous performers, there are difficulties in recruiting staff with the appropriate skills and problems in accessing sufficient external funds.

3.19 Asked about factors which encourage companies to locate R&D activity in Scotland, the following were highlighted as important:

- the good science graduates and technical workforce
- strong university departments for collaboration
- access to government support.

3.20 The results of this survey of attitudes emphasises the diversity of views, a result that arguably makes the "condition" all the more difficult to treat without a careful segmentation of needs, opportunities and, where appropriate, public sector interventions. Whilst the headline national challenge is increasing BERD as a percentage of GDP, the underlying determining factors are many and various.

Mapping the Scottish Innovation System

3.21 In this research conducted by Roper et al[18] on behalf of the Scottish Executive, the following findings relevant to business R&D within the Scottish Innovation System (SIS) were reported:

- in terms of indicators of innovation system performance that reflect public investments, Scotland is in the top quartile of EU regions
- business R&D is in the third quartile
    - employment in medium to high tech manufacturing is in the third-quartile - knowledge diffusion among Scottish manufacturing companies is in the second quartile
    - employment in high tech services is in the second-quartile - knowledge diffusion amongst Scottish service companies is in the third-quartile.
- Scotland is in the third quartile in terms of the share of sales of new-to-the-firm products in manufacturing, but in the top quartile in terms of the overall innovation index, largely due to its standing in human resource measures.

[18] Roper et al (2006) ibid.

3.22 In terms of knowledge generation in the SIS by businesses, Roper at al report that foreign- owned businesses dominate.

3.23 The authors point to a major System weakness in terms of the interaction between HEIs and the indigenous company base. They point to weaknesses in the absorptive capacity of indigenous SMEs. Whilst acknowledging the contributions made by Scottish Executive schemes such as SCORE and SEEKIT (see Section 8: these only influence a small proportion of the business base.

3.24 On the exploitation of knowledge within the SIS, little evidence is found of locally owned medium and low tech firms engaged with other local companies in innovative activity. Links involving high tech firms are stronger. What the authors term knowledge mediation and sharing – or, horizontal connectivity - between Scottish firms and between smaller firms and the university sector are regarded as weaknesses in the System[19].

3.25 It is argued that the low levels of business R&D, especially in indigenously owned companies, not only limits the capacity of firms to develop their own knowledge bases and innovations, but also limits their ability to absorb external knowledge.

3.26 The authors point to a key issue for the universities in Scotland over how they can attune their activities more closely to the needs of the Scottish business base and economy (presumably without negative effects on excellence). For companies, the issue is how to encourage them to re-assess the priority given to R&D and innovation, to upgrade their absorptive capacity and adopt a more "open" stance to innovation links.

Comparison with Community Innovation Survey findings

3.27 The study of the SIS points up a number of issues concerning the Scottish business base which, on the face of it, are at variance with the recent analysis of the Community Innovation Survey (CIS3)[20] for Scotland. The CIS3 results merit closer attention (see Section 5), but this summary of CIS3 findings illustrates some key points. According to the CIS3 analysis:

- Scottish firms tend to make better use of the science base as a source of knowledge and information for innovation activities than their UK peers
  - Scottish innovators have a higher propensity to enter into co-operative arrangements for innovation with the science base
- also, a higher proportion of Scottish innovators have received public support for their innovation activity compared with the UK average, and this support appears to be effective.

[19] The significance of work in support of cluster development in Scotland in this context could usefully be addressed.
[20] Michie et al (2006 The Community Innovation Survey: an analysis for Scotland. Report to the Scottish Executive

3.28 The CIS3 report's authors conclude that the performance of the regional innovation system in Scotland is above average in the context of the UK[21]. Furthermore, they conclude that Scottish firms are able to combine both internal and external resources effectively to enable them to innovate successfully, despite their relatively low levels of investment in R&D. These findings appear to question the presumption of low levels of absorptive capacity in the Scottish business base.

21 Interestingly, the analysis of CIS3 data points to relatively low levels of organisational innovation in the Scottish business base, such as the introduction of advanced management techniques.

4: Business R&D profile in Scotland and its key industry sectors

4.1 In this paper the main indicators of R&D expenditure for Scotland are reviewed together with comparisons with UK and international norms. Relative performance of key sectors in the Scottish economy is reviewed: a section specifically on the services sector is included. This information is drawn from the Scottish Executive's report on Business Enterprise R&D (BERD)[22].

Current policy context

4.2 The challenge set by the Enterprise and Culture Committee of the Scottish Parliament[23] is to increase spending by Scottish businesses on R&D and innovation by almost £1bn per year over the next 10 years.

4.3 In its response, the Scottish Executive points to evidence of progress, but also to the need for further action:

- the most recent comparison indicates that Scottish expenditure on BERD relative to GDP is 38% of the OECD average
- the gap with the OECD is gradually closing - BERD as a percentage of GDP increased from 0.42% to 0.58% in Scotland between 1997 and 2003 – a real terms increase of 40%: the OECD average improved only slightly from 1.48% to 1.53% during the same period
- public sector investment in the Intermediary Technology Institutes (ITIs) and in the R&D Plus scheme is substantial. It is argued that it is yet too early to judge their effectiveness in leveraging additional expenditure on R&D by the private sector
  - therefore, the view seems to be that it would be inappropriate to commit further significant sums of public funding at this stage
- however, the Executive is currently reviewing its business R&D grant schemes overall to ensure they remain fit-for-purpose.

4.4 The Executive's response also acknowledges that improvement in R&D performance is not just a funding issue: it is dependent on an ability to build sufficient "absorptive capacity" in Scotland to utilise additional funding efficiently and effectively. Requirements to achieve this include:

- increased commercialisation of the science base
- support for existing companies to initiate or enhance existing R&D activity

[22] Scottish Executive (2005) Business Enterprise Research and Development in Scotland, 2003.
[23] Enterprise and Culture Committee (2006) *Business Growth – the next 10 years*. Scottish Parliament Paper 520

- the encouragement of more R&D intensive inward investment activity[24].

UK context

4.5 The wish to raise the investment by business in R&D is a common policy theme across the UK and indeed the European Union. The UK Government's ten year Science and Innovation investment framework[25] indicated that a large increase in business R&D would be required to increase the level of BERD in the UK to 2.5% of GDP by 2014, the policy goal that has been set for the UK.

4.6 The framework document pointed to a segmented approach in terms of business response would be required:

- maintaining and growing R&D where there are existing strengths
- attracting investment into the country from multinationals in an already highly internationalised innovation system
- increasing R&D intensity in firms or sectors that are lagging behind their peers
- developing new R&D intensive sectors through the creation and growth of R&D intensive SMEs.

4.7 The DTI paper on R&D intensive businesses in the UK[26] noted that one reason for differences in R&D intensity between the USA and the UK was the strong growth of service sector R&D in the former. However, the report points to difficulties in obtaining like-for-like comparisons because of the different ways that information on R&D are classified.

Summary of the evidence on BERD

4.8 The table below summarises key high level figures on BERD in Scotland together with UK and international comparisons. It is notable that in terms of Gross Expenditure on R&D (GERD) Scotland performs relatively well, including on levels of Government-funded R&D. It is also notable that companies providing R&D services perform relatively well in Scotland, much of this appearing to be the result of business R&D commissioned by clients from outside Scotland. Scottish firms outsource less R&D relative to the UK business base as a whole.

4.9 The relatively low proportion of BERD attributable to development ("D") in Scotland is notable.

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[24] The recent investment by Wyeth in translational medicine research in Scotland in collaboration with the NHS and four Scottish universities is a notable success here.
[25] HM Treasury et al (2004) *Science and innovation framework*
[26] DTI (2005) *R&D Intensive Businesses in the UK* DTI Economics Paper No. 11.

Table 4-1 Snapshots from BERD in Scotland (Scottish Executive, 2005[27])

Statistic	Scotland	UK/international
Number of enterprises in Scotland performing R&D	764	
Business Enterprise R&D (BERD) in Scotland 2003	£521m	= 3.8% of UK BERD
Portion of Scottish BERD relating to “D”	33% on experimental development	UK equivalent is 59%. This gap has widened as the UK spend on D has increased while Scotland’s has remained the same
BERD: GDP in Scotland	0.58% (comparable to Italy)	UK BERD is 1.23% of UK GDP OECD BERD is 1.51% of OECD GDP Since 1997, UK and OECD % have shown at best small increases over time.
BERD per employee in Scotland (all sectors)	£319 (ranked 9th of all 12 UK regions)	UK BERD per employee is £702
% of workforce with higher qualifications (NVQ level 4 or above)	35.3% (ranked 2nd of all 12 UK regions)	UK figure is 29.8%
BERD per manufacturing employee in Scotland	£1,807	UK BERD per manufacturing employee is £3,166
Number of employees in Scotland performing R&D activities	7,363 (NB. 32% less than in 2002)	The BERD Scotland 2003 report n notes: “from a labour market and skills perspective Scotland is certainly not worse placed than the UK as whole of undertaking R&D”.
BERD per R&D employee in Scotland compared to UK spend	Scotland spend is £13,300 less than UK spend per R&D employee	
Increase in BERD in Scotland since 1997	54% in real terms	24% in the UK
Business R&D employment in Scotland	7,363 people (0.5%) of the workforce, excluding public sector	
Gross expenditure on R&D (GERD) in Scotland: business + government + HE	£1,367m	= 7% of UK GERD
Government R&D in Scotland (GOVERD)	£271m	= 13.5% of UK spend
HE R&D in Scotland (HERD)	£575m	= 12.9% of UK spend
HERD + GOVERD in Scotland	> than BERD	In UK it is < 50% of BERD
GERD: GDP in Scotland	1.53%	UK GERD is 1.81% of UK GDP
Funding of BERD in Scotland	80% funded by UK business sources	Higher proportion than UK
Contracted out R&D by businesses in Scotland	£21.85m	Total BERD in Scotland funded by other UK businesses is £143m – more R&D is undertaken in Scotland than is commissioned from Scotland
Performance of R&D services	39% of all Scottish business R&D undertaken by Scotland’s R&D	Equivalent for UK is 25%

[27] Scottish Executive (2005) ibid.

Statistic	Scotland	UK/international
(SIC73)	service sector/ consultancies. 85% of chemicals and pharma R&D contracted out	
Outsourcing of business R&D in Scotland (extra-mural R&D)	4.2% of business R&D is outsourced	17.8% of UK business R&D is outsourced
Sectoral contributions to BERD in Scotland	c. 66% of Scottish BERD supports three product groups: pharmaceuticals, TV and communications equipment (including electronic components) and precision instruments	BERD in pharma in Scotland is £197m out of the total BERD of £521m.
Origin of firms undertaking business R&D in Scotland	US-based firms: 50% Scottish-based firms: 29% Other UK headquartered firms: 8%	
BERD by small firms in Scotland	17% of Scottish BERD. “R&D for service products is dominated by small firms.” Medium sized companies are also more important in Scotland than in the UK overall	10% of UK BERD
Location of BERD in Scotland	>50% in West Lothian and Edinburgh	

Key industry sectors in Scotland

4.10 Scottish Enterprise currently supports nine key sectors because of their potential for strong growth, whilst Highland and Islands Enterprise highlight thirteen. The table below identifies these sectors.

Table 4-2 Key sectors

Scottish Enterprise	Highlands and Islands Enterprise
Creative Industries	Crafts
Electronics	Textiles
Software/e-business	Tourism
Forestry	Forestry
Food & drink	Food & Drink
Aerospace	Aquaculture
Financial services	Renewable energy
Contact centres	Contact Centres
Biotechnology	Health & Biotechnology
	Sea Fisheries
	Manufacturing
	Oil & Gas

Scottish Enterprise	Highlands and Islands Enterprise
	Agriculture

4.11 We understand that Scottish Enterprise proposes to focus down in future on six priority sectors: tourism, food and drink, energy, life sciences, financial services and electronic markets[28]. However, we also note in its response to the Parliamentary Committee's report on Business Growth, that the Scottish Executive recognises the continuing importance to the economy of textiles, aerospace, shipbuilding and marine industries, chemicals and forest industries[29].

BERD by sector in Scotland

4.12 The Scottish Executive's BERD Report[30] provides statistics on overall R&D expenditure in Scotland and then splits these data by sector (based on Standard Industrial Classification categories). BERD in Scotland per sector is addressed not only in absolute terms, but also relative to sectors at a UK level.

4.13 Scotland's share of UK BERD is particularly high (i.e. above 10%, twice the overall Scottish percentage of UK spend) in the following major product groups:

Table 4-3

Product group	Scotland as % of UK
Precision instruments (Scottish BERD = £61m)	17.7%
Extractive industries (Scottish BERD = £11m)	19.6%
Radio, television and communication equipment (Scottish BERD = £48m)	11.4%

4.14 The top five groups in Scotland, with BERD of £30m or above, also include: Pharmaceuticals (with the highest BERD at £194m); Machinery and equipment (£42m) and Computer and related activities (£30m).

4.15 The BERD 2003 report indicates that Scotland's share of UK R&D spend is relatively low in the services sector, at 2.3% of the UK total.

4.16 In terms of R&D expenditure per employee, Scotland is leading in R&D within the UK in Precision Instruments and comes close to the UK norm in pharmaceuticals, chemicals/man-made fibres and extractive industries.

4.17 Whilst the food & drink industry is regarded as a key sector in the Scottish economy, it is not recognised as R&D intensive - although there are likely to be niche areas in which R&D may be crucial e.g. health enhancing foods.

[28] See Scottish Parliament Enterprise and Culture Committee Report ibid.
[29] Scottish Executive (2006) Business Growth Enquiry – response to the Enterprise and Culture Committee's 5th Report 2006.
[30] Scottish Executive (2005) ibid.

4.18 Although employment in the aerospace industry in Scotland is much lower relative to its distribution across the UK, there are plans to enhance Scotland's R&D capacity in this area. A revised Scottish Aerospace and Defence Strategy[31] was approved in January 2005: this aims to attract three new Business Enterprise R&D programmes to Scotland at a potential investment of £55m and creating potential for 350 jobs[32].

4.19 R&D intensity is measured as BERD relative to turnover. The BERD in Scotland report notes that exact figures are not available for all sectors, but it provides estimates of Scottish figures to permit comparisons with UK performance. The table below shows relative R&D intensity of sectors within Scotland in comparison to the UK (for 2002). This snapshot appears to indicate notable differences in the profile of R&D intensity in sectors in Scotland relative to the UK: the pharma sector, however, is ranked number one in both cases.

Table 4-4 Ranking R&D intensities

Industry/Sector	% turnover, Scotland	Rank in Scotland	% turnover, UK	Rank in the UK
Pharmaceuticals	36.5%	1	21.4%	1
Precision instruments	5.5%	2	3.6%	5
Radio, TV and Comms equipment	4.5%	3	6.3%	3
Electrical machinery and apparatus	3.4%	4	3.3%	6
Chemicals and man-made fibres	1.1%	5	4.3%	4
Other Transport Equipment and Aerospace	0.6%	6	8%	2
Motor vehicles and parts	0.5%	7	2.2%	7
Office machinery and computers	0.1%	8	1.2%	8
Extractive industries	?		0.2%	

4.20 The BERD in Scotland data permit spend on "D" for different product groups to be examined. The results are striking. Looking at the product groups important to Scotland, the table below compares Scotland's spend on "D" relative to the rest of the UK. The spend on "D" is much less in Scotland in chemicals, including pharma, and in electricals. This may indicate that much of BERD in Scotland is being deployed closer to the science base and/or further from market, and is arguably more risky from a business perspective. It may indicate that it is being deployed on more radical innovation, something that seems to be borne out by the results of the Community Innovation Survey (see Section 5). This is an area requiring closer investigation.

[31] See: http://www.scottish-enterprise.com/publications/aerospace_strategy.pdf
[32] www.scottishenterprise.co.uk

Table 4-5 Percentage spend on "D"

Product group	% on "D" , Scotland	% on "D", UK
Chemicals, incl. Pharma	34%	59%
Electrical machinery including computers and comms equipment	44%	63%
Mechanical engineering	77%	73%

Sector performance over time

4.21 Over time (period 1997 – 2002), the major R&D spenders in Scotland have been in pharmaceuticals, electrical machinery (including: apparatus, office machinery, computers and radio, TV and communications equipment) and precision instruments[33]. R&D expenditure on pharmaceuticals has increased nine fold in real terms over the period and around half of the total increase in Scottish R&D spending in the period is accounted for by this increase in the pharmaceuticals sector.

4.22 Electrical machinery has continued to attract substantial R&D spend over the last few years, whilst precision instruments entered the R&D intensive product group in Scotland for the first time in 2001. Scotland has a strong foundation in electronics: many Scottish universities have an enviable reputation for microelectronics, optoelectronics and communications technology research.

4.23 The following section examines performance in service sector R&D in Scotland.

Service sector R&D in Scotland

4.24 The 2003 report on Scottish BERD commented that '*in general, comparatively little R&D for service sector products is undertaken in Scotland*'. In 2003, Scottish companies in the services sector spent £67m on R&D, which constituted 2.3% of overall UK expenditure in this sector.

4.25 The low figure for services sector R&D is a concern due to the importance of the sector to the Scottish economy. However, contact centres, which embody significant technological advances, are presented as offering significant opportunities in Scotland. According to Scottish Enterprise[34], "*Scotland offers an ideal location, with low real estate costs, a mature and technologically advanced telecommunications industry, and a level of deregulation that has encouraged fierce competition and kept call charges low*".

4.26 Whilst it may be the case that parts of the service sector do not require high levels of science and technology related innovation, others for example in parts of financial services may have a much greater interest in technological advances. The reasons for the discrepancies between Scottish and UK spending on R&D by this sector requires

[33] Scottish Executive (2005) ibid.
[34] See http://www.scottish-enterprise.com/sedotcom_home/services_to_business_international/lis/key_sectors/contact_centres.htm?siblingtoggle=1

closer investigation. The significance of R&D for financial services is explored in a later Section of this report.

International context

4.27 The most researched products in the OECD are electronics (total R&D share is 14%), pharmaceuticals (7%), precision instruments (6%), office machinery (5%) and aerospace (4%). These are classified by the OECD as high technology industries. For the UK, the sectors receiving most investment are pharmaceuticals (25%) and aerospace (10%), followed by radio, TV and communications equipment, and motor equipment.

4.28 Compared to the corporate base in other countries, the DTI R&D Scoreboard (2004) shows that the largest UK businesses are concentrated in pharmaceuticals and aerospace, i.e. very R&D intensive sectors, and in lower intensity sectors such as food producers, utilities and natural resource based companies.

4.29 Scotland's overall position within OECD economies with reference to sectoral differences highlights that it is *"in transition", moving from an agriculture/mining/manufacturing focussed economy to a more advanced manufacturing/service based economy"*[35].

4.30 In addition, Scotland's business R&D expenditure is 0.58% of GDP, lower than in the UK (1.24%). In recent times, Scotland's and the UK's R&D spend as a proportion of GDP has lagged behind many competitor economies. Specific example include: Sweden spending the equivalent of 2.95% of GDP and Finland spending 2.46%.

4.31 In Scotland, just over 40% of R&D expenditure is performed by businesses.[36] By comparison, in the US, Sweden, Finland and Japan, over 70% is undertaken by the private business sector. The relative contribution by higher education to total R&D expenditure is high in Scotland.

Scotland's Innovation capacity

4.32 Although it is important not to confuse innovation with R&D, the latter is one possible input to the former. There are interesting findings on the role of R&D in innovation in Scotland in the Third Community Innovation Survey (CIS3: see Section 5 for more information)[37]. There are some key points highlighted by the analysis:

- Scotland has a significantly higher proportion of firms that are novel innovators, in other words, those companies that have introduced a product that is new to the market
- however, whilst there is a higher prevalence of novel innovators, Scottish expenditure on R&D per employee is confirmed as significantly lower than the UK average

[35] Robert Huggins Associates (2005) *Intellectual and Knowledge Capital in Scotland* Report to the Scottish Executive
[36] Robert Huggins Associates ibid.
[37] Michie et al (2006) *The Community Innovation Survey: an analysis for Scotland.* Report to the Scottish Executive

- data on Scottish BERD, indicate that enterprises in Scotland spend £390 per employee annually on R&D, just 60% of the UK figure (£669). However, total Scottish R&D expenditure per employee is more closely aligned with the UK figure (£2,100 and £2,900 respectively)

- the CIS3 results appear to suggest that Scottish firms are able to be innovative whilst spending less on intramural R&D per employee.

4.33 This apparent discrepancy requires closer investigation: the CIS3 analysis to some degree goes against received wisdom about the Scottish "condition". It appears to indicate that the Scottish business base is not as deficient in "absorptive capacity" as it is often claimed to be by researchers. It may be pointing up some quite fundamental issues about the importance of sectoral mix and bias in terms of the structure of the Scottish business base when considering only overall performance on BERD as a proportion of GDP.

Business-related R&D conducted within the Scottish university science base

4.34 Figures for research income in universities are shown in the table below. Universities in Scotland received 8.8% of their total research grant and contract income from industry and public corporations in 2002-03. This is lower than the UK figure of 9.9%.

Table 4-6 Sources of research grants and contracts income 2002/03 (£000s)[38]

	UK				EU	Other overseas	Other	Total
	OST/RCs	Charities	Central & local Govt	Industry, public corporations				
Total UK	819,997	652,655	456,162	257,496	218,172	130,013	60,950	2,595,445
	31.6%	25.1%	17.6%	9.9%	8.4%	5.0%	2.3%	
Scotland	103,329	88,862	68,610	30,598	32,126	17,425	7,147	348,097
	29.7	25.5%	19.7%	8.8%	9.2%	5.0%	2.1%	

4.35 The results of the Higher Education Business and Community Interaction survey (2002-3)[39] provide further information on the types of industrial R&D that Scottish universities undertake. HEIs were asked to identify which Standard Industrial Classification (SIC) sectors they undertook work with during 2002-03. The table below shows that, in comparison with UK HEIs as a whole, HEIs in Scotland undertook significantly more work with the fishing, construction, health and social work, financial activities and transport-related sectors, and with international organisations. Indeed, Scottish HEIs appear to work individually with a wider range of SICs than the UK average rather than preferentially with the stronger industry sectors in the economy.

[38] http://www.planning.ed.ac.uk/Pub/Analyses/RGC_Sources_0203.htm
[39] HEFCE (2005) Higher education-business and community interaction survey, 2002-03

Table 4-7 % of HEIs undertaking work with the following SICs, 2002-03

	Scotland (%)	UK total (%)	Difference (+/-)
Health and social work	95	81	+14
Education	84	87	-3
Financial activities	79	63	+14
International organisations and bodies	79	66	+13
Manufacturing	74	71	+3
Construction	74	52	+22
Other community, social and personal service activities	74	73	+1
Transport, storage and communication	68	55	+13
Public admin, etc.	68	68	0
Electricity, gas and water supply	53	48	+5
Property development, etc.	53	51	+2
Fishing	42	18	+24
Wholesale, etc.	42	34	+8
Hotels and restaurants	42	37	+5
Agriculture and forestry	37	35	+2
Automotive	32	47	-15
Mining and quarrying	21	20	+1

4.36 HEIs in Scotland also employ, on average, fewer staff than UK HEIs as a whole in dedicated "third stream" or knowledge/technology transfer-related functions. This is particularly the case with respect to staff directly employed to engage with commercial partners.

Table 4-8 FTEs employed in dedicated third stream functions, 2002-03

	Average per HEI	
	Scotland	UK
Engaging with commercial partners	9	14
Engaging with public sector partners	5	6
Engaging with social, community and cultural partners	4	6

4.37 The majority of Scottish HEIs appear to have the basic infrastructure in place for dealing with initial enquiries from SMEs: 79% of institutions reported having an enquiry point for SMEs (compared with 68% for the UK as a whole) and 89% reported that they offered assistance to SMEs in specifying their needs (compared with 79% for the UK as a whole).

4.38 In terms of consulting links and other external interactions, 95% of Scottish HEIs have some formal management structure in place to handle these kinds of activities.

Table 4-9 Presence of infrastructure to manage consulting links and other external interactions, 2002-03

% of HEIs having ..

	% of HEIs having ..	
	Scotland	**UK total**
Nothing	5	13
Exploitation company	11	8
Internal department	68	49
Both	16	30

4.39 Over the period 2002-03, 53% of Scottish HEIs reported that staff engagement in directly providing services to commercial clients had increased from the level in the previous twelve months, with 47% reporting no overall change.

5: Analysis of the Community Innovation Survey

5.1 The findings of the Third Community Innovation Survey (CIS3) have been referred to in a number of places in this document so far. This Section provides a summary of the main findings of an analysis of the CIS data for Scotland commissioned by the Scottish Executive.[40]

5.2 The survey collated information on the number of enterprises that had introduced any technologically new or significantly improved products (goods or services) which were new to the firm (*product innovation*) and additionally, established whether the product innovations were new to market (*novel product innovation*). The results indicate that the South West and South East regions of the UK have the highest proportion of innovators, whilst Scotland and the West Midlands represent the lowest overall. However, Scotland has the highest proportion (53.5%) of *novel* innovators amongst its product innovators.

5.3 The highest proportion of *novel innovators* relative to all enterprises occurred in the South East (11.5%): Scotland account for 10.4%, higher than the UK average of 9.5%. Whilst a higher proportion of employees in Scotland work in firms that are *novel innovators*, Scottish innovators spend less on R&D. On proportion of *novel innovators* in Scotland, compared to the UK, Scotland performs above average - despite relatively low overall spend on business R&D.

Process innovation

5.4 Process innovation is defined as '*the use of new or significantly improved technology for the production or the supply of goods and services*'. In terms of Scotland's performance in process innovation, 18.4% of firms introduced a new process, in line with the UK figures. However, a greater proportion of Scottish process innovators introduced *novel* processes compared with the UK norm. More specifically, Scotland shares a high number of novel process innovators with London and the South East regions.

5.5 The survey overall suggests that Scottish innovators tend to introduce more radical innovations on average than UK counterparts.

Organisational innovation

5.6 The South East has the highest proportion of enterprises (48.4%) in the UK that have implemented new or significantly changed corporate strategies. Scotland with 37.9% has the lowest score.

[40] Michie et al (2006) ibid.

5.7 On average, 36% of UK firms introduced new management techniques. Regionally, the South East accounted for the highest proportion (39.8%) whilst Scotland represented the lowest (30.4%).

5.8 In terms of implementing new marketing techniques, the South East is leading the way (50%), whilst Scotland and Wales lag at the back. In short, Scottish firms are less active in organisational innovation activities than those in most other regions.

R&D expenditure

5.9 R&D expenditure per employee and R&D expenditure as a percentage of turnover in Scotland are both significantly lower than the UK average. Specifically, the level of R&D expenditure per employee in Scotland is just over half (57%) that of the UK average.

5.10 In terms of total innovation–related expenditure per employee, Scotland achieves just two-thirds of the UK average. It is highest in the Eastern region and the South East, more than twice the UK average.

