Sourcing Science

The use by Industry of the Science Base for Innovation; Evidence from the UK's Innovation Survey

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Abstract

This paper draws on the UK's version of the 3rd European Community Innovation Survey (CIS-3) to investigate the contribution that the 'public science base' – that is universities and publicly funded research institutes – makes to innovation in firms. We use the CIS-3 to investigate the *direct* and *indirect* links between the science base and innovation in firms. Although, with some exceptions, the direct links are not widespread, there is evidence that as firms' own commitment to innovation increases so does the extent to which they engage the science base in their innovation activities. Meanwhile, there is also evidence that the indirect links between the science base and industry are more important than the direct links, but overall access to technology is not amongst the most significant impediments to innovation in firms. Other factors (such as market conditions, lack of ambition, access to finance, and the quality of demand) have a greater role in explaining the innovation performance of firms. Essentially, the primary reason why firms rarely engage the science base is that relatively few firms have high commitments to innovation.

1.0 Introduction[1]

In recent years, the economic contribution of 'the science base' has come under increasing scrutiny. Science budgets have often been cut precisely because they could be reduced without an immediate and noticeable impact on the economy. Following what Paul David has described as 'the new spirit of "economic instrumentalism"' (David, 1999, p. 1), universities and the science base are increasingly expected to 'be useful' in order to justify government's largesse. This is certainly the case in the UK, where, Charles Clarke, the government minister with overall responsibility for higher education has said on a number of occasions that:

> [T]he "medieval concept" of the university as a community of scholars is only a very limited justification for the state to fund the apparatus of universities. It is the wider social and economic role of universities which justifies more significant state financial support.[2]

Elsewhere, the same minister is reported to have suggested that the 'truth seeking' role justifies only about 1% of the government's expenditure on universities.[3]

Throughout the 1980s and 1990s, universities in the UK came under increasing financial pressure, largely because the massive expansion in student numbers has not been matched by increased funding, and in real terms funding per student has declined by more than half since 1975.[4] Since 1997, Britain's 'new Labour' government has at least halted the decline in funding per student, and has come to recognise that the university system 'is undoubtedly under severe pressure and at serious risk of decline' (DfES, 2003, p. 13). It is also beginning to increase in real terms expenditure on higher education. But as a price for this increased funding, the government expects reform, and one aspect of this reform is that universities, and the science base more generally, increase their links with industry.

Having been neglected for so long, the universities and science base are now seen as a strategic asset in the 'knowledge economy'. The recent White Paper entitled 'the Future of

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1 The research presented in this paper has been partially funded by the DTI through two projects, the first undertaken by Peter Swann on 'Innovative Businesses and the Science and Technology Base: An Analysis using CIS-3 data' (Swann, 2002), the second involving both of us as part of a wider project 'Knowing How, Knowing Whom A Study of the Links between the Knowledge Intensive Services Sector and The Science Base' (Miles et al., 2003). We gratefully acknowledge these sources of funding. We are also grateful to the DTI, and in particular Dr. Ray Lambert, for access to the data analysed in this paper. Previous versions of this paper were presented at the International Workshop on Innovation in Europe: Empirical Studies on Innovation Surveys and Economic Performance in Rome in January and at the CIS users group meeting, in London in June. We thank the participants for their comments. The views expressed in this paper are those of the authors, and do not necessarily reflect those of any other parties.

2 Letter to the Guardian newspaper, 10th May, 2003

3 BBC Website (http://news.bbc.co.uk/1/hi/education/3014423.stm) Friday, 9 May, 2003

4 Writing in the Guardian newspaper on 5th December, 2002, Anthony Giddens the Director of the London School of Economics notes: 'Funding in British universities per student fell by 29% in real terms between 1976 and 1989, and by a further 38% from 1989 to 1999. The UK spends only 1.1% of its GDP on tertiary education, compared to 2.3% in the US and 2.5% in Canada. £3.5bn would have to be spent per year merely to bring the UK up to the EU average, which is itself well below that of North America.' He concludes: 'The status quo is simply not an option. It is a recipe for continuing decline and decay.'.

Higher Education' (DfES, 2003) states that: 'In a knowledge-based economy both our economic competitiveness and improvements in our quality of life depend on the effectiveness of knowledge sharing between business and higher education' (DfES, 2003, p. 36). This places universities and the science base 'centre stage' in economic development. Similar sentiments are reported elsewhere. For example, Lord Sainsbury, the minister responsible for 'science and innovation' has written: 'Creating strong links between Higher Education Institutions (HEIs) and businesses is an essential part of improving our economic performance, and HEIs have an increasingly important role to play in increasing the competitiveness of regional economies' (DTI, 2002). In this climate, the Treasury and the Department of Trade and Industry (DTI) have asked Richard Lambert to undertake an inquiry into business-university collaborations. The Lambert Review is premised on the view that while the UK performs well in terms of its science and technology base, it is not as good at commercialising the knowledge generated as other countries – notably the US (Lambert, 2003). The brief given to Lambert clearly indicates the intention to strengthen the interaction between business and universities by encouraging universities to become more responsive to the needs of business.[5] For example, it is notable that Lambert has not been asked to examine the opportunity costs or possible negative consequences of greater interactions between business and universities.