5.11 As R&D expenditure is significantly higher across the UK, the question arises: *Why is Scottish innovation performance in some areas above the UK average?* The analysis of CIS3 commissioned by the Executive suggests four key factors to help explain Scotland's above average performance:

- Scottish enterprises employ a higher proportion of graduates, including a greater proportion of scientists and engineers, compared with the UK as a whole. Scotland has the fourth highest proportion of science and engineering graduates (7.2%), behind London (9.7%), the South East (8.3%) and the Eastern region (7.3%)
- a higher proportion of Scottish innovators (44%) use the science base as a source of knowledge and information for technological innovation compared with 38% for the UK. In addition 40% of process innovators used universities and other HE institutes as sources of knowledge and information for technological innovation compared with 36% in the UK. In this area, Scottish firms outperform the UK which may suggest that there are better linkages between industry and the science base in Scotland
- Scottish innovators are more likely to embark upon cooperative arrangements for innovation with the science base, for example; with universities and research centres
- a larger proportion of Scottish innovators have obtained public policy support for innovation activity compared with the UK average.

Impacts of innovation

5.12 The CIS3 survey also examined the impacts of innovation. The 'top three' effects of innovation are:

- an increase in the range of goods and services (89% of Scottish product innovators and 92% of process innovators cite this as an important impact)

- improvement in the quality of goods and services (88% of Scottish product innovators and 83% of process innovators cite this as an important impact)

- entering new markets or increasing market share (85% of Scottish product innovators and 73% of process innovators cite this as an important impact)

5.13 Just one in ten of Scottish product innovators and 16% of Scottish process innovators cited that innovation had an important impact on lowering labour unit costs, suggesting that innovation is regarded as being about competitiveness more broadly, rather than simply pursuit of efficiency gains.

Factors constraining innovation

5.14 In terms of the factors hampering innovation, the five most important factors cited in the CIS3 survey include:

- the direct costs of innovation are too high

- the cost of finance

- perceptions of excessive risk

- lack of qualified personnel

- the availability of finance.

5.15 There is little difference in the relative ordering of these factors between Scottish and UK firms. The most significant difference is evident in the impact of regulations and standards on innovation: Scottish companies cited regulations and standards as less of a restriction than UK firms.

Summary and implications

5.16 The CIS3 suggests that Scottish firms overall are able to be more innovative whilst spending less on R&D per employee. There are a number of reasons suggested for this as outlined previously. However, in many areas Scotland's innovation performance lags behind that of other UK regions. Therefore, the analysis of the CIS3 highlights a number of implications for future Scottish innovation performance:

- the significance of absorptive capacity, what it really means and how to address it needs to be resolved – there appears to be conflicting messages between different pieces of research

- Scottish firms have lower levels of organisational innovation: closer consideration and implementation of innovative and more advanced management techniques should be actively encouraged.

Wider strategic significance – towards open innovation

5.17 The resolution of apparent differences between research findings concerning the collaborative behaviours and absorptive capacities of Scottish businesses is important for a number of reasons, including the allocation and targeting of resources to public sector interventions in support of R&D, innovation and business growth.

5.18 It is also important in what is seen by some as a paradigm shift in the business innovation process – towards so called "open innovation". Chesbrough[41] contrasts two views of innovation among firms:

> *"successful innovation requires control. …… This paradigm counsels firms to be strongly self- reliant, because one cannot be sure of the quality, availability, and capability of others' ideas: if you want something done right, you've got to do it yourself."*

and

> *"Open innovation …… assumes that firms can and should use external and internal ideas, and internal and external paths to market. ……… The business model utlizes both external and internal ideas to create value, while defining internal mechanisms to claim some portion of that value."*

The Fourth Community Innovation Survey

5.19 Data from CIS4 were put into the public domain on July, 2006. An analysis of the data for Scotland is likely to be published by the Scottish Executive in due course.

5.20 The positive messages that have come from the analysis of CIS3 data for Scotland should to be re-assessed in the light of the CIS4 results and apparent contradictions between different research findings re-examined to ensure a robust evidence base for policy implementation.

[41] Chesbrough (2003) ***Open innovation- the new imperative for creating and profiting from technology***. Harvard Business School Press

6: Significance of R&D for financial services

6.1 In Section 4, the scale of BERD in Scotland associated with the services sector was examined. In this Section the focus is on financial services, one of the key sectors in the Scottish economy. In particular, the significance to this sector of R&D is examined using insights gained for example from recent research in the USA.

The Scottish financial services industry

6.2 Scottish Financial Enterprise (SFE), the representative body for the financial services sector in Scotland, describes the importance of financial services to the Scottish economy. As SFE points out[42], the industry accounts for £6 billion (over 6%) of Scotland's GDP. In the five years (2000 – 2005), financial services in Scotland grew by 36% while the overall Scottish economy grew by 9%. The whole of the UK financial services industry grew by 15% - so Scotland's performance stands out.

6.3 The financial services industry accounts for one in ten Scottish jobs, with over 113,000 people directly employed in the industry and over 100,000 more employed in support services. In the six years to 2004, direct employment in financial services in Scotland rose by 31.5% compared with 7.5% for the economy as a whole.

6.4 The financial services industry in Scotland encompasses a number of sub-sectors – banking, investment management, insurance and asset servicing, and is supported by a wide array of professional advisors. The need for innovation in these various areas is recognised by SFE, which sponsors (in conjunction with Ernst & Young) the annual Innovators Awards. The variety of innovations introduced by the award winners in 2005 demonstrates how broad the definition of "innovation" needs to be when applied to the financial services sector - ranging from the MSc degree course in Finance and Investment introduced by the University of Edinburgh (the overall winner) to a new form of ATM and an online mortgage shop (see also para 6.7).

Scottish Financial Services Strategy

6.5 The Strategy for the Financial Services Industry in Scotland was launched in March 2005 by the First Minister and a Financial Services Advisory Board (FiSAB) comprising senior figures in the industry, the trade unions, government and other parts of the public sector. The aim is to ensure that Scotland is a competitive location for investment by continuing to strengthen the quality of the business environment for the financial services industry. A major plank of the strategy concerns innovation.

6.6 The Strategy's 2006 Annual Report[43] sets out progress to date. In addition to research into the supplier base, notable achievements include:

[42] www.sfe.org.uk/info/overview_scottish_financial_industry
[43] The Strategy for the Financial Services Industry in Scotland: Scottish Executive (2006)

- a series of workshops (involving 34 firms) to enhance the capacity of the Scottish supply base to support the global financial services industry
- the launch of 'The Innovators', a new set of awards launched in 2005 to showcase Scotland's skills in the innovation field.

6.7 Amongst the winners of Innovators awards was Clydesdale & Yorkshire Bank with their 'speaking' ATM allowing use by dyslexic and sight-impaired customers. This service was developed in partnership with NCR, an example of an international technology supply company which has been committed to the Scottish market through its major facility in Dundee.

6.8 Looking ahead, the FiSAB's aims are to:

- deliver a programme of seminars and events that will bring together leading industry thinkers, experts and academics
- foster greater innovation by extending and tailoring promotion of the range of public sector support available to the industry
- investigate the benefits delivered by links between the industry and the Scottish and international academic community and how these might be maximised
- further capacity building of the Scottish supplier base.

6.9 The advent of the Financial Service Strategy in Scotland is something of an innovation in itself. Whilst the importance of innovation in financial services is recognised globally, the public sector would not appear to have responded in quite such a specific way elsewhere. Some further work on international comparators may be of use in order to identify best practice examples, especially of collaborative industry initiatives.

Innovation in the sector – a USA perspective

6.10 The National Science Foundation (NSF) and National Institute of Standards and Technology (NIST) in the USA commissioned research[44] to measure R&D in the services sector. Within this overall remit, the researchers examined the US financial services sector as a case study.

6.11 The NSF/NIST work identified a number of trends which are common to both the US and UK/Scottish financial services markets:

- increased competition through deregulation and consolidation which are forcing financial services companies to innovate to maintain profitability
- increased demand for financial services as the 'baby boom' generation approaches retirement

[44] NSF/NIST (2005) *Measuring Service Sector Research and Development*

- dis-intermediation in the financial services sector as companies begin to package products with financial services and deal directly with customers. This is forcing financial companies to reduce costs by using more efficient technologies and to move into new product and service areas.

6.12 The study also found that the level of R&D undertaken by financial services companies depends on the type of firm and its size. Investment services companies rely heavily on technology to ensure that accurate and complete information is available to investors. As the NSF/NIST report states: '*a high rate of innovation is required as the leading companies compete for customers through differentiation via technology'*. The largest companies have specialised in-house teams responsible for innovation and development projects. Such companies rely on external technology vendors only for existing technologies and assistance in installing the purchased kit. The companies will then modify the vendors' products to meet their own system needs.

6.13 Retail banks on the other hand see themselves competing for customers through quality of service. Retail banks perform very few technical development activities in-house, relying on the products developed by vendors. They do, however, constantly seek to innovate their service offering.

6.14 Such innovation has sometimes been implemented in a rather haphazard fashion. One bank, Bank of America, has however sought to bring a more 'scientific' approach to the introduction of new products and services[45]. This involves using an 'innovation market' – a set of branches within the bank's existing network as a test bed for introducing new services in a 'real life' situation. It also involved a rigorous five-stage process for conceiving and executing innovation experiments.

6.15 The most interesting findings of the experiment were not so much that a new service worked (e.g. keeping customers entertained whilst waiting in line for attention), but some of the unforeseen impacts. These included problems over how the staff bonus system could be adapted to accommodate the revised working arrangements required by a new scheme and how to cope with a range of experiments being undertaken in the same test branches. Most important of all, whilst experiments can fail in a laboratory and still yield useful learning points, experiments cannot be seen to fail in a real life banking situation as careers are on the line.

6.16 Thus, what the Bank of America example shows is that innovation does take place in service industries, but it is usually very different in form to the laboratory-based R&D required by for example the manufacturing sector.

6.17 Another US example that could be of direct relevance to the Scottish market is the work that Niteo Partners (a wholly owned subsidiary of NEC) is doing on web services to reduce the cost of interbank transactions for a group of US retail banks. NEC works closely with the research faculty at Stanford University including in the

[45] Thomke, S (2003) R&D Comes to Services. *Harvard Business Review*

areas of knowledge representation, machine-to-machine communication and interaction, and automated computing[46].

Implications for Scotland

6.18 Given the findings discussed above, it would appear that innovation is essential in the financial services market in order that companies remain competitive and profitable. The financial services sector is a very important one for the Scottish economy. However, the Scottish services sector as a whole is not investing as much in R&D even compared with the rest of the UK.

6.19 However, BERD in Scotland does not break financial services R&D spend out of the overall service sector total. It would be helpful to ascertain the BERD figure for financial services. Although a wide range of financial institutions have either their head office or a major corporate presence in Scotland, it may be that their innovation team is based elsewhere and hence its expenditure is not recorded in the Scottish figures.

6.20 Also, where the technology is embedded in equipment purchased from vendors (embodied R&D), this will not show up in financial services R&D data but rather under the sector headings appropriate to the vendors. Further work is required therefore to clarify the significance of the sector's innovation supply chain for the BERD data. This could involve detailed consultations with a range of financial institutions to examine their new product/service development processes and to determine if there are areas where the Scottish market (including the science base) might serve them to a greater degree.

Difficulties in identifying financial services R&D spend

6.21 As indicated previously, the published BERD figures for Scotland do not break out the R&D figures for financial services. The DTI R&D Scoreboard[47] lists only four institutions in the financial services section, none of which is a dominant player in the UK market.

6.22 The likely reason for these omissions is that the type of innovation undertaken in financial services companies does not align clearly enough with the DTI's definition of R&D (see Section 2). As a result, only relatively few financial services companies in the UK show a figure for R&D in their accounts.

6.23 However, *innovation* is clearly going on. A review of financial service company accounts and discussions with industry players suggests that the relevant costs are being absorbed under other headings which are not immediately obvious to the compilers of 'R&D' figures. With banks for instance, spend on new IT infrastructure is one indicator of innovative activity since computers now play such an important

[46] In the Scottish context, centres of excellence in informatics covers these subject areas and would appear to be capable of acting as an invaluable resource for technological developments in the Scottish financial services industry.
[47] http://www.innovation.gov.uk/rd_scorebroard

role in their service provision. In cases where the innovations are less capital intensive, the costs may relate more to the use of expert staff and hence are rolled into the overall costs of the relevant division. However, since the exact treatment of these figures differs from institution to institution, it is difficult to pull together comparative figures from published accounts. The only way to arrive at a more accurate picture would be to undertake a survey of financial institutions to ask detailed questions about how R&D *and* innovation are accounted for. Even then, there may be an unwillingness to answer on grounds of commercial sensitivity.

The importance of innovation in the global financial services industry

6.24 Deloitte has recently published its industry outlook on global financial services[48]. This involved an online survey of senior executives at financial services firms backed up by 21 in-depth interviews. One third of the survey respondents identified technology/innovation as a top profit driver over the next three to five years – especially the technology required to build strategic alliances with customers, partners and other stakeholders.

6.25 As direct access and pricing pressures lead to commoditisation, the respondents felt that customer focus would become central to strategy. Financial institutions are therefore increasingly concentrating on delivering an innovative customer experience – one that is targeted to unique market segments and emphasises convenience, service and value.

6.26 Technology has allowed customers to loosen ties with financial services providers, but it can also be harnessed to rebuild and strengthen relationships. On the retail side, the focus is becoming one of personalisation, ease of navigation and a revival of personal client contact as one component of a multi-faceted relationship. On the institutional side, capital markets firms are set to develop ever more sophisticated client platforms that provide trading scenario analysis, risk modelling and performance management reporting.

Approaches to innovation by Scottish banks

6.27 To test some of the issues raised in this Section in the Scottish context, consultations were undertaken with the two leading Scottish banks (RBS and HBoS).

Definition and approach

6.28 The RBS definition of innovation is '*new ideas delivered to market of economic value*'. RBS has a dedicated innovation team. Innovation is divided into:

- *customer facing* – aiming at improving the customer experience
- *improving internal processes*.

[48] Deloitte (2006) Global Financial Services Industry Outlook

6.29 The innovation team, based in London, is responsible for overseeing all innovative activities across the bank, but is distinct from Group Technology, based in Edinburgh which is responsible for the Bank's technological hardware.

6.30 At HBoS, there are separate divisional teams as the needs of the corporate and retail banking arms are seen as different. Retail needs are more IT reliant. In the Corporate Division, innovation is concentrated on differentiating the Bank in terms of sophistication of financial product.

Drivers for innovation

6.31 Both banks stressed that the innovation undertaken is market driven. The aim is to serve their customers better and increase revenue. There is no interest in research for its own sake.

6.32 The key industry drivers for innovation at present are the desire to:

- enhance internationalisation
- avoid commoditisation
- cope with 'disruptive' technology … and put it to good use when it emerges.

6.33 The final point is telling. Banks do not view technological discoveries as unmixed blessings. Any technological innovation forces the pace of spending as the banks do not want to be left behind in finding ways of exploiting the new advances.

In-house versus bought-in innovation

6.34 Where the product development required is specialised and not dependent on large IT equipment, the banks prefer to undertake the work in-house. However, where widescale, robust IT systems are required, the banks make use of external companies, either as vendors or as joint venture partners.

6.35 A current example of the latter approach is the new contactless payment card which has just been launched by RBS in partnership with Mastercard. This card can be used as a normal debit card, but additionally can make contactless payments of up to £10 to buy small items like coffee or meals. This avoids the need for the customer to carry around small amounts of cash. RBS have been trialling the use of the card through the Starbucks outlets in Edinburgh.

6.36 In this example, the technological innovation is embedded within the cards produced by Mastercard. However, the innovation in terms of customer service offer has been developed by RBS. A tribute to the importance of this innovation has been paid by Brian Triplett of Mastercard's arch rival Visa: '*The contactless infrastructure lays the foundation for a lot of new innovation over the next few years*'.

6.37 However, whilst the service innovation has been developed in Scotland, the technological innovation, in common with many others used in Scottish banks, originated with a global, rather than Scottish company. This bears out the findings of a recent piece of research by Giraffe Consulting[49] into the Scottish financial services sector supplier base for Scottish Enterprise Edinburgh & Lothian (which built on earlier work undertaken by Ernst & Young). This report concluded that Scottish financial services companies are taking an increasingly strategic approach to sourcing and looking for global suppliers. They need reliability and scale: they have concerns about doing business with smaller companies, which of course make up the majority of Scotland's business base.

6.38 The suppliers mentioned by RBS and HBoS during the consultations for this paper, were large global companies (IBM, HP, Microsoft, CISCO). These companies have a presence in Scotland, but it is likely that much of their R&D activities take place elsewhere. This is a subject that would merit further investigation.

Links with the Scottish research base

6.39 None of the consultees in banks involved in the research for this paper have had any contact with the Scottish research base, although they did not rule out the possibility that colleagues may have had prior contact. However, they did not view such contact as essential for their activities. The reason for this probably stems from the fact that they view in-house innovation as driven primarily by customer service rather than technology.

6.40 The major banks do spend a lot of time and money on keeping abreast of customer demand. They commission research from external consultants on market trends and customer requirements. Furthermore, they are willing to commission research from universities on customer behaviour and cognitive psychology. However, it is only if they identify the need for a service innovation that requires the use of some new form of technology that this becomes an issue. At that point, they will assess whether this can be handled in-house and only if not do they then approach their usual technology suppliers. Thus their innovation work is demand rather than supply driven.

6.41 Understanding more fully the links between the Scottish science base and technology suppliers to the financial services sector would be useful. This would involve consulting with relevant university departments in Scotland and with both Scottish and global technology suppliers to see what links there are, and if and how university research is being converted into marketable products of use to the Scottish financial services industry and its supplier base. Ascertaining the extent to which high tech spin-outs from Scottish universities become suppliers to the financial services industry would also be helpful. Review of international best practice on public sector support for financial services innovation would be useful.

6.42 The following provides a preliminary view only of these matters.

[49] Financial Services Supply Network: Giraffe Consulting (Jan 2006)

Financial services R&D and innovation: market players and international comparisons

The banks

6.43 Following on from the consultations held with the innovation departments of the leading two Scottish banks, further interviews were conducted with members of the banks' technology divisions. These yielded similar results, i.e. the banks' preference for tried-and-tested technology and suppliers. Scale and reliability are key requirements. The importance of the first of these two factors leads to the use of large global suppliers: neither bank pursues a 'buy Scottish' policy.

Scotland based suppliers

6.44 However, despite these comments made by the banks, the situation for Scotland-based suppliers, both small and large, is a more positive one.

Example 1: Ecebs

6.45 Founded in 2000, Ecebs is an independent specialist smartcard software company based in East Kilbride. RBS is a major customer and the two entities are partners in the ITSO (Integrated Transport Smartcard Organisation) consortium, an initiative to turn the London Transport Oyster Smartcard into an 'open system' capable of a wider set of applications. Ecebs has won the contract from the Department for Transport to develop the cryptographic software and RBS will act as guardian of the security keys.

6.46 Ecebs undertakes 80-90% of its own R&D but has developed a close link with Glasgow Caledonian University through a Knowledge Transfer Partnership (KTP). The arrangement was brokered by the West of Scotland KTP Advisor who heard of Ecebs through the Local Enterprise Company. Ecebs found the process very straightforward and used the KTP structure to sponsor research at Glasgow Caledonian on the use of biometrics as a more sophisticated smartcard security system than chip-and-pin. Ecebs was so pleased with the outcome of the KTP that it is now looking at ways to expand the relationship with Glasgow Caledonian.

Example 2: NCR Financial Solutions Ltd

6.47 At the other end of the size range is NCR, a US$7 billion global market leader active in 130 countries worldwide. NCR has had a significant presence in Dundee since just after World War Two. In fact it was the speed with which the Scottish market responded to the advent of the ATM in the late 1970s that led to NCR's decision to base its global R&D centre for financial services in Dundee.

6.48 Its size and global reach means that NCR has strong vendor relationships with all the banks based in Scotland. NCR undertakes joint research projects with these banks, extending from early brainstorming sessions through to advanced proof of concept testing both in its labs and in the field in banks' branches in Scotland.

6.49 NCR has a wide ranging set of relationships with Scottish universities:

- a regular summer intern programme with its local universities i.e. Dundee, Abertay and St Andrews. Where it can be aligned with their degree course, students may also be offered ongoing part-time work (8 hours per week)
- NCR funds research at the Robert Gordon University. This is a high level, multi-year project and has already led to a spin-out from NCR in security technology
- NCR funds eight PhD students undertaking relevant research at Scottish universities (at Abertay, Glasgow and Napier). NCR staff act as 'industrial supervisors' and are actively involved in the research as it progresses.

6.50 NCR clearly cherishes its university connections and has a strong commitment to making them work. Its extensive experience in this area has led the consultee to make the following observations:

- universities need more familiarity with the processes of modern business, particularly the time pressures under which commercial entities operate
- universities need a more mature attitude towards IP
- it is better for companies to develop long term relationships with a few professors/faculties they know and trust. As NCR has found for example with Glasgow University, such collaborations can go from strength to strength over time
- universities need to undertake joint projects for the right reasons. They need to appreciate what both sides will achieve through the process, rather than seeing commercial links simply as a source of research funding for personal interest projects
- the Scottish innovation support system is too crowded. There are too many schemes and entities, often appearing to compete with each other. The consultee would like to see greater clarity and simplification.

Links with the research-base

6.51 As the examples above show, there is a fair level of financial services R&D interaction taking place between the technology vendors in Scotland and the various universities. However, there is considerable scope to do more. A prime example of this is the University of Edinburgh's School of Informatics.

6.52 The School has recently appointing a new Director of Commercialisation and is designating three floors of a building as commercial interaction space. The School has existing links with the major pharmaceutical and IT companies, but has so far not focussed on the financial services industry (the reason being the banks' perceived preference for working with vendors on technological developments). There are however, plans to change this as it is appreciated that that the School has unique and relevant specialisms to offer.

6.53 Opportunities are likely to occur in two areas in the immediate future:

- *Internet security* – the School's theoretical computer science team is working on ways of verifying web downloads in a different and innovative manner to that used at present. This work is being pursued through the relevant Intermediary Technology Institute and includes contacts with representatives from the major banks

- *Derivatives modelling* – this requires a combination of high level computing and mathematical skills. Work done by the School has recently led to the formation of a spin-out company specialising in this area.

International comparisons

6.54 Examples of university involvement with the financial services sector in Boston, London and Toronto are summarised below.

USA – MIT Laboratory for Financial Engineering (LFE)

6.55 MIT's LFE is an example of an advanced collaboration between academia and the financial services industry. It demonstrates what might be achievable in the Scottish context.

6.56 As its website states[50], the LFE is an MIT research centre created as a partnership between academia and industry, designed to support and promote research in financial engineering and computational finance. The principal focus of the LFE is the quantitative analysis of financial markets using mathematical, statistical and computational models. Research projects are grouped into three areas:

- *Capital markets* – focussing on the mainstream of financial engineering: the pricing and hedging of financial securities, the determinants of capital market equilibrium and the empirical and econometric analysis of financial market data

- *Risk management* – focussing on the entire spectrum of issues surrounding the process of rational decision making under risk

- *Financial technology* – focussing on various methodological aspects of financial engineering: mathematical, statistical, computational and visual

6.57 The LFE has a number of high profile sponsors from the financial services and related industries: Credit Suisse First Boston, Gifford Fong Associates, Investment Technology Group, Merrill Lynch & Co and Reuters Holdings PLC. Sponsors benefit from unique and timely access to state-of-the-art research in financial engineering as well as broad exposure to leading faculty members and students through LFE conferences, campus visits and specific project-related collaborations.

6.58 The LFE model is one that the Scottish research-base may wish to consider if it decides to pursue stronger links with the financial services industry.

[50] http://lfe.mit.edu/about/intro.htm

City of London – Cass Business School

6.59 The Cass Business School, which forms part of City University, lies in the heart of the City of London. As a result it is well attuned to the needs of the financial services industry. Its website[51] has a link through to its services for business and, given its geographical location, the main business collaborations are with the financial services and related industry.

6.60 In addition to tailored executive education in the financial services field, there is the opportunity to commission research in the key areas of finance, management and actuarial science. Recent topics include: new market mechanisms for risk management in the agricultural sector for the Futures and Options Association; a review of SETS (the London Stock Exchange's trading service for UK blue chip securities) for Plus Markets Group (equity traders); a review and validation of the Nationwide Building Society life model of economic capital for Nationwide.

6.61 Cass also has a set of research centres focussing on specific areas of financial services activity. These include: the Alternative Investment Research Centre, the Centre for Research on European Financial Markets and Institutions, the Emerging Markets Group and the Risk Institute. In each case, there are regular workshops and conferences to test ideas in front of an audience of market practitioners.

Canada – Rotman Centre for Finance[52]

6.62 Established in 1998, the Centre for Finance is a research and teaching centre at the Rotman School of Management, part of the University of Toronto. Areas of research include: financial engineering, financial economics, corporate financial management, investment management and financial institution management. The Centre is active in building links with the financial community in Toronto through a series of seminars, workshops and conferences. These networks are strengthened by the large percentage of Rotman MBAs who go on to work in the financial services field in Canada.

6.63 Another centre of excellence within Rotman is the Capital Markets Institute (CMI), set up in the same year as the Centre for Finance as a result of a C$750,000 donation from the Toronto Stock Exchange. The aim of CMI research is to assist policy makers in dealing with issues that are of current interest to capital markets participants. The CMI encourages broad participation by academics, market participants, regulators and legislators in the design, execution and presentation of its research programmes through roundtable discussions, informal meetings and presentations of work in progress, as well as articles in both academic and practitioner journals and joint industry-academic conferences.

[51] http://www.cass.city.ac.uk/
[52] http://www.rotman.utoronto.ca/finance/centre/

Key issues

6.64 At present, Scottish financial institutions and the research base appear to prefer to work with each other through the intermediary filter of the vendor market. There are examples of effective links on either side of this arrangement where the research base appears to be serving its technology industry customers (both large and small) well. However, as the international comparisons show, academia and financial institutions in Scotland would appear to be missing a trick. It is likely that the contribution of the research base to innovation in financial institutions would be much richer and more immediate if the contacts were more direct.

6.65 Whilst improvements in retail banking services may be large-kit technology driven, the more intangible improvements in risk management, for instance, require collaboration across a range of academic disciplines (mathematics, computing, cognitive science). This is the area where there could with benefit be a more joined-up approach both within the research base and with the market. The excellence in informatics research within Scotland would appear to possess the necessary capacity and capabilities to deliver significant value to the industry. Current developments to strengthen commercialisation capability will be important in ensuring its unique selling points can be promoted and exploited in the context of a more open stance towards innovation.

7: Constraints on R&D growth in Scotland

7.1 This Paper considers a number of hypotheses concerning potential constraints on the growth of R&D in Scotland. It reviews in particular three potential constraints on R&D.

'Growth in business R&D is constrained by a dearth of good project managers'

7.2 The importance of effective management skills has been stressed by The Scottish Council for Development and Industry (SCDI), which considers it crucial that Scottish business leaders '*have the knowledge and insights to make key decisions on investment, R&D innovation and employee development*'[53].

7.3 The SCDI considers that an understanding of the importance of R&D needs to be instilled at an early age. They consider that the Government needs to ensure that basic education promotes an interest in science and technology in order to produce a pool of skilled young people from which employers can draw.

7.4 Although such skills may exist in larger companies, the same does not appear to be the case in SMEs. A recent report on the Scottish Innovation System (SIS)[54] stated that '*A very consistent picture was drawn of the relative thinness of the SME sector in Scotland in terms of scientific and managerial competence, and the lack of absorptive capacity in the sector to make use of the (often world class) research being carried out in Scottish universities*'.

7.5 This perception may colour Scottish HEIs' willingness to deal with SMEs as they do not consider them for example as good vehicles for licensing activity - a significant channel for the commercialisation of the publicly-funded Scottish research base. This perceived impediment to commercialisation via existing companies is in contrast to the SIS report's findings that the Scottish HEIs perform well in commercialisation activity generally: most of this activity, however, is geared towards a sophisticated worldwide community of science users, relatively few of which are said to be found among indigenous enterprises in Scotland, or alternatively focused on new firm formation.

7.6 The Scottish Executive and Scottish Enterprise have developed a range of initiatives to improve knowledge transfer and R&D commercialisation. However, the SIS report held that whilst a number of funding initiatives were highly regarded, the market felt that the poor absorptive capacity of SMEs needed to be addressed more fundamentally before the relevant initiatives could be effective. (However, as indicated earlier, an analysis of the Third Community Innovation Survey implies at

[53] Evidence to the Business Growth Enquiry by the Scottish Parliament Enterprise and Culture Committee: SCDI (April 2004)
[54] Roper et al (2006) ibid.

the very least that the issue of *absorptive capacity* in the Scottish business base requires closer inspection.)

7.7 The problem is not a purely Scottish one. The Council for Science and Technology (CST)[55] found that '*many UK technology based businesses, both large and small, are finding it increasingly hard to find top quality, highly qualified people with CVs bridging the two worlds of business and research to fill senior positions*'. The CST favour the US approach where trained scientists spend time after their postgraduate or post-doctoral studies working in a commercial environment. Whether they end up in senior posts in HEIs or companies, they develop an in-depth understanding of both environments.

'Growth is constrained by a dearth of risk-taking leaders at company level'

7.8 The recent report by DTZ Pieda for the Scottish Executive on Scottish Business Attitudes to Research Development and Innovation[56] found that amongst the 30 companies it used as case studies, "risk" was an important factor in the decision as to whether or not to undertake R&D. The relevant risk factors depended on the type of company.

7.9 University spinouts and other companies that have been set up to undertake high risk but high return research tend to have high R&D cost requirements, sometimes with long lead times to a return on investment and with no guarantee of success. Traditional manufacturers on the other hand tend to undertake R&D in the context of particular customer requirements, as this is relatively lower risk (the importance of "demanding customers" here is evident as a driver of innovation, as indicated by the seminal work by Michael Porter on successful clusters). Where companies base R&D activity on a perceived market gap, this is higher risk but can be managed by focusing on markets where returns are likely to be greatest and where demand has been found to exist.

7.10 From this it is apparent that not only sectoral differences impact business performance with respect to R&D spend, but also the origins and business models adopted by firms. Exploring the R&D issues for a segmented business base rather than searching for the "silver bullet" seems the way to proceed.

7.11 The importance of risk was also brought out in the SIS report[57]. This found that '*factors limiting R&D and innovation activity tended to be market related – linked to risk returns and opportunities rather than input availability*' This suggested that the structural characteristics of the firm – sector, size, ownership and previous R&D experience – were the main determinants of R&D activity.

7.12 Scottish Executive programmes such as SMART and SPUR seek to mitigate some of the financial risk of undertaking R&D by providing matched funding for technology

[55] Council for Science and Technology (2002) Technology Matters
[56] DTZ Pieda (2005) ibid.
[57] Roper et al (2006) ibid.

development. As one company quoted in the SIS report put it: '*SMART and SPUR have been good for us and have given us real ability to punch above our weight. Even big companies find it hard to pick winners – these schemes allow small companies to have a portfolio of technologies – this type of incremental investment is very important in facilitating a firm's growth rather than stagnation*'.

'Growth is constrained by limited growth of companies to the size needed to support R&D activities'

7.13 In considering this hypothesis, care needs to be taken over meaning: as the DTZ Pieda report found, '*size is not a significant variable; both large and small companies are as likely to be involved in innovative behaviour*'. The BERD Report for 2003[58] shows that of the 764 Scottish companies undertaking R&D, 575 had less than 100 employees. Larger companies, however, account for the largest part of R&D spending. In 2003, firms with over 400 employees undertook 66% of all Scottish R&D but this was a lower percentage than in the UK as a whole (74%).

7.14 The DTZ Pieda survey[59] asked how small companies not currently undertaking R&D might be encouraged to do so. Two key suggestions arose:

- improve the performance of the business – through business information and advice
- training – since many non-R&D companies appear not to have the expertise required to undertake R&D/innovative behaviour.

Other constraints - finance

7.15 Access to finance is highlighted as a key issue in the literature. The CST's 'Technology Matters' report[60] states: '*the ability to access the appropriate level and type of finance is one of the main factors influencing the performance and growth of technology based businesses*'. Likewise, the DTZ Pieda report identified accessing external funds as being the major difficulty perceived by Scottish companies undertaking R&D (mentioned by 88% of those surveyed).

7.16 The Scottish Executive and Scottish Enterprise have developed an extensive range of programmes to address the finance issue. The DTZ Pieda report notes that companies found public sector grant assistance effective, especially small companies, advanced manufacturers and those in R&D services. However, loans were preferred by a quarter of small companies due to the simpler paperwork.

[58] Business Enterprise research and Development in Scotland 2003: The Scottish Executive (Sept 2005)
[59] DTZ Pieda (2005) ibid.
[60] CST (2002) ibid.

8: Profile of public support for business R&D in Scotland

8.1 Across the UK, the public sector is aiming to encourage increased levels of private sector R&D through direct financial support and through encouraging closer links with the publicly funded research base. Support available to Scottish companies in respect of both these types of intervention is explored below.

Financial support for industry R&D

8.2 The Scottish Executive operates a number of R&D funding schemes for Scotland-based companies or companies looking to locate in Scotland. It offers a progression of public sector funding schemes in what is referred to as a "pipeline of support".

SMART

8.3 SMART:Scotland[61] provides 75% funding of the cost of a technical and commercial feasibility study (6 and 18 months) up to a maximum of £50,000, and is open to companies with less than 50 employees. Follow-on funding is available through SPUR (which incorporates what was previously SMART Stage 2).

8.4 The ratio of SMART applicants is 1 to 3 or 4 in terms of academic-derived companies to others. SMART take-up is equally split between science base derived and other companies.

8.5 Scottish Universities have a strong track record of creating companies that go on to win SMART:Scotland awards; for example, University of Edinburgh spin-outs and start-ups have won 36 awards overall, including 5 in 2004-05[62]. Academic spin-outs tend to be better prepared when applying to SMART. Evidence indicates that projects that have previously received Proof of Concept (PoC) or PoC Plus funding from Scottish Enterprise are well prepared – PoC appears to be helpful in getting applicants to SMART investment readiness.

8.6 SMART is designed to support leading edge technology. Companies bidding unsuccessfully for SMART often fail because they are not engaged in leading edge technology. The argument is made that they should be applying to the Small Company Innovation Support (SCIS) scheme instead (see below).

8.7 It appears that angel investors will often become "interested" in business propositions at the stage of SMART awards.

[61] http://www.scotland.gov.uk/Topics/Business-Industry/support/16879/6782
[62] www.research-innovation.ed.ac.uk/company/smart.asp

SPUR and SPUR PLUS

8.8 SPUR[63] grants assist SMEs (up to 250 employees) to develop new products and processes up to pre-production prototype stage. Projects are between six months and three years duration, and funding covers 35% of eligible costs, up to a maximum grant of £150,000. Eligible project costs must be at least £75,000.

8.9 SPUR+ [64] funds SMEs for 35% of eligible costs up to £500,000, where total eligible costs are at least £1 million. Similar to SPUR, this programme supports development of new products or processes, up to pre-production prototype stage.

8.10 Demand for these three schemes is reported to be high and increasing year-on-year[65]. The total number and total value of funding offers made over the last four years are shown in the table below (figures for 2005-06 cover quarters one to three only).

Table 8-1 Number and value (£000's) of funding offers made under SMART, SPUR and SPUR+, 2002-2006

	2002-03		**2003-04**		**2004-05**		**2005-06**	
	Number	**Sum**	**Number**	**Sum**	**Number**	**Sum**	**Number**	**Sum**
SMART	40	£1,753	38	£1,796	52	£2,538	29	£1,432
SMART2	9	£859	2	£105				
SPUR	5	£607	16	£2,129	22	£2,501	13	£1,668
SPUR+	6	£2,567	14	£6,639	4	£1,730	4	£1,816

8.11 As indicated below, the average value of SPUR and SPUR+ awards fell in 2004-05, but is again showing an increase on average in the first three quarters of 2005-06. The table also shows that the average value of SMART awards has increased by 11% over the four year period documented

Table 8-2 Average award value (£000's):

	2002-03	**2003-04**	**2004-05**	**2005-06**
SMART	£44	£47	£49	£49
SMART2	£95	£52		
SPUR	£121	£133	£114	£128
SPUR+	£428	£474	£432	£454

8.12 An independent evaluation of SMART, SPUR and SPUR+ in 2002[66] concluded that these schemes are '*generally effective in relation to objectives*' and that they have '*genuinely encouraged technological innovation in SMEs*'. Helping companies to innovate through these schemes has not only helped them make a market impact

[63] http://www.scotland.gov.uk/Topics/Business-Industry/support/16879/6783
[64] http://www.scotland.gov.uk/Topics/Business-Industry/support/16879/6953
[65] www.scottishscience.org.uk/main_files/pdf/Presentations/Ian_Howie_Nov_05.pdf
[66] Evaluation of SMART: The impact in Scotland. PACEC (2002)

(over 80% of projects resulted in new or improved products, services or processes reaching market), but assisted with the overall company development (more than 50% increased overall company value as a result). The schemes were also felt to address a distinct market failure in the supply of finance to SMEs, and thus their effects were largely found to be additional.

8.13 However, the evaluation did identify scope for increasing the aggregate benefit of the schemes through an increase in scale and market penetration, and through improving integration with the wider business support infrastructure.

8.14 In terms of the companies successfully applying for awards under SMART, SPUR and SPUR+, a significant minority in the four years leading up to the evaluation (20%) had originally spun out from a university or college. Following the award, almost 50% of companies sought further finance to enable marketing of project outputs, and most of these were wholly or largely successful: the majority of these beneficiaries thought that being an award winner made it easier to obtain further support. Of the firms that sought further finance, half of these applied for another public sector grant (two thirds applied for another SMART or a SPUR award).

SCIS

8.15 The **Small Company Innovation Support** (SCIS)[67] is a single-company R&D scheme managed through local enterprise companies. It provides funding for development and introduction of new products and processes. Little information was found initially on this scheme in the public domain – it appears to have a fairly low profile - but with the assistance of a consultee in Scottish Enterprise a fuller account of SCIS has been prepared.

8.16 SCIS is a discretionary, single company grant of up to £50,000 total assistance. Funding is available for three distinct phases of activity. Phase 1, Market Research (MR) and Phase 3, Market Launch (ML) activities provide a combined maximum of up to £25,000, at up to 50% of eligible costs. Phase 2 is the development (or R&D) phase of the new product or process, and provides a maximum of up to £25,000, at up to 35% of eligible costs.

8.17 SCIS aims to:

- increase levels of innovation in SMEs through stimulating and increasing the levels of spend by businesses on the research and development of new products and processes
- build good product development practice within supported SMEs by ensuring that consideration and possible support is given to Market Research, Product Development and Product Launch. In this way, SCIS is seen as distinct from other forms of support, as it provides a full support framework for single company R&D projects spanning initiation (initial idea); through research and development; to the

[67] http://www.scottish-enterprise.com/publications/scis.pdf

exploitation of the product/process, through supporting the preparations for market launch of the product

- improve competitiveness of those firms from undertaking R&D.

8.18 Scottish Enterprise as a whole spends some £2m a year on SCIS. This typically amounts to some 100 companies per year receiving aid under the Scheme. In 2005-2006, 97 companies received support and £2.17m of funding was committed.

8.19 In terms of the total commitment (i.e. £2.17m = 100%), for year 05/06 the distribution of funds was as follows: Market Research = 7.5%, R&D = 72%, Market Launch = 20.5%. Companies can obtain support for all three components of the scheme, or two, or just one.

8.20 One key difference between SCIS and Smart/SPUR is the level of innovation required: SCIS is looking for innovation at the company level i.e. new to the company as opposed to new to the country/world. The majority of projects are primarily associated with product development rather than with the development and implementation of new processes.

8.21 The SCIS product is regarded as best suited to companies undertaking technical development and this is reflected in the companies utilising the product - manufacturing companies and product owning, technical companies. It is not geared to service companies i.e. the tourism and financial services industries. This could be seen as a weakness of SCIS given the structure of the Scottish business base.

8.22 SCIS has been limited to SMEs of up to 100 employees. This was revised for 2006-07 to allow applications from companies that have up to 249 employees and who meet the other European Commission's conditions for SME eligibility. With the introduction of the R&D Plus scheme for large companies there was seen to be a gap in Scottish Enterprise support provision for firms of between 100 -249 employees which has now been addressed.

8.23 SCIS operates within the wider innovation support provided by the SE Network. Innovation support from the Network generally (including SCIS) is discretionary. As SCIS is operated by each Local Enterprise Company (LEC), companies wishing support for product development would contact their LEC to discuss requirements and intended projects, either through their client or account manager where an existing relationship exists or via the Led's innovation practitioner/contact.

8.24 The Network tends not to market the SCIS scheme widely: rather it responds to enquiries to the LEC about general product development and innovation support. Companies are then directed to SCIS where appropriate. Promotion by the LECs tends to be focused on the need for companies to innovate. Staff involved with the Business Gateway would be aware of SCIS as one of many "products" that support innovation within the wider Network offering and where appropriate would direct enquiries to the innovation contact in the LEC. Where a relationship exists between client and the LEC, the client or account manager would handle the enquiry.

8.25 Each Local Enterprise Company will have an innovation specialist or an individual responsible for innovation in its area. All are full time members of staff: in addition some Local Enterprise Companies will have part-time innovation staff or specialist 'innovation' contractors working for them to provide support to meet clients' innovation needs.

8.26 The average size of Award for SCIS in 2005-06 was £22,391. Projects are of typically 6-9 months long but can take up to a year to 18 months to complete.

8.27 Looking at the last 20 SCIS awards in 2005-06 as an example, eligible R&D project costs (project size) varied from £16,962 (smallest) to £312,500. Numbers and types of projects vary between areas, with Edinburgh, Glasgow Grampian, Fife and Lanarkshire supporting more projects than some of the smaller or more rural LECs. LEC innovation promotion activities/events also have an impact on the pipeline of SCIS projects coming through from each LEC. This stream can take from 3 months to a year as potential projects are planned/considered/worked up by companies in conjunction with their LEC.

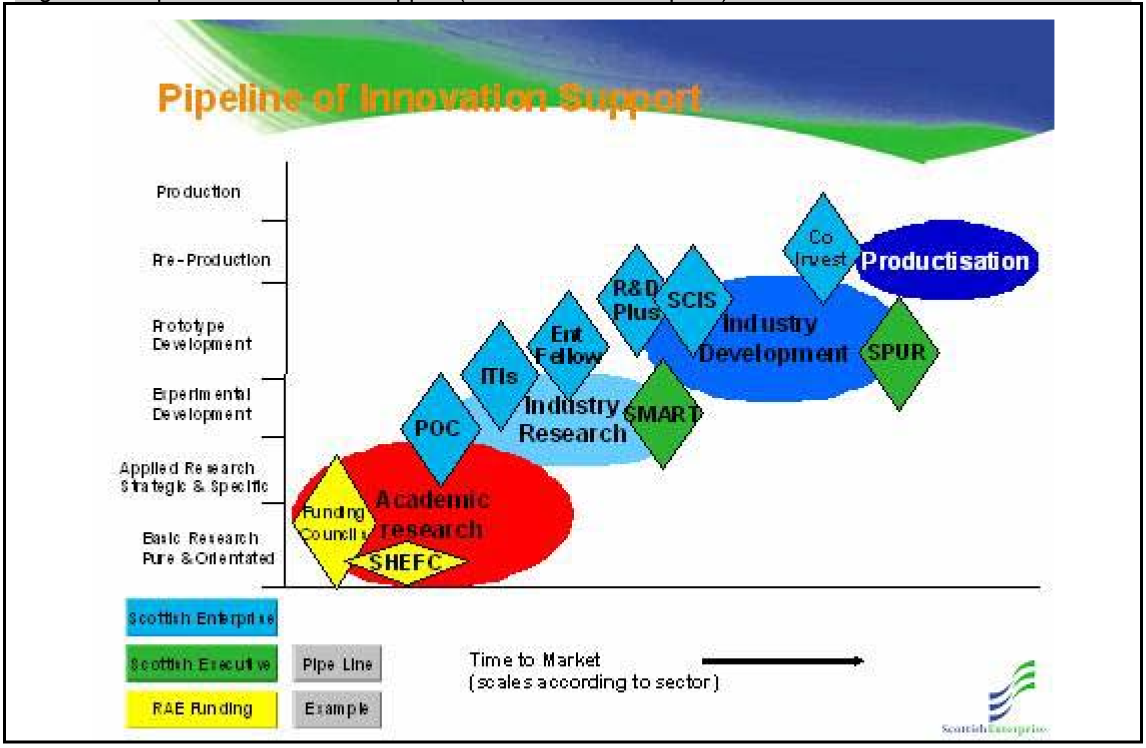
8.28 An analysis of 110 SCIS projects gives the following distribution with respect to business/technology categories:

- 801 Manufacturing Technology 17
- 802 Materials technology 13
- 803 Information Technology 38
- 804 Biotechnology 13
- 805 Environmental Technology 3
- 806 Communications 6
- 807 Instrumentation and Control 7
- 810 Separation techniques 1
- 812 Medical technology 2
- 813 Other 10

8.29 Increasing trends in types of companies utilising SCIS include ones in the creative industries sector in Tayside and software companies.

8.30 The slide below is one representation of the pipeline of innovation support in Scotland showing SE's view of the positioning of SCIS in relation to other forms of support.

Figure 8-1 Pipeline of innovation support (from Scottish Enterprise)



8.31 SCIS appears to be an important part of the pipeline of business R&D support. However, it seems to have a relatively low profile and to attract quite a narrow range of companies and projects – product not process development projects, and manufacturing and technology-based product companies. The recent trend towards an increased uptake by businesses in the creative industries and software sectors provides an indication of its wider relevance.

8.32 The public profile of SCIS should be enhanced. It would be useful to learn more about the trends in supply and demand for SCIS over recent years.

Innovation counseling

8.33 Support is available to Scottish firms from ICASS (Innovator's Counselling and Advisory Service for Scotland, http://www.icass.co.uk). It is understood that the service is open to academics looking to set up a business, but appears to be under-utilised by this group.

R&D Plus

8.34 R&D Plus[68] provides support for large companies located within Scotland, or who are planning to establish within Scotland. Grants of up to 25% of costs are available, to undertake industrial research or pre-competitive development.

[68] http://www.scottish-enterprise.com/publications/r_d_plus.pdf

Intermediary Technology Institutes (ITIs)

8.35 The three ITIs (Techmedia, Life Sciences and Energy) are funded by Scottish Enterprise, and have a budget of £450 million over ten years. Their aim is to 'bridge the gap between publicly-funded early stage research and privately-backed commercial development'. This is to be done through commissioning market-focused pre-commercial research projects and by publishing market intelligence and market foresighting reports.

8.36 Each ITI is a membership-based organisation, with 230 members joining during 2004-05, the first year of operation[69]. These included all the Scottish universities and 87 companies (from a target of 65). Eleven R&D programmes were launched during 2004-05, with over half of the programme participants (21) being Scottish companies.

Table 8-3 Outcomes of ITIs 2004-05

	R&D programmes	Participants	Scottish participants	Members
ITI Energy	3	6	2 SMEs 2 Universities	77
ITI Life Sciences	4	16	4 companies 1 University 1 start-up	70
ITI Techmedia	2	15	6 companies 2 Universities	64

8.37 A total of seventeen R&D programmes are now active; seven in ITI Energy, four in ITI Life Sciences, and 6 in ITI Techmedia.

8.38 The view of the ITIs is that for the level of BERD to increase in Scotland, a long term flexible approach to R&D is essential. This has led ITIs to take a long term strategic approach (albeit with annual accountability of performance)[70].

Developing links between the private sector and the research base in Scotland

8.39 In contrast to industrial R&D where Scotland carried out 3.8% of the UK total in 2003, Scotland performs much more strongly on measures of public sector research activity. Over the same period, 13.5% of UK research in government establishments, and 12.9% of all University research was undertaken in Scotland[71]. Given that the recent Lambert report stated that the biggest single challenge to university-business interactions lies in boosting business demand for research[72], the key for Scotland would seem to lie in maximising the depth and breadth of these interactions as the

[69] A year of progress: Annual report 2004/05. ITI Scotland Limited (2005)
[70] Submission from ITI Scotland Limited to the Enterprise and Culture Committee: Business Growth Inquiry, September 2005
[71] Business Enterprise Research and Development in Scotland 2003. A National Statistics publication by the Scottish Executive, September 2005
[72] Lambert review of business-university collaboration. R Lambert (2003), HMSO

public sector research base would already seem to be in a position of strength. There are several sources of public sector support for facilitating university-business interactions in Scotland.

8.40 **SCORE**[73] supports R&D projects jointly undertaken between public sector research bodies and Scottish SMEs. Financial support is available at 50% eligible project costs, up to a maximum of £35,000 per project. The key objectives of SCORE are to increase the competitiveness of SMEs through support for product or process development; to encourage increased co-operation between enterprises and research organisations; to help effect wealth creation from the science base; and to provide a framework for collaborative research projects involving SMEs across a wide range of sectors. Between March 2004 and April 2005, 10 projects were funded[74]; nine of these were between a single company and a single HEI, with one between a single company and two HEIs. The average grant size of these projects was £31.5K, with projects running for between six and eighteen months. A further eight projects have been funded since April 2005.

8.41 **SEEKIT**[75] is designed to build university infrastructure for facilitation of R&D co-operation and knowledge transfer between Scottish universities and Scottish SMEs. The key objectives of the programme are to help effect wealth creation from the science base; to increase the competitiveness of SMEs through their engagement with the science base; and to encourage productive knowledge transfer links between business and the science base. Between July 2004 and October 2005, 13 grants were awarded, with an average size of £286K, from a total of £3,716,498[76]. The direct beneficiaries of the funding were eight Scottish HEIs and the Scottish Optoelectronics Association, with the universities of Stirling and Strathclyde receiving two and three awards respectively. Of course, it is assumed that the main beneficiaries of the funding as projects are developed will be Scottish SMEs.

UK-wide schemes

R&D Tax Credits

8.42 Other financial support for business R&D available in Scotland includes R&D Tax Credits[77], introduced by the UK Government in April 2000 as a company tax relief allowing companies to deduct up to 150% of qualifying expenditure on R&D activities when calculating their profit for tax purposes. They were initially introduced for SMEs, and extended to larger companies in April 2002. The scheme is run on a UK-wide basis by HM Revenue & Customs, and is being amended to increase uptake[78].

[73] http://www.scotland.gov.uk/Topics/Business-Industry/support/16879/14115
[74] http://www.scotland.gov.uk/Resource/Doc/980/0019419.pdf
[75] http://www.scotland.gov.uk/Topics/Business-Industry/support/16879/14127
[76] http://www.scotland.gov.uk/Resource/Doc/980/0019420.pdf
[77] http://www.hmrc.gov.uk/randd/index.htm
[78] Supporting growth in innovation: next steps for the R&D tax credit (2005). HM Treasury & HM Revenue and Customs

8.43 Recent research into the uptake of R&D Tax Credits across the UK by Deloitte[79] indicates that less than half of eligible smaller firms are taking advantage of R&D tax relief. Also, of those failing to claim, a quarter indicated that they were unaware that the scheme existed.

8.44 Given the importance accorded to enhancing business R&D performance in Scotland and the policy intention that R&D Tax Credits should act as a substantial incentive for firms to undertake R&D, the status of uptake amongst the Scottish business base should be reviewed.

Knowledge Transfer Partnerships

8.45 Other collaborative R&D funding schemes and innovation support includes Knowledge Transfer Partnerships (KTPs). This scheme aims to '*strengthen the competitiveness and wealth creation of the UK by the stimulation of innovation in business through collaborative partnerships with the UK knowledge base*'. The regional breakdown of current KTPs is shown below[80]:

Table 8-4

Region	Number	%
East of England	61	6
East Midlands	76	7
London	81	8
North East England	39	4
Northern Ireland	64	6
North West England	95	9
Scotland	110	11
South East England	126	12
South West England	101	10
Wales	100	10
West Midlands	110	11
Yorkshire and Humber	83	8

8.46 A further 82 KTPs have been completed, with nine of these having a Scottish commercial partner.

[79] Deloitte (2006) Missing the boat? R&D tax incentives – SMEs fail to optimise.
[80] http://www.ktponline.org.uk/

Small Business Research Initiative

8.47 In the March 2005 Budget Speech[81], it was proposed to stimulate small technology intensive companies with a guaranteed £100 million share of public sector research contracts. A new mandatory target has been set for Government departments and agencies to place 2.5 per cent of their extra-mural R&D contracts with small- and medium-sized enterprises (SMEs), under the Small Business Research Initiative (SBRI). Spend by UK Government departments and Research Councils to date can be found at http://www.sbri.org.uk/rdfigures.doc .

8.48 The SBRI aims -

- to provide opportunities to those existing small firms whose businesses are based upon providing R&D - by increasing the size of the market
- to encourage other smaller businesses to increase their R&D capabilities and capacity - to exploit the new market opportunities
- to create opportunities for starting new technology-based or knowledge-based businesses.

8.49 We have not been able to identify levels of take up by firms in Scotland.

European Framework Programmes

8.50 The EU Framework 6 Programme[82] is a €17.5 billion research and development programme, offering substantial grants to part fund many different types of projects, in many industries and across many market sectors. Projects all relate in some way to the development of novel technological solutions that can be exploited in the form of new competitive products, processes or services, and tend to have a time to market of 24-48 months. Most are collaborative in nature, and encourage European organisations and companies to pool their resources and expertise to drive technology forward faster, whether through R&D or demonstration.

8.51 Access to EU FP6 in Scotland is supported by the Innovation Relay Centres[83] using a network of locally-based advisors. The **Scottish Proposal Assistance Fund** provides funding to help applicants meet some of the costs of developing a FP6 project proposal**,** and aims to increase the number of successful FP6 proposals from Scotland.

A business perspective

8.52 On a UK level, an analysis of the results from the latest UK Community Innovation Survey (CIS-3) suggests that overall access to technology is not amongst the most significant impediments to innovation in firms. Other factors (market conditions, lack

[81] (see http://www.hmtreasury.gov.uk/budget/budget_05/bud_bud05_speech.cfm)

[82]http://www.scottish-enterprise.com/sedotcom_home/services-to-business/ideas-and-innovation/innovation_ec_framework_6_programme.htm

[83] http://www.ircscotland.net/about_irc/overview.cfm

of ambition, access to finance, and the quality of demand) have a greater role in explaining company innovation performance.

8.53 However, there is evidence that as a firm's own commitment to innovation increases, so does the extent to which it engages the science base in innovation activities.

8.54 There is also evidence that indirect links between the science base and industry are more important than direct links[84]. Data from CIS-3 found that only 1.4% of UK firms with more than 10 employees regarded universities as sources of information of high importance for their innovation activities, and only 0.4% gave this status to government research organisations. One percent of firms reported collaborative arrangements for innovation with a government research organisation, and less than 3% with a university. Inability to access the science base was not reported as a major impediment to innovation.

8.55 This finding has implications for the design of interventions to assist Scottish companies gain value from the research conducted by the Scottish science base in universities. The role of intermediaries – brokers, "translators" and commercial R&D performers - may require closer attention.

[84] Tether, BS and GMP Swann, GMP (2003) Sourcing science - the use by industry of the science base for innovation: evidence from the UK's innovation survey.

9: Funding "foodchains" and "pipelines" in Scotland

Private sector equity investment in Scotland: current profile

9.1 In 2004, 150 recent start-ups and spin-outs in Scotland received risk capital investment (Don and Harrison[85]). The same publication documented a 40% increase in investment activity in young Scottish companies between 2003 and 2004, with investment in 2004 of £170 million. Of this £170 million, 71% was accounted for by institutions (defined in the report as venture capital companies and other financial corporations). Business angel (BA) investment stood at £34 million, up 70% from 2003, with Scottish-based BAs accounting for £26 million of the total.

Business angels

9.2 Angel investment has been a growing segment of the risk capital market in Scotland over the past five years, accounting for around 27% of all investment over this period (excluding blockbuster deals). An average BA investment package in 2004 was £338K[86]. However, where the BA provided funds as a sole investor, the average package was £179K, whereas when the BA co-invested with another investor it was £475K. The majority of BA deals in 2004 were co-investments with other investors[87] (see below).

9.3 Total BA investment in Scotland in 2004 was more than twice that reported by British Venture Capital Association members as *commitments* to early stage companies, reinforcing other analyses of the angel market that suggest that BAs are the most important funding source for early stage companies across the UK.

9.4 Angel syndicates are a relatively recent development in the private equity market in Scotland, and have increased the range of BA investment size at the upper end. This phenomenon of BAs moving up the 'financial foodchain' has also been documented in the US[88], and tracking of investment activity suggests that the formation of syndicates has been the main driver behind increases in both the number and volume of BA investments in recent years. Around 14 BA syndicates are operating in Scotland today, constituting the majority of current private equity activity. Whilst syndicates do not always have a defined geographic or sectoral focus, most are committed to technology-based companies. There may be some geographic bias: one interviewee in Scotland reported BA investment tilted 3:1 east to west, driven solely by quality and volume of opportunity.

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[85] Don, G. and Harrison, R (2006) The equity risk capital market for young companies in Scotland 2000-2004 Equitas and Queen's University in association with Scottish Enterprise
[86]. Don and Harrison (2006) ibid.
[87] Don and Harrison (2006) ibid.
[88]www.businessweek.com/smallbiz/content/dec2005/sb20051227_049074.htm?link_position=link5&campaign_id=nws_smlbz_Jan4

9.5 Two of the most mature syndicates are Archangels and Braveheart[89]. Braveheart in particular is providing some support at the emerging company end of the spectrum through the Alpha EIS Fund[90], a recent deal with a small number of Scottish universities to invest up to £20K in a minimum of 10 spin-out companies to match up to £50K of SMART funding. However, there is concern in some quarters that the terms and conditions attached to this fund may be unattractive to spin-outs.

Venture capital

9.6 The British Venture Capital Association report for 2004[91] documented total member investment of £14 million in Scottish start ups and early stage companies, and a further £69 million in expansion stage funding. This expansion financing dominated the number as well as the total investment value of all VC transactions. The average value of VC investment in early stage companies was reported to have fallen from £50 million to £10 million since 2001. Interviews conducted as part of the research for this paper also stated a scaling back of VC investment in Scotland, with the majority of investments being made in existing portfolios. This is supported by the finding of the Don and Harrison (2006) report that VC companies appear to have lost interest in new investments in Scotland.

9.7 Scaling back of VC activity is partly a result of, and hangover from, the dotcom bust. Following this, mainstream VCs retreated up the market to invest in existing portfolios, management buy-outs etc., and a number of international VC companies who had opened Scottish offices withdrew. As a result, companies which had already received BA investment and were trying to raise VC-level funding were left in a funding gap, which helped to drive the formation of BA syndicates, although interviewees pointed out that syndicates also formed as a result of the equity market starting to mature in Scotland, which may have been accelerated by the emergent funding gap.

9.8 It is not solely size of investment that differentiates BAs from VCs. BAs are wealthy individuals who are investing their own money, whereas VCs are managing money for clients. As a result, BAs are under no obligation to make investments, nor need to make a living from the process. BAs are also primarily locally based, with the understanding of local markets that this brings. A mature private equity system needs strength and depth in both components.

Recent developments

9.9 With the development of BA syndicates, private sector deal structures have become more complicated: even within a syndicate, BAs may invest not as a single fund but as individuals, so the company acquires more shareholders than if a single fund invested. BAs are also now having to follow initial investments with further funding rounds given the scaling up of VC investment: this then makes companies less

[89] http://www.braveheart-ventures.co.uk/
[90] http://www.braveheart-ventures.co.uk/index.php?option=com_content&task=view&id=93&Itemid=55
[91] British Venture Capital Association (2004) Report on Investment Activity

attractive to VCs demanding preference shares (BAs also resist this as they have taken most of the risk by providing several funding rounds). Companies are forced to continue taking BA investment. This can only go so far and is unlikely to be enough to turn the company into a sustainable, global business. Although a vicious cycle, at the moment there are few other options for early stage companies seeking funding.

9.10 Interviewees reported that there is no lack of available BA funding in the Scottish marketplace, with investors currently spending about 20% of what is available. There is also no lack of demand from companies seeking funding. Rather, it is the quality of demand that needs addressing (see below). This has been compounded by the fact that because BAs have shifted up the foodchain, this has introduced more rigour to the supply side - in a number of cases this has included demands for evidence of revenue streams before gaining a commitment to invest.

Relationship to public sector support

9.11 A number of public sector funds are available to start-ups and spin-outs before they seek private equity investment. Companies are free to apply to these funds a number of times, for example, almost 25% of companies obtaining awards from SMART, SPUR and SPUR+ up to 2002 sought further finance for their project from another public sector grant[92]. However, stand-alone grants can only sustain the early development stages, and in the majority of cases, growing companies will have to seek equity funding at some stage.

Co-investment funding

9.12 Most BA investment in Scotland is now made as a co-investment with public sector support funding. Public sector funds are categorised (along with several other investment vehicles) as ‘hybrids’, combining policy, charitable and/or social aims alongside financial aims. These hybrids operate primarily in the sub £1 million investment space, and are reported to supply the risk capital requirements of an increasing number of new and small companies in Scotland[93]. As such, they are at least partly responsible for increasing the deal flow moving along the capital pipeline, usually funding in partnership with BA investments.

9.13 During 2004, two Scottish Enterprise funding products, the Business Growth Fund (suspended to new investment from 31st March 2006) and the Scottish Co-investment Fund (SCF), accounted for 7% of total monies invested in young Scottish companies, and were represented in 55% of all deals recorded (up from 4% and 44% in 2003).

9.14 Some sources argue that such hybrids[94] (with the Scottish Co-investment Fund cited as a particular example) have helped leverage BA investment. However, others argue

[92] Evaluation of SMART: The impact in Scotland (2002). PACEC
[93] The equity risk capital market for young companies in Scotland 2000-2004 (January 2006). G. Don & R. Harrison, Equitas and Queen’s University in association with Scottish Enterprise
[94] The equity risk capital market for young companies in Scotland 2000-2004 (January 2006). G. Don & R. Harrison, Equitas and Queen’s University in association with Scottish Enterprise

that this is not necessarily the case, and there is sufficient available BA investment in the system anyway. For example, in many BA syndicates the core board (usually 5 or 6 people) will take a lead in an investment, and then offer it to other syndicate members (as many as 90). The syndicate may only approach SCF if there is a funding gap at the end of this process: the best investment opportunities will not have a large gap in most cases, which makes leverage look high on paper, even though it has been driven by the private rather than public sector.

9.15 Either way, the documented ratio of private sector leverage of public sector funds in Scotland is approximately 8:1[95].

9.16 In more detail, the **Scottish Co-investment Fund**[96] (SCF) was established by Scottish Enterprise in 2003 to address a perceived market failure in early stage funding. It provides equity investment to SMEs on a co-investment basis with selected private sector partners, on deals up to £2 million. Whilst the maximum initial leverage was £500K, this was extended 18 months ago to enable BAs to co-invest up to £1.5 million to match the £500K available from SCF. As at March 2006, SCF had invested £18.6m in 128 deals.

9.17 Part-funded by ERDF, there are 24 formal partners, with BA syndicates involved in over 80% of all deals done. SCF is regarded by the private equity market as a good example of a positive relationship between private investment and public sector funding. It has given BAs confidence to invest in more companies. It has also enabled BAs to plan their investments more strategically. SCF is reported to be of sufficient size to fund all the good propositions that approach it.

As a quality indicator

9.18 As well as providing a co-investment mechanism, spreading risk and enabling strategic planning, the receipt of certain public sector funds also provides additional confidence for private sector investors. The possession of a SMART award was reported to hold a certain weight with business angels, as it is perceived to be a measure of a company being well run. It also helps to deliver a degree of technology diligence. The Technology Talent Initiative[97] run by Scottish Enterprise was also reported to find favour with investors: it is understood that the BA community is interested in seeing this programme rolled out further. Its attractiveness lies in the fact that it is focused on raising commercial awareness and capability, something that investors feel is generally lacking in Scottish start-ups and spin-outs (see below).

9.19 Conversely, in the view of some commentators in the investment community, whilst SE's Proof of Concept money was seen as something that has been skilfully used by academics and their institutions to develop research ideas, consultees suggest that

[95] Business Growth – the next 10 years (March 2006). Enterprise and Culture Committee, Scottish Parliament (SP Paper 520)
[96] http://www.scottish-enterprise.com/sedotcom_home/services-to-business/businessfinance/equity/finance-sco-profile.htm
[97] http://www.talentscotland.com/view_item.aspx?item_id=3086

some in the private sector consider that it could have done more to help turn research into real commercial propositions.

The funding profile: supply and gaps

9.20 With the development of hybrid investments and the related resurgence of the angel investment market, the supply of capital in the sub-£2 million category for start-up and young companies is more buoyant than in previous years. However, as angel syndicates develop, these and other hybrids are extending into larger deals than before. This will have implications for finance at the very lower end of the market.

9.21 There is an emerging structural gap for start-ups requiring initial investments of £2 million or less, and for more established companies requiring investment in the £2 million to £10 million range. Whilst VCs are active in this latter range, they are primarily only investing in their current portfolios. In order to address this, Scottish Enterprise was planning to introduce the Scottish Investment Fund (SIF) from April 2006, since delayed. This aim of the fund is to increase the available level of risk capital and the number of providers of that capital to Scottish companies.

9.22 The Scottish Executive response[98] to 'Business Growth – the next 10 years' sets out proposals to create two new investment products which align with both the gaps outlined above. The first, the **Scottish Seed Fund**, will provide 40-50 grants per annum of up to £100,000 each in very early stage companies with high growth potential. The **Scottish Venture Fund** will invest on average £20m per annum in deals of between £2m and £5m, perhaps reaching as much as £10m. A number of different public sector initiatives are therefore in place to address identified gaps in the funding pipeline.

9.23 One recent report[99] by a joint US-EU working Group concluded that public money should now be allocated to larger funds that can command economies of scale rather than to a proliferation of smaller new funds, and that *"public sector action to stimulate early-stage investment should work with markets and not crowd out private sector investment"***.** Recent evidence to the Scottish Parliament[100], although identifying funding gaps at every level, recommends that if funds are created to address these gaps, they should be established on a public-private partnership basis.

Company use of investment

9.24 There is little information in the literature on the uses to which companies put public sector funding or equity investment. Interviewees pointed out that the majority of funding at the outset of any company goes on research and proof of concept, before private equity funding is sought. When companies do move to seek private investment, requirements depend on the size of the company, but could include

[98] www.scottishparliament.uk/business/committees/enterprise/businessgrowthexecutiveresponse.htm
[99] Joint US-EU Working Group on Venture Capital: Final Report (October 2005). US Department of Commerce and EC Directorate-General for Enterprise and Industry
[100] Business Growth – the next 10 years (March 2006). Enterprise and Culture Committee, Scottish Parliament (SP Paper 520)

development of commercial skills, product development, recruitment and market analysis, and recruitment to develop an international presence (perhaps through a new Chief Executive and/or non-executive board with appropriate experience). It was also pointed out that emerging companies spend much money on fire-fighting because of the time taken for deals to be finalised.

9.25 Whilst BAs might support product development if this was specific to 'productisation' or technology verification for the marketplace (or to meet a new opportunity or application for an existing product), they would be very reluctant to fund research. In addition, with the shift to bigger deals, BAs are not having to invest in as early-stage companies as they once did, and are often now looking to fund companies with existing customers (therefore implying that all the research and most of the development has already been done).

9.26 Whilst R&D undoubtedly happens in larger companies, it is extremely unlikely that those companies would want to give up equity to fund this. Investors may provide funding for technology development for a company already in their investment portfolio - Lab 901 and Optos were cited as examples here, having received four BA rounds in three years and 11 rounds in 14 years respectively. The decision to invest or not is ultimately commercial, and not based on the technology.

9.27 The closest BAs come to consciously funding R&D is when syndicates such as Braveheart match SMART funding (the Alpha EIS fund). However, in this example, Braveheart is risking an amount equivalent to a single late stage investment to get first option on up to ten new spin-outs, which is therefore arguably a relatively low average risk.

Barriers to private sector investment

9.28 The private sector appears to consider that the key barrier to investment is not availability of funding, but the quality of the opportunities on offer, an issue relating to the quality of early stage support. Companies looking for investment are often technology "heavy" and commercial capability, sales and marketing "light". With global ambitions, companies need strong management teams and strong market awareness, with the right people being put in touch with companies early in their development, to help shape them.

9.29 This is particularly important given that interviewees stated that 85% of the decision to invest is made on the basis of the management team. At present, existing management teams do not often recognise when they need to expand their skill set through recruitment. This echoes the recommendation in 'Business Growth – the next 10 years', that:

> *"Scottish Enterprise and its enterprise agencies should work alongside bodies such as the Federation of Small Businesses and CBI Scotland to increase the placement of business people from the Globalscot and other networks into Scottish companies that would benefit from their services and advice".*

9.30 There is also an issue around providing the infrastructure, skill sets and finance to get companies to the marketplace *in time* to capitalise on the identified market opportunity, particularly given that Scottish SMEs are competing for these opportunities with other SMEs from all over the world where these other factor conditions may be in place.

9.31 Trade bodies may have a role to play in opening up dialogue between large companies and start-ups/spin-outs, helping the latter identify (alternative) markets for their products.

10: Support for industry R&D in the English Regions

10.1 To provide context, the clusters/sectors prioritised by English Regional Development Agencies (RDAs) are compare with those that have been prioritised by Scottish Enterprise[101]. Those in bold in the table form part of the sub-set that have been newly prioritised by SE (namely: tourism, food and drink, energy, life sciences, financial services), electronics being its other priority sector.

Table 10-1 Priority cluster areas identified on web-sites of English RDAs and Scottish Enterprise

Cluster subject	**Scot**	**NE**	**Yorks & Humber**	**East Mids**	**East**	**Lond on**	**SE**	**SW**	**West Mids**	**NW**
Health and medicine		X		X					X	
Biotechnology	X	X	X		X	X	X	X	X	X
Food and agriculture	X		X	X	X			X	X	X
Creative	X	X		X	X	X		X	X	X
I&CT	X	X	X		X	X	X	X	X	X
Environment	X			X		X	X	X	X	X
Advanced engineering	X	X	X	X	X	X	X	X		X
Tourism and leisure	X				X	X	X	X	X	X
Chemicals	X	X	X							X
Energy	X			X						X
Textiles	X			X						X
Finance	X				X	X			X	X
Manufacturing					X		X		X	
Transport					X		X		X	
Building							X		X	X
Marine							X	X		X

10.2 A review and analysis of the RDA web-sites indicates that cluster/sector priorities across the UK are very similar. In particular there is a focus on biotechnology-pharmaceuticals, communications and IT, leisure and media, advanced engineering

[101] Adams and Smith (2004) *Research and regions: An overview of the distribution of research in UK regions, regional research capacity and links between strategic research partners*. Higher Education Policy Institute

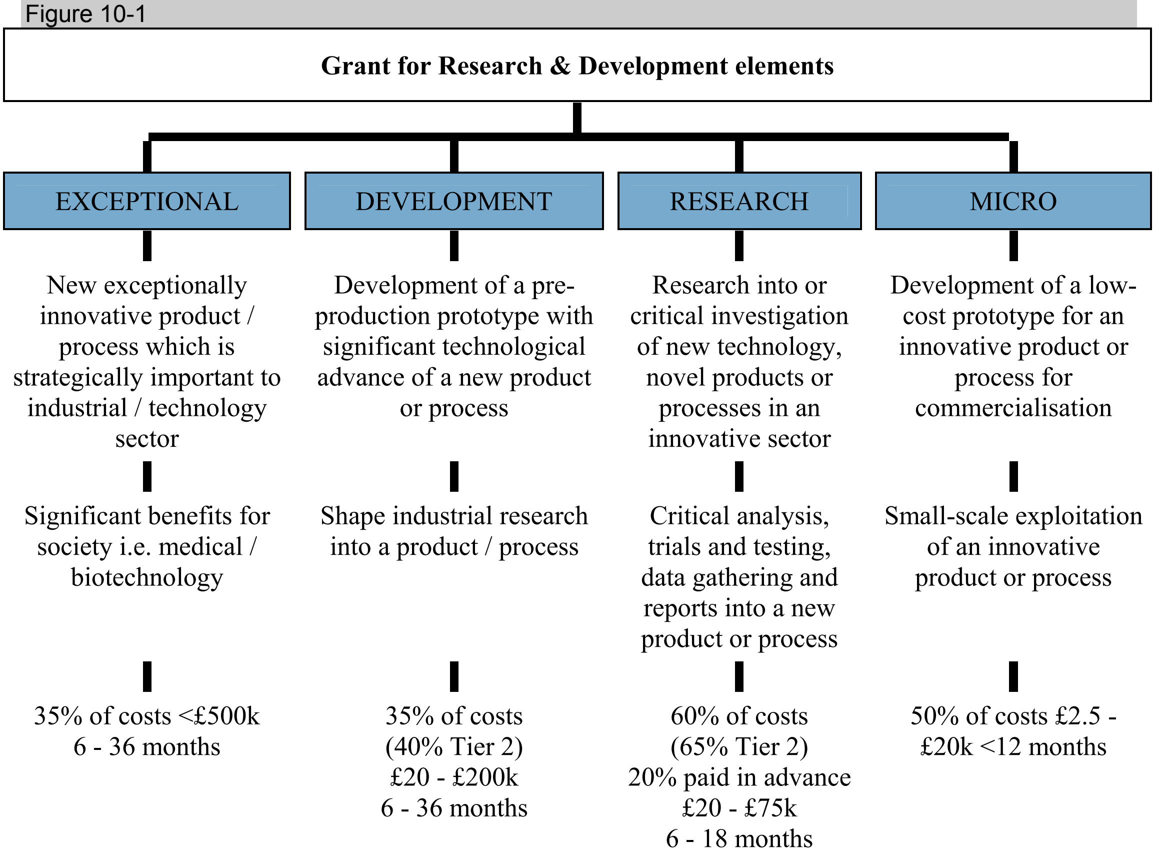
and tourism. These are also common to many national strategies on economic competitiveness in other parts of the world.

Support for R&D

10.3 The prime source of support for SMEs to conduct R&D is the *Grant for Research & Development* (Grant for R&D) which replaces the DTI's former SMART scheme. It aims to help start-ups and SMEs carry out research and development work on technologically innovative products and processes. Grant for R&D is focused on encouraging businesses to carry out projects that they would not necessarily undertake without the grant and lever in to these projects finance from reluctant private investment sources. From April 2005, the English Regional Development Agencies became responsible for delivering Grant for R&D.

10.4 To be eligible, projects must fit with the criteria for one of the four grant types - micro, research, development and exceptional - outlined in the diagram below. The project must carry out "*research or development work on a technologically innovative product or process at the pre-production stage. This does not include natural product improvement, enhancement, extension or development of existing known products*."

Figure 10-1



10.5 An **Exceptional Development Project** needs to be more than just a larger development project. It is likely to have a major effect on quality of life and/or create significant benefits for society at large. It is concerned with the development of a new technology, which is strategically important, providing a major technological advance which will result in sustainable major development for the UK.

10.6 A **Development Project** involves developing a pre-production prototype which has significant technological advance in a new product or process for commercial use.

10.7 A **Research Project** is described as a feasibility study into the technological and commercial potential of turning highly innovative technology into a new scientific/technical knowledge product or process. It would involve critical analysis, trials and testing, data gathering and reports.

10.8 A **Micro Project** is for the development of a low-cost prototype involving an innovative product or process prior to commercial exploitation.

Strategic context

10.9 As an example of regional strategies, the East of England Development Agency in its current Regional Economic Strategy (RES) set out the strategic framework[102] (see the panel extracted below) for science, technology, research and innovation. (R&D has a fairly high profile in the EEDA document: in the 130 page RES document a word search shows 38 references to "R&D".)

10.10 The other key strategic issue of relevance when considering comparisons with the English regions is the current focus on Science Cities.

10.11 In the *Science and innovation investment framework 2004-2014: next step*s published by HM Treasury in 2006, "*Government welcomed plans by the RDAs to develop Science Cities, which will provide a focal point for businesses seeking to collaborate with world-class research establishments in the regions*". Science Cities are currently being developed in Manchester, Newcastle, York, Birmingham, Nottingham and Bristol.

[102] Extracted from http://www.eeda.org.uk/embedded_object.asp?docid=1002978

SUMMARY OF GOAL THREE:
Global leadership in developing and realising innovation in science, technology and research

Stimulating demand for research and development and knowledge transfer among the region's SMEs	> raise business awareness of the importance of innovative developments in products, services and processes > ensure that businesses and research establishments have access to specialist advice on innovation where appropriate, and that service providers have a forum to link their complementary services > support innovative businesses in accessing appropriate finance, such as at proof of concept stage > capitalise on opportunities to build businesses that exploit local university-based research.
Ensuring strong links between regional universities, research institutes, and the private sector	> ensure that the region's universities and research centres are among the world's most accessible to industry > ensure the region's firms are well-informed, intelligent customers of the science and technology resources on offer > encourage corporate R&D to work in collaboration with research establishments and establish close ties between themselves and the SME community to ensure maximum exploitation of intellectual property > develop enterprise hubs as a focus for networking activity for innovation, science and technology, integrated into the business support infrastructure.
Maintaining and building upon the quality of research establishments in the region	> collaborate with partners in London and the South East to maintain and build upon the greater south east research cluster > promote the strengths and distinctive roles of the region's universities and research establishments to the business community nationally and internationally.
Facilitating international partnerships that enable knowledge transfer and collaboration on R&D	> support the development of international partnerships with complementary knowledge-based economies in other European and international regions > work with other regions to influence and advance European innovation policy developments > maximise the region's potential for accessing funding for R& D projects, through programmes such as the European Union Sixth Framework Programme > grow regional support for businesses to access international opportunities through partnering schemes and international networks.
Making full use of the research assets and global reputation of Cambridge to achieve benefits for the region	> support the Oxford-Cambridge Arc and the growth of an ICT-based economic corridor between Cambridge and Ipswich > support the development of knowledge-based clusters across the region > share good practice on the commercialisation of the knowledge base developed in Cambridge, with other parts of the region > ensure the strengths of Cambridge feature as an integral part of the international marketing of the region.

11: Methods for assessing the quality of business R&D

11.1 The purpose of this paper is to examine measures of industrial research and development (R&D) and consider their relevance to Scottish industrial R&D efforts. It also addresses:

- efficiency and effectiveness measures of R&D, their strengths and weaknesses and implications in the Scottish context
- measures of R&D quality that include ISO 9001 standards
- discuss issues concerning R&D measures and innovation
- provide recommendations and further considerations regarding R&D measures in the Scottish context.

Measures of R&D

11.2 R&D measurement is commonly undertaken by a company:

- to validate the investment level on R&D, given that R&D competes with other investments within the company
- to manage, control and improve the R&D function.

11.3 R&D measurement is accepted as a difficult undertaking[103] due to a number of contributing factors:

- difficulty in isolating the contribution of R&D to company performance from other business activities (i.e. engineering, manufacturing, marketing)
- time lag between R&D efforts and pay-offs
- lack of consensus over which R&D indicators to select
- data for measurement may not be easily available
- level of acceptance of R&D performance measures by scientists and staff may be low
- difficultly in capturing benefits of new knowledge generated from R&D, e.g. spill-over effects (e.g. flow of knowledge across department and company boundaries)

[103] Garcia-Valderrama, T. and Mulero-Mendigorri, E. (2005) "Content Validation of a Measure of R&D Effectiveness", *R&D Management*, vol. 35, no. 3, pp. 311-331; Ojanen, V. and Voula, O. (2003) "Categorising the Measures and Evaluation Methods of R&D Performance", Lappeenranta University of Technology, Working Paper 16, Lappeenranta; and Brown, M. and Svenson, R. (1998) "Measuring R&D Productivity" Research *Technology Management*, vol. 41, no. 6, pp. 30-35.

- potential uncertainty over R&D contribution to company strategy.

11.4 R&D measurement often begins with a conceptualisation of R&D as a stand-alone 'black box' function. A 'typical' R&D production function is represented in Figure 11-1. R&D measures may be undertaken to examine R&D in the entire company, individual R&D projects or particular elements of the production function. A common approach to measurement is to compare R&D inputs with outputs, as discussed below.

Figure 11-1 Elements of the R&D Production Function[104]

INPUTS	PROCESSES	OUTPUTS	USERS	RESULTS (Impact)
Personnel Equipment Investment Knowledge	R&D strategy Planning & control Skills Training	New products (NPs) New processes IPR (patents) Quality improvements Completed projects	B2C B2B Inter-firm Research centres Public institutions	Profits Market share Competitive capacity Mgmt benefits

Input and Output Measures

11.5 The objective of input-output measures is to achieve a positive relationship between the amount of resources allocated to R&D and actual R&D output. In other words, the higher the R&D expenses, the more effective the output. Most input-output measures are therefore quantitative. Table 11.1 identifies some traditional input-output measures, their strengths and weaknesses and potential implications given the Scottish context.

Table 11-1 R&D Inputs and Outputs: 'Traditional' Measures

Measure	**Strengths**	**Weaknesses**	**Implications in Scottish Context**
Number of patents (or other intellectual property rights, e.g. trade secrets, trademarks)	Simple output measure	time lag between R&D activity and IPR criteria for patent not a reflection of R&D 'quality' no guidance on what should be appropriate no. of patents generated from certain level of R&D commercial use of patent unknown is patent generation relevant to company strategy? is patent defensible?	large services base: low patent generation non-patentability of most process innovations non-disclosure of R&D output in services; reliance on trade secrets
Financial performance of R&D-generated products and services	simple output measure examines relative costs of new products or processes versus their relative performance	resource-intensive; need to track (monthly) on control chart time lag	domain of larger firms; bias to large manufacturing capabilities not present in Scotland

[104] Adapted from Brown and Svenson ibid.

Measure	Strengths	Weaknesses	Implications in Scottish Context
	(quality, service level, unique design features, etc.)		
Price-to-research ratio (PRR): market value of company divided by annual R&D expenditure	identifies technology-competitive companies (e.g. PRR of 5-10 strong)	Only identifies R&D investment No indication if R&D spend has desired effect	potential measure for new technology-based firms seeking investment
Price/growth flow model: annual R&D expenditure divided by shares outstanding provides R&D per share. This then added to company's EPS and divided by share price.	Attempts to directly link R&D to share price	Assumes that all R&D is productive and contributing to share price	Not particularly relevant for early-stage or smaller firms i.e. larger organisations able to spend smaller % of revenue on R&D with no discernable impact on performance

11.6 Most measures in Table 11.1 other than PRR, do not appear to have strong relevance to a Scottish R&D landscape characterised by smaller companies with modest R&D product portfolios and R&D budgets.

11.7 Measures of inputs vs. outputs have four identified deficiencies:

- do not eliminate the effect of other elements in the R&D production function, such as process and user influences as identified in Figure 11.1
- treat output at a given point in time as the only measure of R&D performance, i.e. do not accommodate for time lag
- do not inform company on the appropriateness of its R&D strategy
- do not inform a company on the efficiency or the effectiveness of its R&D output.

11.8 Overall, input-output measures are identified as poor indicators of R&D performance.[105] Companies well known for their innovative capabilities often spend far less on R&D than do their less effective competitors[106].

[105] Garcia-Valderrama and Mulero-Mendigorri (2005); Ojanen and Voula (2003); Brown and Svenson (1998) and Kerssens-van Drongelen, I and Bilderbeek, J. (1999) "R&D Performance Measurement Systems", *R&D Management*, vol. 29, no. 1, pp. 35-46.

[106] General Motors has invested more in R&D over the last 25 years than any other company yet has seen a decline in its market share.

Process and Qualitative Measures

11.9 A critical element of R&D measurement is to link the measures to the strategic intent of R&D within a company. In other words, how is R&D relevant to the company? What competitive role does or will R&D provide for the company in its market, i.e. to lead, to be a fast follower of established player, or to plan an exit?

11.10 Figure 14-1 identifies 'process' elements such as strategy, planning and skills that contribute to R&D outputs. While it is acknowledged that these are essential to sustaining R&D, they are primarily qualitative, intangible and difficult to measure.

11.11 Strategic measures include:

- overall R&D objectives and alignment with corporate strategy, policies and values (to include criteria measuring the compatibility and consistency of each R&D project with company's strategy and long-range plan)
- specific R&D 'output' and 'results' objectives, e.g.
  - targeted number of new products (NPs), processes and patents
  - profitability, percentage of sales and profits from new products (NPs) introduced over particular time horizon
  - percentage of sales and profits from products 'with significant enhancements' over particular time horizon
  - time to market : average concept to launch time, time for each phase (concept, design, initial production, launch)
  - design performance (manufacturing cost, manufacturability, testability)
  - customer satisfaction (functional product performance, product range, product variety, quality, etc.).

11.12 Strategic objectives should inform R&D measures and in turn these measures should concern the domain within which R&D managers can take decisions to be effective. For example, measures of individual R&D projects should include estimations of expenditures and future revenue projections that have been previously agreed by R&D managers and senior administration to reduce the degree of uncertainty. In the event of company's change in strategy, new R&D objectives and measures may easier be modified along with the progress of the R&D work.

11.13 Along with strategy and R&D alignment, cross-functional integration and communication between the R&D function and other business functions are identified as key aspects in the innovation process of the modern company. This may include measures of the level of integration of R&D activities with other major company functions such as:

- integration with manufacturing function; measures of R&D manufacturing success

- interaction with marketing and measures of R&D marketing success.

R&D Efficiency

11.14 R&D efficiency refers to the extent to which the R&D function produces the desired output with the allocated resources. This usually refers to two main areas:

- R&D productivity
- adherence to R&D scheduling.

11.15 Measures of R&D productivity concern the ratio of technical success to the amount of resources that have been used to achieve this result.

11.16 Technical success of R&D activity is defined by measures that demonstrate progress towards defined technical objectives. Such measures include:

- the achievement of specific technical objectives set out for the project that may include achieving associated cost and time-based targets
- the difference between the past performance of a product, process or technology and the current performance of that product, process or technology; the improvement being the result of the project being evaluated
- perceptions of technical achievement by users. If R&D activity results in a product or process, one measure is to compare technical performance and technical progress in a certain time span with competitors.

11.17 Measures of the amount of resources spent can be in terms of time and costs and include the ratio of:

- technical progress to costs
- technical progress to time.

11.18 More complete measures can be obtained combining the three parameters identified above -technical progress, cost and time. These can be the ratio of:

- technical progress per time unit (month, year, etc.)
- time to technical progress, i.e. time employed to improve technical progress unit
- cost to technical progress that measures the cost per unit of technical progress
  - including number of redesigns and average time of redesigns
- cost to time and to time per technical progress unit.

11.19 Adherence to scheduling includes measures of how projects are carried out adherently to plans. These measures can simply reflect whether, at a certain milestone, time to completion is as planned.

11.20 R&D efficiency measures may include an aggregate measure of the portfolio of R&D projects active in the company as the unit of analysis. R&D efficiency as a total portfolio measure can identify the extent to which there is a balanced distribution of technical risk among projects and can be used at both planning time and during R&D projects.

11.21 Efficiency measures allow the company to understand the extent to which it avoids duplication of common functions and is able to exploit projects or resources to multiple objectives. These measures can include:

- accurate definition of R&D expenses
- whether or not expense decisions are undertaken by R&D managers or defined by corporate leaders on a project by project basis
- the number of applications generated from single project or sequence of projects
- the number of project parts jointly carried out with other projects
- the number of duplications.

11.22 In summary, measures of the adherence to scheduling in R&D processes can reduce the degree of uncertainty concerning the time to market, which in turn may affect revenues.

11.23 Measures of efficiency provide evidence of the ability to keep R&D costs at the budgeted levels and to identify how well resources have been allocated to projects. Such measures can be:

- percentage of projects technically successful
- percentage pf projects abandoned after a certain degree of completion (for example 25 per cent, 50 per cent etc.).

R&D Effectiveness

11.24 R&D effectiveness refers to the impact of R&D 'outputs' on the company**.** This impact is described under the 'results' heading in Figure 11-1 and is a function of inputs, processes and outputs.

11.25 Figure 11-1 suggests that R&D results are closely associated with the end-users of R&D outputs. For example, end users may be another department within the company or another research centre; therefore profit may not be a realistic result as it would with business to business (B2B) or business to consumer (B2C) end-users.

11.26 End users within the company may also have different expectations of R&D impact. For example, shareholders are likely to seek to maximise profits, while managers may focus on new product development, increasing sales and market share and cost reduction.

11.27 One important output of R&D activity is new products (NPs) or processes. Measures of R&D effectiveness will often focus on the financial performance arising from new product development (NPD), where economic value is a contribution from:

- existing R&D activities, from which predictable cash flows are and will be generated
- strategic intent of future R&D activities that company can undertake from its own available resources generated from NPs.

11.28 Table 11.2 describes R&D effectiveness as measured by NPD and identifies strengths and weaknesses of measures and implications in the Scottish context.

11.29 One aggregate measure described in Table 11.2, the R&D Effectiveness Index (RDEI),[107] compares the profit from NPs to the investment in R&D devoted to new product development. The RDEI is increasingly in use in industrial R&D and is further discussed below.

Table 11-2 Measuring R&D: New Product or Process Development

Mechanism	**Strengths**	**Weaknesses**	**Implications in Scottish Context**
New product (NP) revenues: NP margin: Revenues (£) per unit of time/R&D spend NP success rate (i.e. % of NPs reaching 75% of revenue targets by year 3) **% of sales:** from products released last 3 years	• sense of R&D success • Provides R&D output measure • Allows for R&D comparisons related to NPD	• Lag between R&D investment, NPD and revenues • financial results dependent on other factors (e.g. general market conditions, competitor activity, outsourcing, strategic change, etc.) • variations in R&D spend affecting NPD • need accurate annual sales information for NPs	Not particularly relevant for new firms (i.e. less than 5 years old)
Ratio of new products sales to total sales	• used in OECD surveys of innovation	• similar weaknesses as above	As above
R&D Effectiveness Index (RDEI) measures NP profit impact for every £ of R&D expenditure	• more accurate measure of R&D impact on profits • increasingly used in industry	• Need clear definition of NP • Must pay close attention to product life cycle	Application for NPD-focused firms with focused R&D
R&D project contribution to shareholder value (NPV)	• Generates total R&D value in company by combining all R&D	• does not capture interactions, spill-overs among different	Most relevant to large, multiple R&D projects not common in Scotland

[107] Developed by Pittiglio Rabin Todd and McGrath (PRTM); McGrath, M. and Romeri, M. (1994) "The R&D Effectiveness Index: A Metric for Product Development Performance", *Journal of Product Innovation Management, v*ol. 11, no. 3, pp. 213-220.

Mechanism	Strengths	Weaknesses	Implications in Scottish Context
sum of incremental net cash flows related to the project and discounted in order to consider the value of time	project NPVs.	projects • in combining large number of projects, evaluation of future net cash flows becomes less reliable • NPV does not allow a timely evaluation; usually *ex ante* measurement	

11.30 The RDEI measure in Table 11.2 is obtained by multiplying the percentage of revenue from NP introduced over a particular time period (suggested 3 years) by the rate of net profit combined with the percentage of R&D spending. Net profit is used instead of gross margin to cover related selling and administrative costs associated with the NP. As a general guideline, when the index is above 1.0, the return from new products is running at a rate greater than the investment.

11.31 The RDEI defines NPs as those that are still in the first half of their product life-cycle; however, consistency by each company in determining the definition of a new product or process is most important here. For example, the entire product life cycle could be used to evaluate a NP opportunity. The objective of the measure is relative comparisons rather than absolute performance.

11.32 Most measures described in Table 11- assume a relationship between R&D activity and profitability or market share from NPs. However, evidence suggests that the industry sector and capital intensity will affect this relationship.[108] Consumer electronics, for example, are identified as highly profitable without requiring large capital investments.

11.33 Conversely, chemicals and steel are identified with large capital investments but have limited profitability. It is further suggested that the lower the capital intensity, the easier it may be to carry out radical changes in R&D, i.e. in new markets where there are no existing businesses.[109]

11.34 Indeed, the RDEI shows variations by industry. Studies suggest that a low R&D effectiveness index may be more of an indication of an industry's potential and reflect a much higher payback per pound spent on R&D.[110] Increases in the RDEI can be generated by:

- decreasing time to market
- improving product or process profitability
- increasing product development productivity

[108] Ojanen and Voula (2003).
[109] Ibid.
[110] McGrath and Romeri (1994).

- reducing wasted research and development activities.[111]

Summary of R&D Efficiency and Effectiveness Measures

11.35 Many R&D measures are similar to traditional performance measurement (PM) mechanisms in that both attempt to determine how certain defined activities contributes to creating economic value for the company.

11.36 Table 11-1 summarises R&D measures previously discussed using a balanced scorecard approach.

Table 11-1 Figure 4: Balanced Scorecard Measures of R&D[112]

Scorecard Element	Objective	Measure
Efficiency Measures	Productivity Speed to market Quality of output	Time, cost, use of resources and technical success Current time to market vs. planned Number of times re-work and re-design First-time right to design
Effectiveness Measures	Survive Succeed Prosper	Present value of R&D outputs & expenditures Percentage of sales from NPs Market share gained from R&D Increase rate of market-accepted products, processes
User Measures	High customer satisfaction Anticipation of user needs R&D 'success' rate	Score on customer satisfaction audit Percentage of user driven projects Early adoption of new products, processes % of projects terminated before implementation

11.37 Previous discussion suggests that different sets of R&D measures should be employed depending on how a company structures its R&D and given its stated R&D strategy and objectives. Case 1 identifies how a company like Exxon Chemical measures its R&D effectiveness.

[111] Ibid.
[112] Adopted from Kerssens-van Drongelen and Bilderbeek (1999).

Case 1: Exxon Chemical's In-process R&D Measures

To measure its R&D efficiency and effectiveness, Exxon Chemical utilises three **process measures:**

- penetration, i.e. the percentage of the new production development (NPD) budget utilizing an innovation process;
- percentage of new projects utilizing an innovation process; and
- Focus and Culling, i.e. the percentage of No Go or Hold decisions made during a period of time by the end of stage two of the innovation process,

The company also uses three **output measures:**

- speed of innovation;
- performance, i.e. second year EBIT (earning before interest and tax)versus gate four of the innovation process; and
- percentage of revenue from products more than five years old

As a large multi-national in a mature, competitive industry, Exxon's measures reflect longer time horizons from research to application and defined stages of innovation and product life cycles.

11.38 Case 1 identifies the importance of R&D alignment with strategic objectives, as well as tight, concise measures that are integrated and easily measured and monitored.

R&D Quality

11.39 Previous discussion of R&D measures has not made explicit the notion of R&D 'quality'. It is generally accepted that R&D quality is holistic and involves multiple elements of the R&D production function.[113]

11.40 Although it is common to define R&D quality in terms of features, functions and technical performance of resultant R&D products, such measures would fail to inform how quality has been created through the R&D production function. R&D quality, similar to R&D efficiency and effectiveness, is difficult to accurately measure with a single metric.

11.41 R&D quality is the consequence of a series of processes undertaken during the R&D production function, requiring consideration of efficiency and effectiveness measures. As stated earlier, R&D efficiency involves meeting productive and scheduling objectives. Technical success will affect customer satisfaction and influence future revenues while resource usage influences cash outflows occurring over a defined time period.

[113] Jayawarna, D. and Pearson, A. (2001) "The Role of ISO 9001 in Managing the Quality of R&D Activities", *TQM Magazine,* vol. 13, no. 2, pp. 120-28

11.42 Adherence to the scheduled time is important, as profitability is also related to the capability of providing NPs and processes in a short time. R&D costs may include those of engineering and manufacturing, which are partially dependent on R&D and its degree of integration with these functions. Therefore, revenues from R&D will depend on how well these functions are integrated in the R&D planning phase.

11.43 R&D effectiveness also depends on the capability of the R&D function to meet user needs and depends on how well users needs have been accurately identified. Therefore, revenues from R&D will depend on user and result objectives in the R&D planning phase and the degree of integration with other company functions, such as marketing and customer service, which influences costs and revenues.

11.44 R&D quality measures may be more externally driven or informed, such as:

- benchmarking R&D outputs to comparable outputs of market leaders or peers;
- comparisons of technical performance of products or process with previous models or competitors;
- meeting or exceeding user or customer expectations;
- dissemination of research results to peer review; targeting of prestigious journals for publication of R&D findings.

ISO 9001

11.45 ISO 9001 is recognised as a valid model to measure and improve R&D quality.[114] There are 20 quality elements of ISO 9001 that provide minimum requirements for companies in order to qualify for the ISO 9001 designation. A key objective of ISO 9001 is to better control the R&D process and continuously raise R&D standards.

11.46 For companies engaged in significant R&D activity, ISO 9001 treats customer satisfaction as a strategic priority by ensuring the accuracy and relevance of customer input and satisfaction as ongoing R&D inputs.[115]

11.47 ISO 9001 also treats new product development (NPD) as a priority by outlining processes of product design and development with specifications for organisational and technical interfaces necessary to operate the NPD process across various business functions of the company.

11.48 Although ISO 9001 appears well suited to large R&D-intensive companies, its adoption by SMEs could be challenging given the level of discipline, time and resources required to incorporate and maintain such standards.

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[114] ISO (international standards organisation) is identified with the concept of total quality management (TQM) and is designed to increase the efficiency and effectiveness of organisational processes that include R&D.
[115] Jayawarna and Pearson (2001).

R&D Measures and Innovation

11.49 One criticism of R&D measures is failure to acknowledge a key element of innovative activity - the **rate** of productivity improvement within a company that is the result of its R&D activity. R&D outputs and results, it is argued, must eventually translate into faster productivity improvements for the company to justify its R&D efforts.[116]

11.50 A recent report by Booz, Allen, Hamilton found that higher R&D-to-sales ratios were associated with higher gross margins: the percentage of revenue left over after subtracting the costs of materials, labour, manufacturing, and direct shipping, and after paying other expenses incurred in making products or services sold. Their study also makes a similar point about R&D expenditures and patent output as indicators of innovation.[117]

11.51 The implication here is that R&D is seen as a cost-effective investment whose objective is to differentiate the company from competitors and generate medium to longer term profits.

11.52 R&D measures then should make explicit sustainable productivity improvements that relate to innovative products, process improvements and profits. As argued earlier, this requires R&D objectives and alignment with company strategy that make explicit the relationship between user and market needs and R&D efforts and results.

Key issues

11.53 This paper has identified elements of the R&D production process and the various measures of R&D effectiveness, efficiency and quality. Strengths and weaknesses of various measures were identified, along with potential implications for the Scottish R&D context. Because industrial R&D in Scotland is not the domain of large, R&D intensive multi-national companies, a number of the R&D measures described here and standards such as ISO 9001 are likely not always to be appropriate or are too advanced for SMEs with limited R&D budgets and project portfolios.

11.54 However, the RDEI measure appears appropriate. The RDEI can be used to measure the differences in R&D opportunities across industries and as a benchmark comparison to other companies. The index can also be used as a metric of relative performance; therefore, it can measure consistent performance in the product development process as a longer-term metric. Benefits in using RDEI by Scottish firms could include:

- wasting less investment on products or processes that do not have commercial application
  - ➢ cancelling projects earlier in the development cycle

[116] Brown and Svenson (1998).
[117] Booz, Allen, Hamilton Resiliance Report: 'Money isn't Everything', Dec. 12, 2005 http://www.strategy-business.com/resilience/rr00027?pg=1

- investing proportionally more of R&D investment on new products and platforms
    - maximising R&D investment by increasing returns on NPs.

11.55 This research indicates that companies with existing or proposed R&D functions clearly define their R&D objectives and map out their R&D production function. Determining what is to be measured and why is critical to ensuring that accurate measurement of R&D efficiency, effectiveness and quality is achieved. R&D measures must be appropriate to the scale and scope of R&D activities.

11.56 Ongoing monitoring of R&D measures is necessary to facilitate rapid, informed, decisions regarding adjustments in the R&D function given changing strategic, financial or market conditions. R&D measures should also be used to increase awareness and visibility of R&D efforts, performance and results, particular in the Scottish context, where industrial R&D requires greater visibility and exposure.

12: Internationalisation of business R&D

12.1 In this paper issues associated with the internationalisation (off-shoring) of business R&D are explored, including the findings of a recent survey into the motivations and drivers for US and European multinationals to locate R&D outside their home country. Factors influencing the location of business R&D activity of multi-national companies (MNCs) to China and India are reported. Competitive locational factors and the positioning of Scotland with respect to these are discussed.

12.2 Thursby and Thrusby[118] have undertaken research funded by the Marion Ewing Kauffman Foundation[119] and the industry partners in the US Government-Industry-Research Roundtable (GUIRR[120]) in the USA on the factors influencing the choice of MNC's R&D location. Key findings are as follows:

- of 201 respondents, c. 40% anticipated that world-wide distribution of technical employees would change over the next 3 years
- of those anticipating change, most saw China and India as the main beneficiaries.

12.3 The survey asked about the importance of different factors in making location decisions. Based on those identified most often as of key importance when locating to an "emerging economy", the top factors in order of rank (most important first) are:

1) the country has high growth potential
2) there are highly qualified R&D personnel in the country
3) the R&D facility is established to support sales in the country
4) concerns about IP protection
5) ease of negotiating ownership of IP from research relationships
6) exclusive of tax breaks and direct government support, the costs of R&D are low.

12.4 However, despite a trend towards off-shoring R&D in Asia, the survey found that companies are keeping their cutting-edge research in developed countries where IP protection is strongest. According to the survey, only 22% of R&D effort in emerging countries is for new science.

12.5 Looking at location factors for locating in both developed and emerging economies, the survey of MNCs identified the following common factors influencing decisions about R&D locations:

- market growth potential

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[118] Thursby, JG and Thursby, MC (in press) *Here or there? A survey on the factors in multinational R&D location and IP protection.* Marion Ewing Kauffman Foundation Research Report
[119] See: http://www.kauffman.org/
[120] See: http://www7.nationalacademies.org/guirr/About_GUIRR.html

- quality of R&D talent
- university collaboration
- IP protection.

12.6 Cost of R&D was not found to be the most important factor. The authors claim their most surprising finding to be the relative importance given to the role of university collaboration in the corporate decision-making process with respect to emerging countries.

Examining the nature of R&D off-shored by MNCs

12.7 A major report by the UN Conference on Trade and Development (UNCTAD) on international R&D[121] is reviewed in brief. In this report overseas R&D by MNCs is described as a multifaceted activity: it is analysed in terms of the nature of the R&D activity undertaken and in terms of the motives for undertaking the R&D abroad.

12.8 The following provides illustrations of the different categories identified by the UNCTAD report.

Based on the nature of technological activity in foreign affiliates

12.9 This typology divides foreign affiliates conducting R&D into four broad types (sometimes with sub-categories) on the basis of the kind of R&D undertaken:

- *Local adapters:* "market-seeking" R&D units for absorbing and adapting technologies, essentially to support product and process engineering departments in making existing technologies work more efficiently in new environments
- *Locally integrated laboratories*: these are more advanced than local adapters and are capable of independent innovation aimed primarily at local (and perhaps regional) markets. The units remain linked to local production and are usually a natural evolution from adaptive R&D
- *International technology creator:* the most advanced type of innovative activity by foreign affiliates and places them on an equal level with core innovating centres in the home countries (and in other developed countries). Also known as "internationally interdependent laboratories", these facilities can do both research and development, and their output is typically aimed at global exploitation by the parent company. They may evolve out of locally integrated laboratories, and so retain tight links with production in the host economy, or they may be set up independently of local production to tap local innovation clusters and skills
- *Technology scanning or monitoring unit:* this is normally a "business intelligence" function undertaken by an "asset-seeking" R&D unit under the headings above, but in

[121] UNCTAD (2005) *World investment report: transnational corporations and the internationalization of R&D.* UN, New York

the absence of a separate R&D facility, scanning can also be done by another department of the TNC.

Based on TNC motivation

12.10 This typology groups affiliate R&D activities by the technological objectives of the parent company.

- *Technology-seeking FDI in R&D:* the MNC seeks to offset areas of weakness in the home country innovation system by setting up R&D facilities or acquiring local innovators in countries with complementary strengths. A number of R&D-related Mergers and Acquisitions in the United States in biotechnology, electronics and pharmaceuticals are of this type. Developing country firms with technological ambitions also undertake such R&D investments or acquisitions.

- *Home-base (or asset-) exploiting FDI in R&D*: this essentially corresponds to the adaptive category in the typology above, where the main functions of the R&D are to absorb and adapt technologies transferred by the parent company so that the MNC can effectively exploit its technology assets.

- *Home-base (or asset-) augmenting FDI in R&D*: this is where MNCs undertake R&D in technologies in which they are strong at home and where the host country also has strengths. This has been called "strategic asset-seeking R&D" by MNCs. It aims not only to access foreign technological assets but also to capture the externalities created by host-country technology clusters. The distinction between this and technology-seeking FDI is not very strong, especially in the case of developed countries, as it hinges on an evaluation of the relative strengths of home- and host-country innovation systems.

12.11 There are other ways to classify foreign R&D, for example, by the organisational strategy of MNCs and by their R&D management practices.

China

12.12 The OECD[122] examined China's R&D performance. It stated:

> *"Foreign firms that invest in China appear to have engaged in only limited levels of R&D activity, and their role in the innovation process seems even more limited. Foreign companies appeared to treat their joint ventures in China as production bases for their global business strategies. Only 1% of foreign companies in China had R&D departments, and half of these did not receive stable funding, one third did not perform R&D regularly, and nearly 40% lacked the necessary experimentation and testing equipment."*

12.13 The report points to signs of greater interest by foreign companies in investing in R&D intensive industries in China and in forming R&D joint ventures. The focus is

[122] OECD (2002) Science, Technology and Industry Outlook

in high tech industries such as software, telecoms, biotech and chemicals. Several factors appear to explain the change:

- foreign companies are now convinced of the longer term potential of the Chinese market and have begun to make long term investments
- some firms have recognised the value and cost advantage of the Chinese R&D workforce
- there is also a need for major adaptation of products for the Chinese market, with joint R&D and production in certain industries such as software.

12.14 The UNCTAD report[123] profiles the R&D investment by MNCs in China. Most of the known projects are:

- recently established, after China's accession to the World Trade Organisation in December 2001
- most foreign-affiliate R&D centres are wholly-owned by their parent companies, although some of them are joint ventures (such as the one established by Lenovo and Intel in 2003)
- the majority of these centres still focus on adaptive innovations for the Chinese market. However, some do innovative R&D that is closely integrated with the MNCs' global innovation networks, and thereby target global markets
- R&D-related FDI inflows have been concentrated in technology-intensive industries such as ICT, automotive and chemicals. The ICT industry, in particular, has witnessed a boom in R&D investment by MNCs. Motorola one of the largest foreign investors in China, had set up 15 local and global R&D centres in China by the end of 2004, with several others under construction. In addition to Motorola, major R&D investments have been made by Microsoft, Nokia, GE as well as IBM, Siemens, Nortel, Dupont, General Motors, Honda, Hitachi and Toshiba. Foreign-affiliate R&D centres in China are concentrated in large cities with strong technological bases and skilled human resources, particularly in Beijing and Shanghai.

12.15 A recent study on R&D investment by MNCs in China, conducted for the Industrial Research Institute[124] in the United States highlights some of the perceived advantages of locating industrial R&D in China, many of which are the result of government policies:

- the supply of talented manpower exceeds demand, at least by foreign firms
- Universities and research institutes are eager to get funding from private firms
- the possibility of entering into IPR agreements with top Chinese universities
- a large number of high-technology parks

[123] UNCTAD (2005) ibid.
[124] See Armbrecht (2003) in http://www.iriinc.org/

- incentives, and
- the potential for cost reduction across all stages of the R&D value chain.

12.16 The study emphasised that while cost savings matter, MNCs expand R&D in China primarily for strategic reasons: to tap the vast pool of talent and ideas, and to stay abreast of competitors in the increasingly sophisticated markets of China and Asia.

India

12.17 MNCs have performed R&D in India since the1970s, but it was then limited to adaptation or product development for the Indian market. Such R&D was conducted mainly in response to government regulations and to certain unique characteristics of the market. Since the mid- 1980s, the scope and characteristics of MNC R&D have changed.

12.18 Starting with Texas Instruments (1986) in semiconductor design, followed by Astra (1987) in biopharmaceuticals, more MNCs have set up globally-oriented R&D units in India – mostly without local links to manufacturing activities. The 1990s saw the entry of MNCs in diverse industries: for example Motorola (telecommunications software), Microsoft (computer operating systems), STMicroelectronics (semiconductor design), Daimler-Benz (avionics systems) and Pfizer (biometrics). Since 2000, other entrants include Intel (semiconductor design), GE (e.g. aircraft engines, white goods and medical equipment) and Pfizer (veterinary medicines).

12.19 According to the UNCTAD report, these MNCs are attracted for several reasons, the most important being the availability of qualified scientists and engineers, in significant numbers and quickly.

12.20 A second attractive feature is the existence of internationally reputed R&D institutes such as the Indian Institute of Technology, Indian Institute of Science, Indian Institute of Chemical Technologies and Centre for Drug Research. Many of the MNC R&D units in India collaborate with these institutes and several MNCs that do not have an R&D presence in India outsource R&D to them.

12.21 Thirdly, several Indian firms have become global players and are forming R&D alliances or subcontractual relationships with other MNCs. The Indian software companies TCS, Wipro and Infosys, for example, have alliances with Ericsson, Nokia and IBM. Similarly, Indian pharmaceutical companies have R&D alliances with Novo Nordisk, Novartis and GlaxoSmithKline.

12.22 In a survey conducted at the end of the 1990s, the availability of R&D personnel was ranked by MNCs as the most important reason for locating R&D in India. For MNCs in new technology industries this factor was even more important, followed by low costs of performing R&D in India. Conversely, for more conventional industries, proximity to manufacturing and to the Indian market were more important reasons.

12.23 According to UNCTAD, Government incentives were relatively unimportant for both groups of companies. The use of English as the business language and medium of instruction for technical and managerial education in universities is an added benefit. A revised IPR regime is now in compliance with the international regulatory framework.

Generic factors in locating R&D

12.24 The general investment climate – macroeconomic and social stability, security, transparency, administrative rules and regulations – is as important for R&D location as it is for FDI in general. Similarly, the type of R&D that may be attracted depends on the economic structure of the location, including the industrial structure, market size and growth, culture and language, natural resource endowments, living conditions and physical infrastructure. Most of these factors are "created" assets and therefore can be altered through government intervention.

12.25 The following assessment of factors related to different business purposes are extracted from the UNCTAD report:

- *Adaptive R&D* is typically closely related to production and involves the adaptation of imported technologies. This is the dominant form of R&D by foreign affiliates in Latin America and in Africa to date. The location of such development work is determined by the need to support production and adapt technologies, to be near customers, to cooperate with local partners, to access markets, to improve the local "image" of a company, to launch a product simultaneously, to facilitate rapid scale-up in manufacturing and to overcome protectionist barriers against imports

12.26 The larger the host market, the greater the need for local adaptation of goods and services. As national markets become regionally more integrated, some countries may become the preferred base for adaptation, not only for the local market but for the region as a whole. In this case, appropriate skills and other aspects of the national innovation system (such as the technical and economic infrastructure, proximity to suppliers/key customers) become more important. Depending on the industry, adaptive R&D needs technical and engineering skills that are specialized in the technologies used in production. Cost factors are likely to be of secondary importance.

- *Innovative R&D* has emerged as a feature of some foreign affiliates in parts of South, East and South-East Asia as well as in some transition economies. Internationalisation of such R&D for global markets is driven by the search for advanced skills in relevant areas of science-based technologies. Such R&D work can be intended for regional or global markets and is determined primarily by the quality of the national innovation system (NIS). In China, adaptive R&D is evolving into more advanced forms of innovation, with the local market serving as a test-bed for new products for regional or even global markets.

12.27 The features of a host country that are needed to attract innovative R&D depend on the industry and activity involved. Key determinants in host developing countries for attracting innovative R&D include a large pool of scientific and technical manpower, a well functioning NIS featuring strong public research institutions, science parks and an adequate system of IPR protection, and government incentives. The availability of the right kinds of scientific and engineering skills is probably the most critical factor in attracting innovative R&D, especially in new, science-based technology industries.

12.28 The importance of researchers and scientists covering a broader range of disciplines is not new. What is new is that competitive pressures are forcing companies to pay greater attention to *wage costs* and *availability of scientists and engineers in large numbers*. With wage rates for skilled researchers in developing country R&D locations significantly lower than those in developed countries, the attractiveness to MNCs is compelling.

12.29 However, the UNCTAD report notes that wages *per se* are not the main location determinant. MNCs value the ability to set up a research facility rapidly and tap into an existing knowledge centre where they can find skilled researchers (often in the hundreds) at short notice. This gives a "critical mass" advantage to countries that combine low wages with good education systems turning out large numbers of well-trained researchers. As their low ranking in the *UNCTAD Innovation Capability Index* shows, China and India are not the most attractive locations in terms of human resources normalized by population size. However, when MNCs need to recruit researchers in large quantities, these countries offer a growing body of skilled people at low cost.

12.30 The global distribution of enrolments in tertiary education has changed dramatically. Developing Asia has emerged as the main source of new university graduates, and this trend appears to be continuing. This is one of the main reasons why, for example, a growing number of MNCs are turning their attention to China and India for innovative R&D work.

12.31 While the absolute number of skilled people plays an important role in R&D location, it is nevertheless possible for small economies with high levels of technical skill to attract global R&D as long as they also have a large MNC presence in technology-intensive activities and can offer specialized R&D competence. Ireland, Singapore and Hungary are regarded as good examples of small newcomer countries that have attracted a large MNC research presence.

12.32 The UNCTAD report examined whether government incentives help attract R&D from MNCs. The question is important especially in light of the increased use of R&D incentives around the world. In general, incentives are effective only when other, more important determinants are in place. By reducing costs, government incentives may induce MNCs to expand or deepen their R&D activities. However, if the necessary skills and research capabilities are lacking, incentives may induce firms merely to re-label routine technological activities and report them as R&D

Summary of main drivers for internationalisation of R&D

12.33 According to UNCTAD, the main driver for the internationalisation of R&D by MNCs is their need to adapt products and processes to conditions in host-country markets. However, the recent increase of R&D by MNCs in selected developing countries, especially in Asia, is driven by a more complex set of factors:

- *pull factors*, such as a growing market, availability of large talent pools at favourable costs and developing Asia's emergence as a global production base in some industries
- *push factors*, such as shortages of skills in specific categories in home countries, rising costs and complexity of R&D, greater competitive pressure that forces MNCs to innovate more without increasing costs
- *policy factors*, such as host-country efforts to strengthen their Innovation System, to invest in education and to use targeted investment promotion and incentives
- *enabling factors*, including advances in ICT, investment and trade liberalisation, all of which make it easier for firms to restructure their operations internationally, while at the same time adding competitive pressure on firms to do so.

13: International policy comparisons

13.1 The purpose of this paper is to describe key factors that support R&D investment and to provide an international policy comparison of public initiatives to promote industrial R&D, looking specifically at tax incentives, grants and skills programmes. The paper then considers from this review implications for the Scottish R&D context.

Location Advantages for Attracting R&D

"When an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade getting from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously."

Alfred Marshall, Principles of Economics (1890)

13.2 Economists have long associated co-location of economic activities with competitive advantage. The need to be close to final markets and to respond to local market requirements has also long been identified as a driver for located and operating overseas R&D.[125]

13.3 However, research suggests that firms are moving to a more dispersed approach to gaining competitive advantage through their innovative capacity, and increasingly are establishing R&D operations in foreign locations. While not yet a universal phenomenon, and still found predominantly in larger firms from industrialized countries, many researchers contend that R&D activities of MNCs will increasingly be globally distributed.[126]

13.4 For example, small, 'skill-labour abundant' countries such as Sweden and Finland are among those with the highest R&D expenditures as a share of their GDP, but not necessarily among those most specialized in high-tech production.[127] Whilst Sweden is home to many MNCs (multi-national companies) operating in the high-tech sector and conducting their R&D in Sweden, these MNCs carry out a substantial part of their actual production in other large OECD economies, where comparative advantages such as labour costs exist.

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[125] E.g. Jones G, Teegen H. (2002) "Factors Affecting Foreign R&D Location Decisions. Management and Host Policy Implications: *International Journal of Technology Management*, vol. 24, no. 1.

[126] Cantwell J and Janne O. (1999) "Technological Globalisation and Innovative Centres: The Role of Corporate Technological Leadership and Locational Hierarchy", Research Policy, vol. 28, pp. 119-144; Dunning J. and Narula R. (1995) "The R&D Activities of Foreign Firms in the United States. *International Studies of Management and Organization, vol. 25,* pp. 39-73; Granstrand O. (1999) "Internationalization of Corporate R&D: A Study of Japanese and Swedish Corporations", *Research Policy* 28: 275-302.

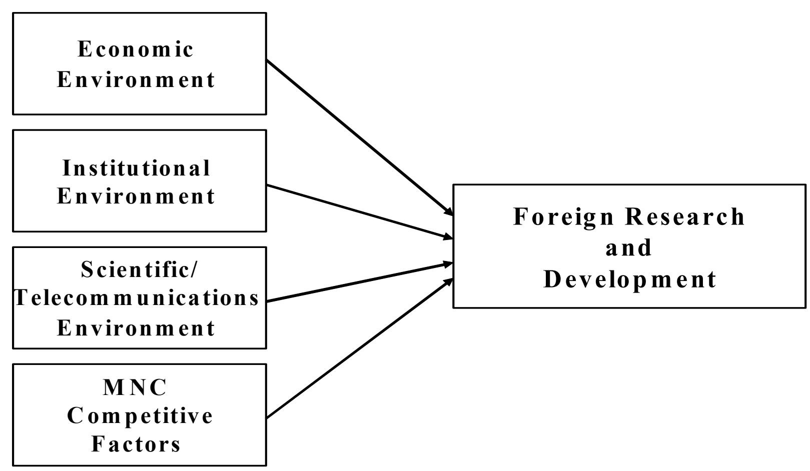
[127] Niosi, J. (1999) "The Internationalization of Industrial R&D: From Technology Transfer to the Learning Organization*", Research Policy,* vol. 28, no. 2, pp. 107-17.

13.5 Various economic supply and demand factors also contribute to R&D location and re-location decisions. Supply side factors include: factors of production endowments; qualities of the local scientific and technical base; experienced R&D managers; presence of local institutions encouraging communication, labour mobility, effective professional networks and the host country's industrial composition.

13.6 Demand side characteristics include: proximity, size, & composition of markets for R&D activities; regulatory characteristics; local tax & other public policies; and pressures to undertaken R&D from innovation-oriented competition.

13.7 Figure 13-1summarises four factors that have been shown to make a host country more attractive to foreign R&D.

Figure 13-1 Factors Attracting Foreign R&D[128]



13.8 These four factors will be more or less important given particular sectors and markets, but are identified as necessary and complementary for attracting foreign R&D. Table 13-1 examines these four factors in more detail.

Table 13-1 Host Country Factors Attracting Foreign R&D

ECONOMIC	INSTITUTIONAL	SCIENTIFIC, TELE-COMMUNICATION	MNC COMPETITIVE FACTORS
Quality of political environment	R&D tax breaks	University faculty with special scientific or engineering expertise	Current level of MNC R&D investment
Extent of corruption	Other direct government assistance, i.e. R&D grants	Ability to collaborate with universities and public	Previous history (success) of MNC

[128] Adapted from Doh, J. (2002)"Foreign Research And Development And National Innovation Systems: An Empirical Study Of Host Country Influences", *Strategic Management*,

ECONOMIC	INSTITUTIONAL	SCIENTIFIC, TELE-COMMUNICATION	MNC COMPETITIVE FACTORS
		researchers	investment
Overall political risk	Low R&D costs (exclusive of tax breaks & other government assistance	Highly qualified R&D personnel	Industrial structure of country attractive for MNC investment
Overall economic risk	Cultural & regulatory environment conducive to spinning off or spinning in new businesses	Easy to negotiate ownership of IP from research relationships	
Strong protection of intellectual property (IP)	R&D facilities to support sales to foreign customers.	Telecommunications infrastructure strong	
High growth potential of country	Few regulatory and/or research restrictions		

13.9 A number of insights can be drawn from Table 13-1. It can be seen that some economic and institutional factors characterise the economic, regulatory and legal foundations of a particular country and are therefore not easily manipulated by government intervention initiatives.

13.10 For example, creation and maintenance of an R&D 'friendly' legal environment, through measures to stimulate more patent activity or lessen constraints of anti-trust legislation, is increasingly difficult for individual countries in the European Union, even though they would increase the likelihood of generating an acceptable return from R&D investment and thus encourage such investment by the private sector.

13.11 On the other hand, national governments can provide incentives to stimulate certain institutional and scientific factors shown in Table 13-1 that promote R&D. Governments can provide financial incentives, such as R&D tax incentives and research grants to stimulate more companies undertaking R&D or stimulate the creation and maintenance of a skilled scientific research community.

Public Support of Industrial R&D

13.12 The basic rationale behind public support of industrial R&D is based on a compelling economic rationale that sole reliance on the private sector will lead to under-investments in R&D.[129]

13.13 R&D grants and tax incentives are two financial instruments most widely used to support industrial R&D in developed as well as in developing countries.[130] Other financial instruments to support R&D include:

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[129] Nobel Laureate Kenneth Arrow (1962) argues that R&D under-investment will occur because private sector firms fail to recoup full returns from their R&D investments, despite the existence of institutional mechanisms such as a patent monopoly to exclude others from use of R&D results.

130 Leyden, Dennis Patrick, Link, Albert N. (1992), *Government's Role in Innovation,* Berlin: Springer**;** Lall, Sanjaya (2001), *Competitiveness, Technology and Skills,* Cheltenham, UK and Northampton, US*:* Edward Elgar**;** Mani, Sunil (2002), Government, Innovation and Technology Policy: An International Comparative Analysis, Cheltenham, UK., and Northampton, US: Edward Elgar.

- joint cooperative R&D projects between government and the private sector
- subsidising exchange of R&D personnel between public and private sectors
- promotion of national R&D projects
- creation or improvement of specialised financial market mechanisms (such as venture capital).

13.14 Table 13-2 summarises advantages and disadvantages of tax incentives and grants for R&D.

Table 13-2 Financial Instruments to Promote Industrial R&D[131]

Mechanism	Advantaged	Disadvantages
Tax Incentives	Low interference in the market Higher potential innovation outcomes Higher political feasibility Less bureaucratic & more predictable Stability of R&D incentive policy	A blunt instrument which does not allow targeting of R&D to specific areas Perceived as entitlement Insufficient return from finished projects
Research Grants	Allows governments to target areas with high social returns Could prompt potentially higher increase in business R&D Reward on a 'case-by-case' basis Selective incentive systems.	High market interference Dependent on annual budget reviews Temporary and unstable Require complex bureaucratic mechanisms.

13.15 Tax incentives represent an indirect form of support for business R&D by providing tax relief that lowers the costs to the company of R&D activities. Tax incentives in theory involve less interference in the market than grants as they provide more discretion to private companies, since the market, rather than the government, decides on allocation of resources to R&D investments. Tax incentives also allow firms to retain autonomy in devising their R&D strategies in response to market signals, and to select which R&D projects to carry out.

13.16 By comparison, R&D grants provide government support to companies directly and are inherently discretionary. Governments can define the support by industry sector and specify the selection criteria, amount and timeframes for funding. This allows a government to orient business R&D efforts towards projects with high social returns.

13.17 High social returns from R&D are often identified as 'spill-over effects' that include expanding the overall stock of scientific knowledge and skills available from R&D efforts. This benefit is expected in addition to stimulating private R&D funding beyond government investment and generated more businesses to engage in R&D.

[131] Adapted from Doh (2002) ibid.

13.18 Compared to grants, a tax incentive such as tax credit cannot be targeted at R&D projects with an expectation of large return in external benefits. Tax incentives are therefore described more as a blunt public intervention instrument.

13.19 In addition to these financial measures, there are non-financial mechanisms undertaken by governments to stimulate industrial R&D. These include:

- skills programs and human resources development policy
- policies aimed at diffusion of technology
- stimulating collaboration with university and government R&D
- public procurement (particularly in defence)
- intellectual property right (IPR) regime
- industrial standards
- industrial and trade policies.

R&D Tax Incentives

13.20 Most OECD countries have special tax treatment for R&D expenditures, such as immediate write-off of current R&D expenditures (all countries) and various types of tax relief such as tax credits or allowances against taxable income.[132]

13.21 Table 13.3 provides tax incentive comparisons for ten OECD countries including the UK. Despite variations within each country, the Table suggests that many countries provide significant tax incentives that include particular industry or regional incentives to retain domestic R&D as well as attract foreign R&D.

13.22 Tax incentives offer several advantages over grants if the objective is to boost a country's rate of commercialisation of new products, processes or services. As commercialisation success usually requires a thorough comprehension of market conditions, tax incentives leave R&D investment decisions to the market and individual companies rather than government agencies.

13.23 Direct funding of industrial R&D through grants may result in misallocation of resources among sectors of the economy. Tax incentives are less difficult to administer, since most grants are allocated on a case-by-case basis and require a certain level of administrative support. Grants may also be subject to yearly review and budget allocations, making them less predictable in the long run.

13.24 Yet tax incentives also have a number of limitations in relation to their administration. R&D tax subsidies tend to operate as entitlement, allowing all firms that qualify to claim a subsidy whether they actually need that subsidy or not. Tax credits can also be abused. For example, routine expenditures, such as those incurred

[132] OECD (2003) Science, Technology and Innovation Scoreboard.

in quality control and regular testing, may be classified as R&D expenditure, and claimed as a tax credit accordingly.

Table 13-3 Country Comparisons of R&D Tax Incentives[133]

Country	Description of Incentive	Impact and Implications
Australia	125% deduction for R&D expenses *Plus* 175% deduction for R&D expenditures exceeding a base amount of prior-year spending.	125% deduction is equivalent of a flat 7.5% R&D tax credit. Objective to attract foreign R&D facilities (approximately 50% of Australia's most innovative companies are foreign-based)
Canada	20% flat (i.e., first-dollar) R&D tax credit *Plus* various provincial governments offer various incentives (e.g., refundable credits) to locally based companies performing R&D.	Strong promotion to US to re-locate in Canada (e.g. 2003, U.S. subsidiaries spent US$2.5 billion in Canada Among most generous R&D tax credits in OECD; Canada has lower cost structure for R&D than either US or Europe
China	Provides foreign investment enterprises with 150% deduction for R&D expenditures, provided that R&D spending has increased by 10% from previous year.	10% incremental-increase not a difficult qualifier for successful western companies to grow start-up operations in China
France	50% R&D tax credit includes 5% flat credit and 45% credit for R&D expenditures in excess of average R&D spending over previous 2 yrs.	Incremental threshold requirement not likely difficult for “inbound” companies growing their operations in France (e.g. 2003, U.S. subsidiaries spent US&1.8 billion in France)
India	100% deduction of profits for 10 years for R&D companies. Auto industry entitled to 150% deduction for expenditures on in-house R&D facilities.	Over 100 global companies have established R&D centres in India in last 5 years
Ireland	20% R&D tax credit *Plus* full deduction, as well as a low generally applicable 12.5% corporate income tax rate Capital expenditures may also qualify for a separate flat credit	Nearly half of all IDA supported companies (government agency responsible for FDI) now have some expenditure on R&D and over 7000 people are engaged in this activity
Japan	Flat 10% R&D tax credit 15% flat credit provided for small companies, in addition to other incentives	(2003, U.S. subsidiaries spent US$1.7 billion in Japan) Ministry of Economy, Trade, and Industry (METI) estimates that R&D and IT tax relief has created 400,000 jobs and boosted GDP by US$55 billion over last 3 years
Korea	Tax holidays of up to 7 years for high-technology businesses. Variety of tax credits for R&D-type expenditures.	Korea not only promotes tax incentives but also other benefits for foreign companies locating R&D, particularly in the Incheon Free Economic Zone (“IFEZ”).
Singapore	R&D and IP Management Hub Scheme” offers 5-year tax holiday for foreign income earned by Singapore-based R&D	Aggressively seeks and attracts broad spectrum of R&D-intensive companies from across sectors (i.e. biotechnology, manufacturing and complex production operation sectors, IS/IT)”
United Kingdom	125% deduction for R&D expenses *Plus* 175% deduction for expenditures exceeding base amount of prior-year R&D spending	UK leads the world in attracting US investment (2003, US$4 billion) 125% deduction is equivalent of flat 7.5% R&D tax credit

[133] Adapted from the R&D Credit Coalition, “International R&D Tax Incentives Survey”; http://www.investinamericasfuture.org/factsheets.html.

13.25 Table 13-3suggests the high importance of many countries in attracting US R&D investment. Therefore, many of the incentives are biased towards US-style R&D activities. It can also be argued that R&D tax credits are not of immediate benefit to low R&D-intensive SMEs or to early stage high technology start-ups.

R&D Grants and Collaboration Schemes

13.26 As described earlier, R&D grants allow governments to direct R&D support - to particular industries, sectors or regions. This section will describe particular grant and collaboration initiatives among countries.

New Zealand

13.27 New Zealand is characterised by a small population base and low industrial R&D expenditure, similar to Scotland. In response to its trailing position in industrial R&D spend in the OECD, the New Zealand government initiated a series of grant schemes designed to complement its R&D tax incentive measures and its programs to attract and retain skilled scientists and science graduates. Table 13-4 identifies three grant schemes particularly focused on stimulating new companies and SME R&D.

Table 13-4 New Zealand: Government Support to Stimulate Industrial R&D

Scheme	Description
SmartStart	Provides 50% co-funding up to a maximum of $25,000 for qualifying external expenditure from successful applicants
Grants for Private Sector Research and Development (GPSRD)	Focuses on SMEs Provides partial funding of up to 33.3% of the eligible project costs, to a maximum of $100,000 including GST; minimum grant value is $10,000
Technology Expert Scheme	Assists companies to resolve issues associated with research or technology development projects by having the expert work alongside to transfer their skills and knowledge to others in the company Objective is to build new technical and technology commercialisation capabilities Company can apply for up to $168,750 ($150,000 plus GST) per annum per expert to support the expert's salary at what is considered market rates

13.28 While the New Zealand grants are moderate financially, the intention of these grants is to stimulate business to undertake R&D projects that have immediate or near term application rather than supporting intensive, longer term R&D efforts.

Australia

13.29 Australia launched a major initiative to stimulate R&D in 2001 with the *Backing Australia's Ability* program, with AUS$1 billion in public funds dedicated to R&D tax concessions and R&D grants.[134]

13.30 Table 13-5 identifies three grant schemes focused on stimulating industrial R&D.

[134] http://backingaus.innovation.gov.au/

Table 13-5 Australia: Government Support to Stimulate Industrial R&D

Scheme	Description
START	Provides grants and loans of up to AUS$15 million (average between $50,000 and $5 million) for early-stage companies **Core START** is for companies with turnover less than $50 million; funding on matching basis and assessed against strategic value, level of risk and likely spill-over effects of R&D **START Premium** is for strategic, high-risk projects involving large companies/consortia; repayable as royalty if project is successful
CRC (Cooperative Research Centres) Program	Provides 7 years of funding for collaborative R&D between industry, universities and public research centres; 75 projects primarily from environment and rural based manufacturing (56% of total) followed by medical science, mining and energy and manufacturing technology
Commercial Ready Program (CRP)	offers competitive grants to encourage Australian companies to increase R&D, proof-of-concept and early-stage commercialisation grants range from $50,000 to $5 million with maximum duration of 3 years.

13.31 The Australian grants provide support for early-stage companies and SMEs through the CRP and START programmes with criteria focused on commercial potential and strategic value/spill-over effects respectively. The CRC program is intended to stimulate more longer-term R&D collaboration between industry and public research institutions. An interesting element of CRC is the predominance of environmental and rural manufacturing projects, signalling that these grants are funding local and regional R&D initiatives as well as globally competitive R&D initiatives.

13.32 Case 1 identifies the importance of a balanced approach to attracting foreign R&D as described earlier. It identifies Australia as a particularly attractive R&D destination given its ‘host country characteristics compared to R&D requirements for ICT.

Case 1: Australia as a Competitive Location for ICT R&D

In a study commissioned by Invest Australia in 2005, the Economist Intelligence Unit (April 7, 2005) found that Australia to be the second most competitive location for ICT R&D out of 8 leading economies. The study found that overall Australia was second behind Singapore and ahead of Ireland, the United Kingdom, China, India, the United States, and Japan. The study compared the 8 countries using 150 different quantitative and qualitative indicators divided into five areas relevant to ICT R&D operations:

1. costs;
2. human resources;
3. tax;
4. ICT and R&D infrastructure;
5. Overall business environment.

The study notes that Australia's costs are competitive against the other developed countries in the study, but had better human resources, ICT R&D infrastructure and operating environment than its potential Asia-Pacific competitors India and China.

While India and China have some cost advantages, they rank at the bottom two countries in terms of their overall ICT and R&D infrastructure and business environment.

The study found that the cost of running a 10 person ICT R&D operation in Australia is less than 50% of the cost in the US and UK. It also found that the quality and availability of skilled labour is much higher in Australia than in Singapore.

Israel

13.33 Government policies since the mid-1980s are credited with stimulating significant commercial success of Israeli high technology and the leveraging of recognized scientific and technological skills in the country. These policies resulted in stimulating an Israeli market for venture capital (VC) investment, developing a technological incubators program and creating a program for the support of generic projects conducted by consortia of private firms and academia.[135]

13.34 Table 13-6 identifies four R&D grant schemes that subsidise industrial R&D and are administered by the Israeli government (through the OCS).[136]

Table 13-6: Israel: Government Support to Stimulate Industrial R&D

Scheme	Description	Conditions
General	Project lasting at least 1 year; results in manufacture of new product Significant improvement in existing product or new or improved industrial process	50% grant of total R&D expenditures
R&D start-up support	Proposed R&D must be first and only activity of start-up; Start-up must have no other sources of financing	66% of total R&D expenditure of US$250,000 per year for 2 years

[135] Trajtenberg (2002).
[136] OCS (Israeli Office of the Chief Scientist).

Scheme	Description	Conditions
	except from developers	
R&D for existing product	As identified above (under general scheme)	30% grant of total R&D expenditure (regardless if original product received government assistance)
Beta-site stage R&D support	Tests the product for market; Funds use by selected end-users who supply technical feedback and suggestions for modifications or product features, specifications	50% grant for companies with sales (last 3 years) have not exceeded US$6 million 30% grant for companies with sales less than US$30 million in last financial year

13.35 Evidence suggests that these R&D grants have been highly successful in encouraging industrial innovation in Israel, but this success is qualified by four other complementary conditions:[137]

- Israel benefits from a strong and steady supply of highly trained engineers and scientists;
- R&D grants are administered efficiently through a single agency, the OCS;
- R&D grants are not targeted to specific sectors or technologies; therefore a large base of companies, existing and start-up have access;
- Israel benefits from a strong, active venture capital (VC) community; that invests in small and medium sized technology-based companies.

13.36 An important observation here is that these grants encourage Israeli companies that are already 'going concerns' to take on R&D projects once they are in a position to expand and diversify. Only one grant is focused on start-ups and the proportion of start-ups receiving R&D grants overall is just over one-quarter (28%) of the total (the remainder being comprised of SMEs and large companies).[138]

13.37 The OCS grants attract not only start-ups but higher quality companies that may have previously preferred to turn to private investors, but with likely less success than in securing an OCS grant. These grants also have provisions to allow Israeli companies to transfer their intellectual property (IP) and manufacture abroad.

13.38 A fuller account of the Israeli situation is given as a Case Study in the following section of his report.

Canada

13.39 Government support of industrial R&D in Canada is justified by below average R&D intensity among G8 countries. A high degree of foreign ownership and a relatively

[137] Teubal (2002): Israel has the highest per capita number of scientists and engineers in the world.
[138] Teubal (2002).

small size of R&D intensive-industries are identified as main contributors to Canada's poor R&D performance.[139]

13.40 One initiative undertaken by the Canadian government is to support collaboration with countries whose R&D performance is strong. One such program is the Canada-Israel Industrial Research and Development Foundation (CIIRDF), established in 1994 to promote collaborative R&D between firms in both countries. CIIRDF is involved in three broad complementary activities:

- promoting & marketing benefits of Canadian-Israeli R&D collaboration
- matching companies in one country seeking a research partner in the other
- supporting projects by contributing up to 50% of the joint R&D costs.

13.41 Case 2 describes the CIIRDF program.[140]

[139] Institute for Competitiveness and Prosperity, Ottawa, March 10, 2006.
[140] http://www.ciirdf.ca/awards.php

Case 2: R&D Collaboration Schemes: Canada and Israel

The CIIRDF is itself an innovation for Canada, as this is the first analogous foundation established for the promotion of bilateral R&D with another trading partner. For Israel, CIIRDF is one of a number of similar bilateral initiatives, the first being the U.S.-Israel Bi-national Industrial R&D initiative (BIRD). The CIIRDF program design is based on the success of BIRD.

Through CIIRDF, Canada-Israel company partners have the opportunity to receive funding to cover up to 50% of the research and development costs of technology-based products and processes which have a reasonable potential for commercial success. Should the funded project result in commercialization, the partners will be responsible for the repayment of the funding amount to CIIRDF.

CIIRDF actively assists companies in both countries to identify appropriate candidates for such partnerships. In addition to facilitating partner identification, in some cases, CIIRDF will provide financial support for studies exploring the feasibility of pursuing such R&D partnerships.

CIIRDF's major role is that of sharing in R&D risk by investing up to CD $20,000 for feasibility studies and up to CD $800,000 for full-scale R&D projects undertaken as a joint project by Canadian and Israeli partners. The CIIRDF awards are provided on a cost-share basis for up to 50% of the project R&D costs. CIIRDF retains neither equity nor intellectual property rights as a result of its contribution. It does, however, require that the award be repaid by the project partners should the project result in commercialization and revenue generation. If the project does not lead to revenue generation, as a result of either technical or marketing failure, no repayment is required.

At the end of which the Product should be close to market-ready. Project duration may be up to 3 years and Feasibility Studies have a maximum duration of 6 months.

The Israeli company and the Canadian company are collectively referred to as the "Proposer." The agreement reached between CIIRDF and the Proposer is typically a three-party agreement (i.e. between the Canadian and Israeli companies and CIIRDF), and is separate from any agreement or joint business plan in place directly between the Canadian and Israeli companies. Although the company-company agreement is not subject to review by CIIRDF, it is expected that the parties both stand to gain from the Project, and that they have agreed on issues relating to manufacturing rights, marketing, intellectual property rights, etc. Note that the Proposer need not be a legal entity.

Successful Full-scale Projects will receive funding in three instalments: the first upon signing the Cooperation and Project Funding Agreement, the second upon submission and acceptance of the interim Technical and Fiscal Reports, and the final payment upon submission and acceptance of the Final Report. Feasibility Studies will receive two payments, 50% upon signing of the Agreement, and the balance upon submission and acceptance of the Final Report.

CIIRDF investments in full-scale projects are repayable. The Proposer is required to make payments to CIIRDF based on gross sales derived from the sale, leasing or other marketing or commercial exploitation of the product or process innovation resulting from the Project. The repayment rate is 2.5% of gross sales revenue semi-annually, beginning with the semi-annual period during which the first sale was made following receipt of the Award, and ending when at least 90% of the Award value has been repaid to CIIRDF.

The process followed by CIIRDF was developed to keep the administrative burden to a minimum for all parties. There are two categories of project applications: Feasibility Studies (investigations to determine the technical feasibility or market acceptability of a new product or process concept), and Full-Scale R&D Projects. Feasibility Studies can be approved by the CIIRDF President, but Full-Scale Projects require Board approval. After the initial expression of intent by the Proposer to apply for Full-Scale Project funding, CIIRDF may invite a detailed proposal.

Non-financial R&D Support: skill programmes

13.42 In addition to R&D tax incentives and grants, most OECD countries identify the importance of providing programmes to attract and retain skilled R&D labour. Research grants will likely only work effectively when there is a critical mass of scientists and engineers to undertake the R&D activities. Therefore, a steady stream of highly trained personnel is necessary if business R&D is to thrive.

13.43 R&D spend by companies is primarily in personnel and equipment. The quality of personnel available is a function of training and research activities in the higher education system and availability of an international-standard research infrastructure. One suggestion for why the European Union has a net outflow of almost €5 billion in R&D investment to the US is that the US has a more highly qualified base of scientists and researchers and associated R&D support infrastructure.[141]

13.44 One program offered by Invest Australia is the Supported Skills Program (SSP), designed to encourage international firms to choose Australia as a location for R&D investment. The SSP allows companies that make a significant investment in Australia to bring out key expatriate managerial and specialist employees from within the company group who are essential for establishing R&D operations in Australia. Agreements will be granted for three years, although individual visas, once granted, extend beyond the period of the agreement. Agreements are for both permanent and temporary entry of eligible staff and are for circumstances where a number of key personnel are required.

13.45 Although studies suggest a positive relationship between scientific competence and foreign R&D investment, it appears that **research output and productivity** of the scientific community in a locale is a better benchmark of scientific-educational capability that is attractive to foreign R&D.[142] The implication is that R&D activities that are encouraged and rewarded to perform through government incentives are more likely to be successful.

13.46 Similar to Canada and New Zealand, Scotland has a historically low level of business R&D investment and this low level has been associated with Scotland's low productivity growth.[143] While economic theory suggests that innovative activity is usually more concentrated than other economic activities and that regions with greater concentration of innovative activities are more likely to experience economic growth, this has not been the case with Scotland in recent years.

13.47 It is recognised that R&D and productivity are closely associated and provide a measure of how effectively businesses exploit existing technology and develop new products and processes.

[141] http://ec.europa.eu/research/press/2003/pr2511en.html
[142] Doh (2002).
[143] Scottish Executive (2003).

13.48 Of the top 10 publicly quoted companies in Scotland, five are either banks or utilities, suggesting that Scotland has too few major directly R&D-dependent industries.[144]

13.49 A related factor contributing to Scotland's poor business R&D performance compared to the UK average is an identified skills shortage in R&D. Approximately 6,000 people work in R&D in enterprises in Scotland, 3,500 of them as scientists and engineers. R&D provides employment for 6% of all scientists and engineers in the Scottish labour market, but well below the UK average of 13%.[145] Similar concerns have been raised regarding the fragility of industrial R&D in the UK as a whole, as it remains heavily dependent on the investment decisions of a dozen large companies, concentrated in two sectors: pharmaceuticals and defence.[146]

Key issues

13.50 The paper identifies the critical importance of public support to stimulate private investment in R&D, to compete with other countries in a highly competitive R&D global landscape and to ensure a balance among the factors contributing to foreign R&D location decisions.

13.51 The paper describes that most leading OECD countries undertake R&D tax incentives, but that R&D grants and skill programmes provide countries with more flexibility to support sector specific or regional R&D deficiencies or build on existing strengths.

13.52 Specific Australian R&D grants were identified with clear objectives such as commercial, short-term benefits vs. longer-term benefits of public-private R&D collaboration and related spill-over effects to the public. The CRC program was described as relevant to stimulating R&D in domestic industries as well as supporting R&D in globally competitive Australian companies.

13.53 New Zealand grants were identified as moderate financially, but intended to stimulate businesses to undertake R&D projects that have immediate or near term application rather than supporting intensive, longer term R&D efforts.

13.54 The Canada-Israel Industrial Research and Development Foundation programme was identified as an example of a new collaboration approach (for Canada) with a strong globally competitive R&D player (Israel) involved in other bi-lateral R&D collaborations. The objectives are to stimulate shorter-term R&D opportunities between individual businesses and longer-term R&D collaboration between the two countries.

13.55 Given the Israeli success from R&D grants, one implication for the Scottish context is that R&D grants should not be biased towards sectors or towards start-ups who have not yet received private investment and are not yet going concerns. Indeed, the Israeli

[144] UK Parliament (2001).
[145] Ibid.
[146] HM Treasury (2004).

emphasis is on supporting R&D primarily in healthy, already established companies (see later).

13.56 By comparison, a number of R&D grants in Scotland support commercial activities of early-stage or first-time R&D players, many of whom arise from public research efforts. Other schemes appear to assume that simply making grants available for R&D collaboration between industry and the public sector will stimulate new levels of industrial R&D activity. Public support of industrial R&D in Scotland needs to be more explicit in intent, criteria and options if the intention is to stimulate new R&D activities in existing Scottish companies.

13.57 Further, new initiatives should be considered to support R&D collaborations between Scottish and foreign companies rather than relying on collaborations with public sector research to generate new industrial R&D.

14: Case Study: Israel

14.1 This report provides a case analysis of the Israeli innovation model to consider implications for improving Scotland's industrial research and development (R&D) capabilities and performance. Israel is a credible comparator to Scotland, with both nations characterised by small, relative high-cost and open economies, strong public sector research institutions, average levels of entrepreneurship[147] and 'peripheral' challenges relative to accessing 'core' markets in continental Europe and the US. The report concludes with a case summary and recommendations.

Key Success Factors of the Israeli Innovation Model and comparisons with Scotland

Role of Government

14.2 Government intervention is identified as a key factor in boosting the performance of the Israeli economy.[148] A world-class high technology-biased economy has been attained in no small part to the Israeli government's long-term strategy to develop a highly flexible entrepreneurial and market-oriented environment for R&D. Since the 1980's, the Office of the Chief Scientist (OCS) at the Ministry of Trade has managed Israel's R&D strategy through a multi-phased innovation and technology policy (ITP).

14.3 The OCS performs responsibilities that in the Scottish context are undertaken by a number of separate agencies. The OCS manages various support mechanisms for Israel's high tech industries that include a comprehensive R&D grants program. The OCS also works with regional and national authorities to facilitate technology transfer from the public science base to the business sector by promoting links with business and creating the infrastructure and catalytic conditions for investment.

14.4 The Israeli ITP rests on two pillars: 1) decentralization to promote initiative; and 2) co-ordination to promote efficiency. Over the last quarter century, the ITP has evolved in phases to provide individual industrial R&D grants, grants to support generic R&D projects conducted by consortia of private firms and academia[149], a technological incubators program and development of a venture capital (VC) community focused on high technology ventures.[150]

R&D Grants

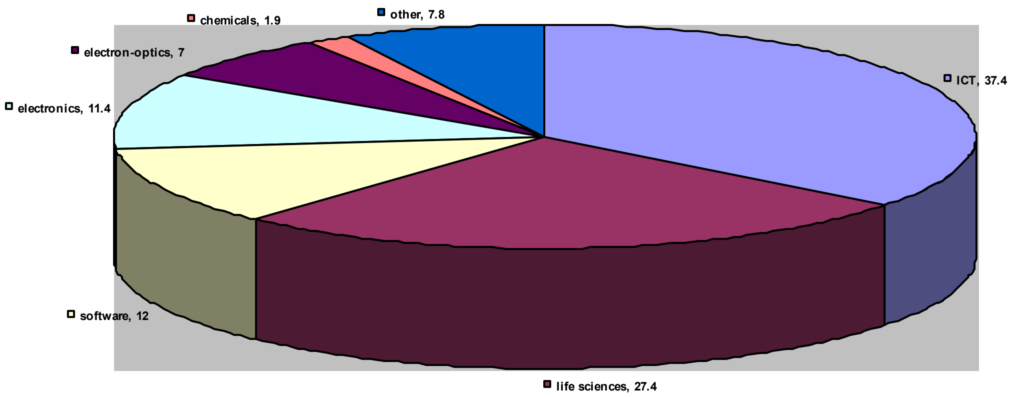
14.5 Strong industrial R&D performance in Israel is identified with a generous R&D grants programme that provides investment *across* a range of R&D intensive

[147] Global Entrepreneurship Monitor (2005).
[148] Trajtenberg (2001) *R&D Policy in Israel,* Haifa University Working Papers Series.
[149] Trajtenberg (2002).
[150] Avnimelech and Teubal (2002) in *The Growth of Venture Capital.* Greenwood Publishing.

sectors.[151] The OCS invested approximately US$300 million in industrial R&D grants in 2005 with over 1000 projects from over 500 companies supported.[152]

14.6 Figure 14-1 shows a percentage breakdown of R&D grants providing in 2004. While three sectors - information and communication technologies (ICT), software and electronics - accounted for 60% of funding, a key objective of the OCS is to stimulate R&D investment and activity across a number of high technology sectors.

Figure 14-1 Israeli Government R&D Grants by Technology Sector (2004)[153]



14.7 Table 14-1 identifies four Israeli R&D grant schemes administered by the OCS alongside four Scottish R&D grants for the purposes of comparison.

Table 14-1: Comparison of R&D Grants in Israel[154] and Scotland[155]

Israel	**Scotland**
General	SMART
Significant improvement in existing product or new or improved industrial process; results in manufacture of new product;	Technical and commercial feasibility study; 6-18 months at 75% of cost
at least 12 months long	For new or existing small independent firms or firms with less than 50 employees
50% grant of total R&D expenditures	Maximum of £50,000
Beta-site stage R&D support	SPUR
Tests the product for market;	Develop new products & processes involving a 'significant technological advance'
Funds use by selected end-users who supply technical feedback and suggestions for modifications or product features, specifications	Focus on SMEs; less than 250 employees
50% grant for companies with sales (last 3 years) have not exceeded US$6 million	6 months to 3 yr projects; fixed grant level of 35% of eligible costs
30% grant for companies with sales less than US$30 million in last financial year	Maximum of £150,000, if eligible projects costs are at least £75,000
R&D for existing product	SPUR PLUS

[151] Frenkel et al. (2001)
[152] Ibid.
[153] Adelman (2005), Office of the Chief Scientist.
[154] OCS (Israeli Office of the Chief Scientist).
[155] http://www.bgateway.com/bg-home/bg-services/bg-technology-innovation.htm

Israel	**Scotland**
As identified above (under general scheme) 30% grant of total R&D expenditure (regardless if original product received government assistance) product must have sizeable potential for export sales	Outcome of 'world-beating products and processes'; development up to pre-production prototype stage Maximum of £500,000 if eligible project costs are at least £1 million; 35% of eligible costs
R&D start-up support Proposed R&D must be first and only activity of start-up Start-up must have no other sources of financing except from developers 66% of total R&D expenditure of US$250,000 per year for 2 years	R&D PLUS Project to either create or safeguard R & D jobs Deliver commercial benefits to local economy Demonstrate strategic importance of project to the company 25% of eligible costs to undertake development of new products or processes to the pre-production prototype stage

14.8 Table 14-1 identifies among the Scottish R&D grants, SMART, SPUR and SPUR^{PLUS}, a strong technical focus to eligibility criteria. These three grants are also designed to be single company schemes, rather than to stimulate joint ventures or collaborative projects in R&D.

14.9 The R&D PLUS programme is focused on retaining or improving the level of R&D activities among large Scottish-based companies and attracting new companies to establish an R&D presence in Scotland. But explicit programme aims – to deliver benefits to the local economy, safeguard or create R&D jobs, confirm the company's strategic prioritisation of R&D – in addition to the programme's low level of eligible costs, are in contrast to the market-driven focus characterising Israeli R&D grant criteria.

14.10 Indeed, important differences between Israel and Scotland are suggested in Figure 2 regarding the eligibility criteria, level of funding and purpose of R&D grant support. The Israeli OCS provides defined, market-focused criteria for its R&D grant options, sets out conditions for R&D collaboration and technology transfer and provides higher funding levels for R&D support.

14.11 Three of the four Israeli grants shown in Table 14.1 support R&D primarily in healthy, already established companies. A typical Israeli company has a large percentage of turn-over attributed to R&D investment (30% on average compared to 1% in Ireland for example). Israeli companies also employ a much higher percentage of R&D workers (25% on average compared to 2% in Ireland). [156]

14.12 The level of funding and scope of R&D activity eligible for securing an R&D grant in Israel may attract higher quality companies that have previously preferred to turn to private investors, but with less likely success than in securing a grant.[157] R&D grants also have provisions to allow Israeli companies to transfer their intellectual property (IP) and manufacture abroad. If an Israeli company that receives an R&D grant sells

[156] Frenkel et al, p.8; reliable data on the % of R&D per Scottish company and % of R&D workers engaged in R&D have not been compiled.
[157] Lach (2002) "Do R&D Subsidies Stimulate or Displace Private R&D: Evidence from Israel", p. 370.

its IP, the government gets back its percentage of investment from the sale price. A similar formula has been approved for companies that make an exit.

14.13 R&D grants are also used in Israel to diversify R&D investment across the regions of the country. Larger R&D grant provisions and capital grants are used by the OCS to stimulate R&D activity outside of the central (Tel Aviv) area along with other government incentives such as corporate tax rates that attract R&D facilities by foreign multinationals to the north and south of the country.[158]

14.14 Israeli grants favour companies that are already 'going concerns' to take on R&D projects once they are in a position to leverage R&D funds, expand and diversify. By comparison, Scottish R&D grants such as SMART often support commercial activities of young companies or first-time R&D players, a number of whom are products of public research efforts. New companies may not have the experience to most effectively undertake R&D internally or have a full understanding of market-driven outcomes for their R&D activities to most effectively leverage the benefits of the grant.

14.15 The eligibility criteria for Scottish R&D grants favour technical achievements. R&D activity less well aligned with market-driven outcomes is more likely, arguably, to result from new companies with limited market experience.

14.16 Funding R&D activity with poorly aligned market-driven outcomes is more likely if these are not explicit grant deliverables or if grants are assessed solely by public sector administrators in the absence of industrial partners or 'market-side' agents. Critics suggest that existing mechanisms to support industrial R&D in Scotland is weakened by funding 'routine' production processes carried out by some Scottish business that are not in fact 'world-beating'.[159]

R&D Collaboration

14.17 Specific government support is provided in both Israel and Scotland to stimulate R&D collaboration between the public science base and industry. Table 14-2 identifies two programmes established to facilitate such collaboration.

Table 14-2 R&D Grants to Stimulate Private-Public R&D Collaboration

Magnet (Israel)	**SCORE (Scotland)**
Collaboration between companies and academic research groups organized in consortia or dual cooperation between one academic group and one industrial company	Support R&D projects jointly undertaken between public sector research bodies (HEIs, Research Institutes, NHS Trusts) and Scottish SMEs
Support for pre-competitive R&D & new generic technologies leading to new generation advanced products	SME or group of SMEs with specific technical problem can assign significant part of required scientific & tech research to public sector research body

[158] E.g. externally-owned companies investing in the peripheral regions of Israel can enjoy full tax remission for 10 years, compared to 2 in central areas (Frenkel, Shefer and Roper (2001): Public Policy, Locational Choice and the Innovation Capability of High-tech Firms: A Comparison between Israel and Ireland.
[158] OCS (Israeli Office of the Chief Scientist).
[159] ITI Scotland (2004).

Magnet (Israel)	SCORE (Scotland)
	50% eligible project costs
Industrial partners receives 66% of approved R&D costs; academic partner receives 80% of said costs; foreign company eligible if bringing a unique contribution	Maximum of £35,000
4 tracks:	Research base partner must incur, defray at least 40% of total eligible costs and receive 100% of their total eligible costs
Magneton: proof-of-concept between academic and industrial partner; 2yrs and up to $800,000	
Nofar: basic research for application for industrial partner use; 1yr, up to $100,000	
Consortium: develop innovative technologies for next generation of products' line; 3-6 yrs	
Association: re-applying existing tech to new applications	

14.18 A number of important differences are evident between the Israeli Magnet and Scottish SCORE programmes, beginning with the scope of funding. The SCORE programme is narrowly focused on technology development between public and private partners and provides a single level of cost deferral and funding.

14.19 The Magnet programme has four options for collaboration depending on the objectives of consortia partners, ranging from market-driven applications for basic research to development of next generation products. Foreign companies are also eligible for funding under Magnet if they can demonstrate a unique contribution.

14.20 The high level of Magnet funding provides incentives for academics and industry to engage with each other and includes larger foreign high-tech companies undertaking R&D operations who are a major presence in Israel. R&D collaboration by multinationals, mostly US, is motivated by access to world-class technical innovation generated by intensive, concentrated R&D and start-up activities in Israel.

14.21 IBM has had a presence in Israel since 1949 and Intel has 5500 employees in Israel, with two state of the art factories. Intel's VC arm - Intel Capital- is the largest VC in the world, committing US$150m to WiFi technology alone in 2002; several of its investments are in Israeli start ups. Applied Materials has over 1000 employees in Israel, while Microsoft has a substantial R&D presence as do Johnson & Johnson and Pfizer.

14.22 Israeli R&D collaboration among academia, local and foreign industry has been further supported by the government's establishment of science parks such as the Weizman Park in 1967. Science parks have been successful in attracting foreign R&D operations to locate in proximity to leading Israeli academic institutions such as the Weizmann Institute of Science and Hebrew University, where high start-up activity is also evident.

14.23 Efforts to stimulate R&D collaboration in Scotland face a number of 'dilemmas' that challenge programs such as SCORE. One dilemma is that Scottish policy-makers appear over-reliant upon the public science base to support and indeed stimulate industrial R&D in SMEs, given the absence of large-scale industrial R&D activity.

14.24 Scotland's SMEs are often characterised has having poor 'absorptive capacity' which limits their ability to pull research from the public science base and higher education institutes (HEIs).[160] This perceived mismatch between public science and the ability of SMEs to absorb such knowledge also relates to the fact that SMEs are not a homogeneous group facing similar problems or requirements that lend themselves to successful R&D collaboration with HEIs. For example, some SMEs may face a class of problems related to managerial performance that benefits from a short-term, low-cost project or collaboration.

14.25 SMEs that require process-based innovations or performance improvements are more likely to benefit from a more extensive, collaborative R&D relationship with an academic partner.[161] However, the successful outcome of such collaboration may require an academic partner who demonstrates 'commercial awareness' in properly assessing the class of problems facing the SME and flexibility to undertake a market-driven rather than research-driven collaboration.

14.26 A related problem is the ability and/or willingness of HEIs and research institutions to assist SMEs.[162] Although initiatives such as SCORE are intent on promoting contact and R&D collaboration between the public research base and SMEs, differing institutional structures and incentives to engage in small-scale R&D collaboration on both sides remain key constraints.

14.27 The Israel innovation system shares with Scotland the absence of large, R&D intensive companies in the economy. However, Israeli policy-makers chose not to simply focus on stimulating collaboration between public science and indigenous SMEs but also to build up the capabilities of each to benefit from the collaboration.

14.28 For this, the government leveraged Israel's advantages in sectors where they had comparative advantages in industrial R&D such as ICT. Israel's world-leading position in the ICT sector derived in part from efforts to transfer military R&D to civilian purposes in the 1970s and resulted in successful ICT companies being formed.

14.29 Successful ICT companies created conditions from which Israel's innovation and technology policy (ITP) provided support to stimulate collaboration with local public research institutes and foreign R&D, to support R&D in upcoming indigenous start-ups through a comprehensive grant scheme and to stimulate a domestic VC industry that would invest in the sector.

14.30 The ICT example serves to illustrate how R&D intensive SMEs can provide a strong incentive to attract collaboration from R&D-intensive multi-nationals, leading to increases in foreign investment in R&D. It is interesting to note that public research

[160] Joint SHEFC/Universities Scotland Taskforce on Knowledge Transfer (2006): Annex A.
[161] AIM Report (2004): The Challenge of University-Industry Collaboration.
[162] Ibid.

institutions play a minimal role in high technology development in Israel's ICT sector today.[163]

14.31 Israel, in contrast to Scotland (or indeed Ireland), has not encouraged inward investment to attract large-scale production facilities, but rather has prioritised the development of indigenous and innovative high technology industry. Foreign-owned manufacturing operations in Israel are rare and are identified as having contributed little as a source of managerial training to the Israeli innovation system.[164] Manufacturing facilities in Israel tend to be smaller and more oriented towards research-driver markets.

14.32 The Israeli government, in supporting development of indigenous R&D *and* foreign direct investment (FDI) in R&D, has reaped important spill-over effects. Multinationals provide Israeli start ups with a window on the world's markets and may act as references, partners and customers for start ups.

14.33 Companies such as Mirabilis (sold to America Online in 1998 for US$400million) and Check Point Software Technologies have provided opportunities for Israelis' to gain experience working in the US in management, marketing and sales positions before returning home.

14.34 Israeli high-tech companies also benefit from international know-how and professional experience from Europe, as many engineers and managers are coming back to settle in Israel. Foreign industrialists and companies like Volkswagen, Hoescht, Henkel, Samsung, Daewoo, Fujitsu, Nestlé, Volvo, Nokia and Carlsberg provide technical and commercial related opportunities and experiences for Israeli personnel that feed back into indigenous companies.[165]

14.35 International R&D collaboration is further supported through the Bi-national R&D Fund (BIRF) which stimulates collaborative R&D programs involving an Israeli company and foreign company. These programs were originally set up to diffuse R&D and innovation from the Israeli defence industry to business and have evolved to stimulate innovation capabilities for Israeli companies through collaboration links with foreign partners.

14.36 BIRF now involves collaborative R&D between Israel and 5 countries: the US, Canada, UK, Singapore and South Korea. Israel has Parallel Funding Agreements with 114 other countries as well as three regional governments (Ontario, Canada, Maryland, US and Victoria, Australia).

14.37 Particulars of the BIRF Programme are described below.[166]

[163] Adelman (2005), Office of the Chief Scientist, CISTRANA Workshop.
[164] Rosenberg (2002).
[165] Kahane and Raz (2005).
[166] http://www.ciirdf.ca/awards.php.

BIRF Programme

The BIRF programme provides bilateral R&D between Israel and another trading partner, with the first being the U.S.-Israel Bi-national Industrial R&D initiative (BIRD).

Through BIRF, company partners from the two countries have the opportunity to receive funding to cover up to 50% of the research and development costs of technology-based products and processes which have a reasonable potential for commercial success. Should the funded project result in commercialization, the partners will be responsible for the repayment of the funding amount to BIRF.

Each BIRF Programme actively assists companies in both countries to identify appropriate candidates for such partnerships. In addition to facilitating partner identification, in some cases, BIRF will provide financial support for studies exploring the feasibility of pursuing such R&D partnerships.

The BIRF's major role is that of sharing in R&D risk by investing in feasibility studies and in full-scale R&D projects undertaken as a joint project by both partners. The BIRF awards are provided on a cost-share basis for up to 50% of the project R&D costs. BIRF retains neither equity nor intellectual property rights as a result of its contribution. It does, however, require that the award be repaid by the project partners should the project result in commercialization and revenue generation. If the project does not lead to revenue generation, as a result of either technical or marketing failure, no repayment is required. At the end of which the Product should be close to market-ready. Project duration may be up to 3 years and Feasibility Studies have a maximum duration of 6 months.

14.38 'Britech' is the Britain-Israel Technology Foundation, a joint initiative of the UK and Israeli governments dedicated to supporting collaborative partnerships between high-technology companies. Since commencing in 1999, Britech has provided grants of more than £12M to collaborative R&D projects and helped to establish more than 100 technology partnerships. As of June 2006, Britech's operational arrangements will change to reflect the Israeli and UK Governments' plans for future technology activities between the two countries. What is not clear is the role played by Scottish companies in Britech or the impact of Britech to date on the technology partnerships involved.

14.39 A key strength of the Israeli innovation system is its international R&D connections and collaborations, in particular with the US. Israel is also active in R&D projects funded by the European Union's Framework Programmes. One programme, Matimop, specifically promotes and assists participation of Israeli companies in international cooperation programmes for industrial R&D. Several liaison offices maintain the presence of Israeli companies in European R&D consortia.

Support for R&D in start-up companies

14.40 Israel's ITP provides an integrated approach to start-up assistance designed to stimulate R&D intensive, indigenous firms to become 'export-ready'. The OCS supports one R&D grant exclusively dedicated to start-ups that comprises 15% of total OCS R&D grant funding. The proportion of Israeli start-ups receiving R&D

grants overall in 2001 was 28%, the remainder being SMEs and large companies.[167] At the same time, larger R&D grants are provided to start-ups (66%) than to established companies (50%).

14.41 The latest phase of the OCS' innovation and technology policy (ITP), since 2000, includes the 'Tnufa' programme designed to encourage and support technological entrepreneurship and innovation at the pre-seed stage. Tnufa assists individual inventors and start ups at the critical early stages and includes evaluating the technological and economic potential of the idea, preparation of a patent proposal for submission to patent authorities, construction of a prototype, preparation of a business plan, establishing contact with appropriate industry representatives and attracting investors.

14.42 Grants of up to 85% of approved expenses are available to a maximum of US$50,000 to each project. The Tnufa programme is designed to provide technologists and entrepreneurs with assistance on go/no-go decisions on their technologies.

Incubator Support

14.43 The Israeli Technological Business Incubators (TBI) Programme allows nascent companies to develop their innovative technological ideas with the primary objective of attracting a first round of venture capital (VC) funding. The TBI Programme emphasises high-tech developments and exports over research centre activity and supports a broad range of scientific, technological or industrial sector preferences. In 2005, there were 23 TBIs, with approximately 200 companies.

14.44 Some TBIs located near research institutes favour projects that can benefit from local technological infrastructures and networks. Other incubators are becoming more specialised and sector-specific. Recent biotechnology incubators have been set up as franchises awarded to companies, or groups of companies. The government participates in the form of a loan, which may later be converted into shares, to finance the R&D in the projects performed in the TBI. The franchise-holder bears the operating costs for the TBI, which is operated, for-profit, for at least six years.[168]

14.45 The TBI Programme offers 85% of eligible costs to a maximum of US$330,000 and provides physical premises, financial resources, tools, professional guidance, and administrative assistance. Each TBI is an independent entity that provides a skilled and experienced general manager and a board of directors, with a management team of six persons on the average managing between ten and 20 projects per year. The TBI also provides financial assistance for marketing expenses of start-up firms. Projects have to prove their viability in less than two years.

14.46 In Scotland, incubator support for technology start-ups has not been centrally administered or strategically planned. A recent report suggests that *"many projects have been developed in isolation and failed to integrate economic development*

[167] Teubal (2002).
[168] OCS (2005).

objectives; many have become property projects driven by occupancy levels and rental income rather than strategic economic objectives or business needs."[169]

14.47 The majority of Scotland's 57 incubators are sector specific: 32% in the software sector; 25% in the biotechnology/bio-medical/healthcare sector and 19% are technology-related.[170] A number of Scottish universities have incubator space and some universities have their own or jointly owned science parks.

14.48 While the incubation function in the Scottish innovation system is identified as *"largely unstructured and fragmented with no apparent common direction or cohesion",* it is also identified with an important support role in the commercialisation of university research, supporting spin-out from established companies and, in more rural areas, acting as a focus for the delivery of business support services.[171]

14.49 However, in comparing Israeli and Scottish approaches to incubation and their role in supporting R&D, Israeli TBIs and their management teams share a common objective of assisting clients in attracting a first round of venture capital (VC). A common market-driven focus characterising the TBI Programme is less evident in Scotland, where incubators will reflect broad variations in economic objectives arising from differing regional development goals, institutional intentions, capabilities, etc.

Investment for R&D

14.50 The Israeli government has been instrumental in stimulated venture capital to support its high tech industry, particularly during the late 1980s and early 1990s.[172] Israel today is the third largest venture capital recipient in the world. From one company in 1994, Israel is now home to over 70 investment companies with more than 50 funds relevant to high tech industry.

14.51 Government intervention arose through the Yozma Program (1993-98), a one-off programme involving US$100M of public funds, of which $80M was invested into 10 VC funds. A key requirement of these 10 funds was that they include local and foreign partners, with the intention that Israeli VCs could learn from foreign, primarily US-based VCs and that foreign VCs would take on risk in investing in Israeli high technology. The Government investment component was privatized in 1997, closing three years ahead of schedule and leveraging over US$200 million in VC.[173]

14.52 While Israeli VC accounts today for just less than half of the private equity raised by indigenous tech companies, Israeli VCs are seen as providing invaluable local support for start-ups and exploitation of R&D efforts. The scale of VC funding available allows Israeli companies to attract funding from seed to mezzanine. Certain funds, such as BRM Group, have US$500 million devoted to early stage-starts-ups and take

[169] Roper et al (2006) "The Scottish Innovation System: Actors, Roles and Actions", section 6.4.
[170] Ibid.
[171] Ibid.
[172] Rosenberg (2002).
[173] Ibid, p. 115.

the role of dramatically decreasing time to market with intensive management support.[174]

14.53 Multinationals also play an important role in investment in Israeli high technology. In the period 2000-2003, the largest investors were Intel (29 co-investments, together with Israeli VCs), followed by J.P. Morgan (16 deals).

14.54 Scotland, on the other hand, has fewer active VC funds. Government intervention to increase the amount of risk funding available for investment in early-stage technology companies is identified in schemes such as the Scottish Co-Investment Fund (SCF).

14.55 Archangels Informal Investments, Scotland's largest angel syndicate, remains active in providing private equity to early-stage R&D intensive companies in Scotland.

14.56 Barry Sealey, Co-Founder of Archangels, identifies the lack of 'good technology deals' rather than lack of private equity investment as a key constraint to high technology investments in Scotland.[175] The low level of larger deals requiring VC funding in Scotland has resulted in contraction of VCs such as 3i from Scotland.

Socio-Cultural Factors

14.57 Examination of the Israeli innovation system, with particular reference to R&D, has identified the influence of a number of socio-cultural factors and conditions.

14.58 Much has been make of the effect of military service within the Israeli Defence Forces, or Tsahal, as an important contributor to Israeli innovation. Tsahal is identified as a central component of Israeli society, fostering a culture of risk and of constant competitive intelligence that is manifest in Israeli companies. Many Israeli companies are organized in small units which are flexible and quick to react, reflecting this military influence. It is suggested that Israeli industry largely reflects this mentality through corporate cultures that are usually informal, with professional relationships weakly hierarchical.[176]

14.59 The level and performance of private equity investment in Israeli start-ups is also identified with the sense of urgency among VCs, entrepreneurs and teams to develop opportunities quickly, to react fast and to understand the challenges. This may be a factor in the rate of angel investment in start-ups, which is one of the highest in the world in addition to VC investments.[177]

14.60 Despite spill-over effects from defence in sectors such as electronics and support from the OCS, it has been left to Israeli entrepreneurs to carve out opportunities in competitive global markets such as the US electronics market. According to the Global Entrepreneurship Monitor (GEM), Israel is 'average' in terms of entrepreneurial activity, similar to Scotland. This suggests the Israel and Scotland have similar low rates of the population who seek to start their own companies.

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[174] http://www.brm.com.
[175] Interview, 29/08/06.
[176] Trajtenberg (2001).
[177] Rosenberg (2002) *"Cloning Silicon Valley"*, p. 106.

14.61 An important difference between Israel and Scotland, however, is in the level of skilled people engaging in R&D. An identified factor contributing to Scotland's poor industrial R&D performance compared to Israel is an identified skills shortage in R&D.[178]

14.62 Skilled immigration remains an important contributor to Israel's innovation success. In the 1990s, skilled immigration from the collapse of the USSR doubled Israel's per capita ratio of scientists and engineers, already one of the highest in the world.[179] The TBI Programme - originally set up to leverage the scientific and technical knowledge of skilled immigration arriving from the former USSR – is likely providing ongoing benefits to the Israeli innovation system by exposing this skilled workforce to an immediate R&D environment.

Implications for Scotland

14.63 A summary of key insights from the Israeli case analysis are suggested below:

- Israel has taken a long-term economic strategy – with acceptable government intervention - to support industrial R&D that includes: a vision of economic development (Innovation and Technology Policy), identification of *systems failures* and generation of *strategic priorities* to overcome system failures;[180]

- ITP strategy is phased to address immediate "systems" failures, and flexible to consider outcomes, success and experiences that inform subsequent phases;

- ITP is administered efficiently through a single agency, the Office of Chief Scientist (OCS);

- ITP has evolved as an externally focused, network-based innovation system, which provides linkages, interactions and collaborations among the world's leading technology nations, regions and companies;

- direct OCS intervention has successfully strengthened R&D performance through high levels of R&D grant support, broad R&D collaborations involving local and foreign partners, and creation of a business environment for intense VC activity;

- OCS support has facilitated a tight relationship of synergy between indigenous universities, research institutes, start-ups and SMEs;

- R&D grants are non-biased to technology sectors - with the objective of generating a broad based of R&D-intensive SMEs and start-ups in Israel; this has resulted in increasing the number of Israeli companies available for and active in R&D collaborations;

1.1 [178] HM Treasury (2004).

[179] Kahane and Raz (2005) "Innovation projects in Israeli incubators", European Journal of Innovation Management.

[180] Israel is not constrained by European Commission (EC) State aid policy; i.e. whereby certain economic sectors, regions or activities are treated more favourably than others; Articles 87/88 of the EC Treaty forbid aid that discriminates between companies that receive assistance and those that do not.

- high levels of R&D activity and collaborations are possible only through a steady supply of highly trained engineers and scientists;
- level and quality of R&D is sustained by further policies (i.e. capital grants) to attract world-class foreign R&D operations to Israel;
- foreign VC attracted by intensity of R&D activities has helped develop Israeli VC that provides more risk capital to indigenous start-ups;
- world-leading position in certain sectors (i.e. ICT and electronics) provides scale and scope to develop a reservoir of managerial talent from multiple company formations and exists - to provide an experienced ‘gene pool’ for start-ups and successful role models for next generation of Israeli entrepreneurs;
- manufacturing facilities are promoted in Israel, but are small and oriented towards research-driven markets and generated from SME activity.

Key issues

14.64 Key issues to be addressed relevant to Scotland’s business R&D performance based on this case analysis are set out below:

- examine closely the potential benefits of a single body to oversee the implementation of an Innovation and Technology Policy (or an “R&D and innovation” policy), similar to the Officer of Chief Scientist in Israel (see also TEKES in Finland and Vinnova in Sweden);
- increase industrial R&D activity in Scotland at three levels:
  - support an increase in industrial R&D activity by world-class, R&D-intensive multi-nationals:
    - provide capital grants and other incentives to attract foreign R&D facilities to locate to Scotland
    - develop a Bi-national R&D Fund that supports collaborative R&D programs involving a Scottish company and e.g. a US company; objectives are to stimulate shorter-term R&D opportunities between individual businesses and longer-term R&D collaboration between the two countries; no bias by sector if companies meet criteria, although world-leading sectors would be actively encouraged to participate
- stimulate and support an increase in the number of existing Scottish SMEs undertaking R&D:
  - promote to Scottish SMEs the support available to undertake R&D projects that have more immediate or near term applications (rather than undertaking intensive, longer term R&D efforts) – see for example the characteristics of SCIS

  - increase the eligibility criteria of SPUR^{PLUS} to facilitate appropriate collaborations that can include foreign partners

  - expand the eligibility of POC to include non-public research institutions, SMEs and corporate spin-outs based in Scotland

  - provide a 'research translation grant' (similar to Israeli Nofar) to convert basic research to use by industrial partners; (e.g. 1 year, up to £75,000); this would support SME collaboration with HIEs and research institutes as well as with R&D-intensive start-ups

- support Scottish technology start-ups to remain R&D-intensive:

  - re-balance the *level* of R&D grant to "going concern" companies (but no bias by sector). For example, this could involve supporting R&D-intensive start-ups whose only activity is R&D but who have demonstrated successful collaboration (or secured contracts) with world-leading companies; up to £175,000 for 2 years

  - continue (and expand) the Scottish Co-investment Fund to support VC and Angel investments in Scotland

  - provide a financial 'support' incentive to management at all Scottish incubators and science parks focused on securing external equity investment for their R&D-active client companies.

15: Issues arising

15.1 From the research conducted in the preparation of these papers, the following issues arise of particular relevance to business R&D in Scotland, including policy implementation issues.

Profile

15.2 There would be merit in raising the profile of the benefits of business "R&D" generally and of business R&D achievements as an input to innovation and competitiveness throughout the Scottish business base. Arguably, business R&D has a relatively low profile in Scotland when compared to other inputs to innovation; to entrepreneurship and new firm formation; and to the research conducted within the publicly funded research base.

Targeted national action

15.3 The argument which links levels of investment in R&D to innovation, to productivity and then to enhanced economic performance as measured by GDP is widely used and underpins much analysis of the (under) performance of the Scottish economy when compared to OECD norms.

15.4 In line with UK-wide goals, the Scottish Executive supports the UK Government's 10 year Science and Innovation Investment Framework published in June 2004 which sets the objective of increasing business and public investment in R&D as a proportion of GDP to 2.5% by 2014. This UK Framework set a goal for business expenditure in R&D (BERD) as a share of GDP of 1.7%

15.5 Although R&D is only one input to business innovation and productivity performance, given the importance accorded to it for Scotland there would be merit in establishing higher profile, integrated and nationally agreed actions focused on promoting the business value of investment in R&D. This should be complemented by existing and where appropriate, targeted new business support interventions (including interventions that do not include provision of financial support for R&D projects), by a cadre of expert advisors on R&D management for businesses, and tracked by statistics on activities, outputs and outcomes to measure progress towards the policy goal of increased BERD.

Disseminating and benefiting from recent policy research

15.6 There appears to be a convergence of activity at this time on matters that are of relevance to the SSAC Working Group on business R&D. This includes the work of the Scottish Funding Council's Knowledge Transfer and Innovation Group as well as recent research commissioned by the Scottish Executive. The latter includes its research into business attitudes to R&D and innovation, its mapping of the Scottish innovation system, and the analysis of the Community Innovation Survey results for Scotland.

15.7 The innovation systems mapping forms part of a portfolio of policy-related research funded within the Scottish Innovative Actions Programme managed by the Strathclyde European Partnership. Other relevant projects in this portfolio include "Growth and Innovation Drivers for business in Scotland" and "Business Environment Mapping", both being undertaken by Scottish Enterprise.

15.8 There would be merit in a public forum to disseminate and learn from this substantial body of new policy-related research.

Ensuring effective incentives

15.9 A number of public sector initiatives available to the Scottish business-base seek to encourage and support business investment in R&D and address associated market failures. In addition to grant schemes (SCIS, SMART etc.), tax relief for R&D expenditure has been available in the UK since 2000, initially for SMEs and since 2002 for larger companies. The R&D Tax Credit is designed to incentivise and reward firms investing in R&D to enhance their performance and ultimately contribute to the competitiveness of the UK.

15.10 In a UK-wide survey of businesses conducted by Deloitte in 2006[181], it was found that fewer than 50% of eligible smaller firms were taking advantage of the R&D Tax Credit. Furthermore, of those firms responding to the survey that had failed to claim, c. 25% is reported as being unaware of the scheme's existence.

15.11 Given its aim of encouraging firms, especially SMEs, to invest in R&D and given the importance of smaller companies to the Scottish economy, it would be timely to analyse the take-up and success, or otherwise, of the R&D Tax Credit scheme in Scotland in incentivising additional investment in R&D.

15.12 There would also be merit in examining the working of the Small Business Research Initiative (SBRI) in Scotland.

Strengthening the pipeline of support

15.13 The Scottish Executive has put in place a so-called "pipeline of support" for R&D and innovation for the Scottish business base. Although R&D grant schemes managed by the Executive are focused on "new to the market" innovation, we would argue the merits of encouraging, in addition, a wider cross-section of companies to engage in R&D, not least because "*undertaking R&D is normally a pre-requisite before firms participate in collaborative projects with the science base*"[182]. Also, Scotland's innovation performance lags in terms of investment in R&D per employee, at 45% of the UK value and ranked ninth of 12 UK areas[183]. "Entry level" schemes to support R&D should be encouraged and given a higher profile.

[181] Deloitte (2006) Missing the boat? R&D tax incentives – SMEs fail to optimise.
[182] Council for Science and Technology (2000) Technology Matters
[183] Scottish Executive (2003) ibid.

15.14 The Small Company Innovation Support scheme (SCIS), managed by the Enterprise Networks, provides support to businesses for R&D, market research and product launch. It is aimed at R&D in support of innovation that is "new to the firm". Anecdotally, it appears that SCIS has a relatively low profile in the Scottish business base. It would be appropriate to re-examine the balance between supply and demand (and opportunity) relating to SCIS, and re-assess whether the present access to SCIS remains optimal.

15.15 Scotland performs well relative to other parts of the UK in terms of take-up of Knowledge Transfer Partnerships (KTP). Again, there would be merit in re-assessing the balance between supply and demand (and opportunity) for KTPs in Scotland and whether the level of present provision is optimal given the findings.

Management capacity and capability

15.16 In its evidence to the Scottish Parliament's Business Growth Enquiry in April, 2004, SCDI stressed the importance of effective management skills in the Scottish business base, considering it essential that Scottish business leaders "*have the knowledge and insights to make decisions on investment, R&D innovation and employee development*". A recent report on the Scottish Innovation System[184] stated that "*A very consistent picture was drawn of the relative thinness of the SME sector in Scotland in terms of scientific and managerial competence ....*". The analysis of the Third Community Innovation Survey results for Scotland[185] points, among some positive messages about the innovation performance of the Scottish business base, to poorer performance with respect to the UK average in terms of organisational innovation, such as advanced management techniques.

15.17 Whilst acknowledging the present provision of business support interventions targeted at e.g. marketing, exporting, managing intangible assets, lean management etc., the provision of management development initiatives for SMEs targeted at business decisions associated with R&D, its management and where appropriate, its procurement appear to be much less in evidence.

15.18 A needs/opportunities assessment for enhancing business management skills directed towards utilising and exploiting R&D investments as an input to business competitiveness should be undertaken. This is likely to involve two strands of investigation: enhancing capability amongst the current cadre of business managers and, for the longer term, ensuring a flow of prospective future managers capable of bridging between science/technology and business.

15.19 The substantial effort and emerging success in universities to create a cadre of people capable of bridging between science/technology and entrepreneurship is an indication that the challenge of bridging between science/technology and business is a tractable one.

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[184] Aston Business School and Cardiff University (2006) *The Scottish Innovation System: actors, roles and actions*. Report to the Scottish Executive.
[185] Michie et al (op. cit.)

Resolving apparently contradictory findings from recent policy research on the capabilities of the Scottish business base.

15.20 In various guises, the view has often been expressed that the Scottish business base fails to exert a "pull" on the research excellence in the Scottish science base. Some have expressed this as a lack of so-called "absorptive capacity" in the business base. This view has been re-stated recently in the findings of the work on the Scottish Innovation System[186]. However, the analysis of the Community Innovation Survey for Scotland[187] (CIS3) on the face of it offers a somewhat different view: the authors of this report state "*Our analysis suggests ..... Scottish firms' greater utilisation of external resources as sources of innovation inputs*", i.e. they absorb from their wider environment and according to this report, appear to do so despite their undoubted relatively low level of spend on R&D.

15.21 It is important that a robust and clear evidence base is in put in place to inform and guide policy implementation in the area of business R&D. The apparently mixed messages about the innovative behaviour and capabilities of the Scottish business base need to be re-examined and resolved as far as possible. This could be done in the context of an analysis of the recently published UK data for CIS4.

Ensuring that the significance of services sector R&D and innovation is understood and valued appropriately

15.22 As reported by the Scottish Economic Statistics (Scottish Executive, 2005), the service sector was largely responsible for the overall growth in Scottish GDP in the year ending June 2005, the sector showing an annual growth of 2.9%. Furthermore, the banking sector showed the largest annual growth. In the context of an analysis of R&D performance, this raises two issues.

15.23 Firstly, it is argued that the structure of the Scottish industry-base, with the importance of the services sector, by itself biases national performance with respect to BERD as a percentage of GDP, and that the importance of the banking sector in particular adds to this "problem". The definitions used in the presentation of statistics therefore present Scotland's innovation performance, so the argument goes, in a poor light with respect to comparator areas.

15.24 It is undoubtedly true that Scotland's financial services, including the banking sector excels in an internationally competitive market and is highly innovative. It is not, however, R&D intensive in a traditional Frascati definition of the term. It does have interests in the output from R&D in its supply chain and it purchases products which embed prior R&D. Furthermore, from research on the sector internationally and from consultations with senior representatives of Scotland-headquartered banks, the Scottish research base has particular centres of excellence that should be of strategic interest to the banking sector in future, including notably in the area of informatics.

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[186] Roper et al ibid
[187] Michie et al (op. cit.)

15.25 The research-intensive Scottish universities together with the Scottish Funding Council, given the latter's interests in knowledge transfer, should engage pro-actively with the global banking sector headquartered in Scotland to assess areas of mutual value through collaboration in research and knowledge exchange. It seems intuitively obvious that given the prominence of the banking sector in the Scottish economy, the work of the Scottish university sector, in research and knowledge transfer, should be seen to relate to and be responsive to this sector's needs and opportunities. This report has offered some international examples that point to what might be achieved.

15.26 The second strand in an analysis of services sector R&D concerns the BERD data that indicate not only that Scotland's performance across the board lags behind UK and OECD norms, but that the services sector as a whole in Scotland appears to perform at a relatively low level of investment – the BERD in Scotland (2003) report records an R&D expenditure per employee in the Services sector in Scotland of £125, compared to a UK figure of £417, a UK: Scotland ratio of 2.4. The same ratio for manufacturing is 1.8 and for all business sectors 2.2.

15.27 There would be merit in a closer examination of the R&D (and innovation) performance of the services sector in Scotland in order to understand more fully what lies behind the evidence of the sector's relatively low investment in BERD. There would be merit in analysing the constituent elements of the headline figures in order to understand the segmentation of different knowledge-intensive services sub-sectors in Scotland and why lower services sector spending on R&D is occurring, even with respect to the rest of the UK.

Tools for businesses investing in R&D

15.28 One factor in proceeding with business investment in R&D concerns having confidence in internal capabilities to ensure quality of the R&D. In the same way as businesses in Scotland can access tools for developing business plans, marketing strategies etc., tools to assist in ensuring the quality of any R&D undertaken by or for the firm would be useful to have in the business toolbox. The delivery of the tool would contribute further to the overall awareness raising and promotion of business R&D.

15.29 The Enterprise Networks should consider introducing a national "product" concerned with the management and quality assurance of business R&D. Exploratory research indicates that the R&D Effectiveness Index may provide a suitable basis for the development of a tool, specifically for smaller companies.

Business-university collaborations

15.30 This has not been the prime focus of this study but some of the observations made by a consultee in one innovative company committed to engaging the university base are selected for repetition here (the full list of observations is given in Section 6):

- universities need more familiarity with the processes of modern business, particularly the time pressures under which commercial entities operate

- it is better for companies to develop long term relationships with a few professors/faculties they know and trust - such collaborations can go from strength to strength over time
- universities need to undertake joint projects for the right reasons - to appreciate what both sides will achieve through the process, rather than seeing commercial links simply as a source of research funding for personal interest projects.

Summary of main drivers for internationalisation of R&D

15.31 The paper identifies the critical importance of public support to stimulate private investment in R&D, to compete with other countries in a highly competitive R&D global landscape and to ensure a balance among the factors contributing to foreign R&D location decisions.

15.32 Most leading OECD countries undertake R&D tax incentives, but that R&D grants and skill programmes provide countries with more flexibility to support sector specific or regional R&D deficiencies or build on existing strengths.

Some lessons to consider from international policy and practice

15.33 There would be merit in researching more deeply the benefits of a more integrated approach to the implementation of innovation and technology policy (or an “R&D and innovation” policy), similar to the Office of Chief Scientist in Israel (see also TEKES in Finland and Vinnova in Sweden).

15.34 Given the Israeli success from R&D grants, one implication for the Scottish context is that R&D grants should not be biased towards sectors or towards start-ups who have not yet received private investment and are not yet going concerns. Indeed, the Israeli emphasis is on supporting R&D primarily in healthy, already established companies.

15.35 Furthermore, new initiatives should be considered to support R&D collaborations between Scottish and foreign companies rather than only relying on collaborations with public sector research to generate R&D.

15.36 The international lessons re-confirm the need to increase business R&D activity in Scotland at three levels:

- support an increase in industrial R&D activity by world-class, R&D-intensive multi-nationals:
    - provide capital grants and other incentives to attract foreign R&D facilities to locate to Scotland (ensuring the appropriateness of the present R&D Plus scheme)
    - develop a bi-national R&D Fund that supports collaborative R&D programmes involving a Scottish company and e.g. a US company in order to stimulate shorter-term R&D opportunities between

individual businesses and longer-term R&D collaboration between the two countries

- stimulate and support an increase in the number of existing Scottish SMEs undertaking R&D:
  - promote to Scottish SMEs the support available to undertake R&D projects that have more immediate or near term applications (rather than undertaking intensive, longer term R&D efforts) – see for example the characteristics of SCIS
  - increase the eligibility criteria of SPUR^{PLUS} to facilitate appropriate collaborations that can include foreign partners
  - adapt Proof of Concept-type schemes to include non-public research bodies, SMEs and corporate spin-outs based in Scotland Expansion of Proof of Concept-type support. Subject to constraints that may be placed on investment by European State Aid rules, there would be merit in an investigation of the needs/opportunities to develop innovative products and processes of value from sectors of these other sectors of the economy
  - provide a 'research translation grant' (similar to Israeli Nofar) to convert basic research into use by industrial partners (e.g. 1 year, up to £75,000): this would support SME collaboration with HIEs and research institutes as well as with R&D-intensive start-ups
- support Scottish technology start-ups to remain R&D-intensive:
  - re-balance the *level* of R&D grant to "going concern" companies (but no bias by sector). For example, this could involve supporting R&D-intensive start-ups whose only activity is R&D, but who have demonstrated successful collaboration (or secured contracts) with world-leading companies
  - continue (and expand) the Scottish Co-investment – type funding to support VC and Angel investments in Scotland
  - provide a financial 'support' incentive to management at all Scottish incubators and science parks focused on securing external equity investment for their R&D-active client companies.