Given the context outlined above, it is perhaps alarming that the recent UK Innovation Survey of 2001 (the UK's version of the third Community Innovation Survey, CIS-3) found that only 1.4% of firms (with 10 or more employees) in the UK regarded the universities as a source of information of high importance for their innovation activities (Stockdale, 2002), whilst only 0.4% gave this status to government research organisations. Combined, this suggests that less than 2% of firms in Britain regarded the 'science base' as being of 'high importance' when sourcing information for their innovation activities. Meanwhile, the same survey found that less than 3% of firms had collaborative arrangements for innovation with a university, and only about 1% had such arrangements with a government research organisation. Combined, only about 3% of firms had collaborative arrangements for innovation with the 'science base'. These proportions are small <u>if</u> links between business and the science base are indeed "essential to economic performance". The government certainly thinks there is room for improvement, lamenting that: 'less than one in five businesses taps into universities' skills and knowledge' (DfES, 2003, Executive Summary - p 4).[6]

5 The terms of the Lambert review of business-university collaboration state that it will: (1.) Identify the benefits to business of greater interaction with higher education, how this can be promoted and how any barriers holding back business demand for universities' knowledge and skills outputs can be addressed. (2.) Examine the national, regional and local economic impacts of business-university interactions, including how Regional Development Agencies and Sector Skills Councils can best support such interactions. (3.) Assess the lessons to be learned from business-university interaction across a range of countries and from best practice across the UK. (4.) Analyse how business employers can better communicate their skills requirements to a responsive university sector, and how they can improve the attractiveness of career paths to graduates and postgraduates, especially in technology; and (5.) Examine the effectiveness of measures such as the R&D tax credits on business demand for research and skills. (6.) Ask business for its views on the present governance, management and leadership arrangements of higher education institutions, and their effectiveness in supporting good research and knowledge transfer and providing relevant skills for the economy.

6 This figure is drawn from an analysis of the UK CIS-3, the dataset we examine in this paper.

In this paper, we will look behind these headline findings, to explore the relationship between the science base and industry. In so doing, we ask three questions. Firstly, why do so few firms report using the science base in their innovation activities? Secondly, are the actual links stronger than those reported? And thirdly, to what extent is a lack of access to technology and skilled personnel – matters about which the science base can directly assist - recognised as barriers to innovation in British industry? We examine these questions – as far as we are able - through an analysis of the UK's version of the third European Community Innovation Survey (CIS-3) of 2001.

The paper takes the following structure. In Section 2 we introduce the data-set that we will examine. The data analysis is undertaken in Section 3. In Section 4 we discuss our findings in the context of the current debate, and in Section 5 we provide some conclusions.

2.0 The UK Version of the Third European Community Innovation Survey

As stated in the introduction, this paper explores the use of the science base by firms in relation to their innovation activities. Here, the 'science base' is composed of universities and publicly funded research centres. We do this by analysing the UK's version of the 3rd European Community Innovation Survey (hereafter the 'CIS-3'). This survey was carried out in 2001 and relates to innovation activities engaged in between 1998 and 2000. The survey was a general survey of firms (or enterprises)[7] with 10 or more employees, and included both manufacturing and commercial service activities.[8] In the context of the current debate the survey is useful because it provides some indications from firms themselves as to which types of businesses use the science base for innovation, and to what extent they are hampered by a lack of access to scientific or technological knowledge. Particularly with respect to services little is known about these links and barriers to innovation.

The UK CIS-3 provides a data-set of 8,172 responses from 'enterprises' engaged in 'production activities' (i.e., extraction, manufacturing, construction and the utilities) and marketed 'service activities' (such as wholesaling, financial intermediation and business services). A total of 4,097 firms with 10 or more employees and primarily engaged in 'production activities' responded to the questionnaire, whilst 3,245 responses were received from firms with 10 or

7 For the purposes of the survey, the response unit was an 'enterprise' (although we shall use the term 'firm'), which was defined as 'the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more locations. An enterprise may be a sole legal unit' (from the survey form of the 'UK Innovation Survey').

8 The survey, which was voluntary and postal, covered firms 'in section C-K of the Standard Industrial Classification (SIC) 1992. All production and construction (here referred to as 'production activities') divisions were included, i.e., sections C (mining and quarrying), D (manufacturing), E (electricity, gas and water supply). In distribution and services (here referred to as 'service activities') only SIC 51 (wholesale trade except of motor vehicles) is included from section G (wholesale and retail trades; repair of motor vehicles and personal and household goods) with section H (hotels and restaurants) excluded completely. Sections I (transport, storage and communication), J (financial intermediation) and K (real estate, renting and business services) are included in their entirety' (Stockdale, 2002, Annex A – see this for further details on the survey's methodology).

more employees and primarily engaged in 'service activities'. In this paper, we will analyse these two samples separately and in parallel.[9]

The CIS-3 is a survey of innovation in industry (including services). It is not a survey specifically intended to investigate the links between industry and the science base. Consequently, only a proportion of the survey is relevant to the debate concerning the links between industry and the science base, and moreover the information that is available is less than ideal for our purpose. Nevertheless, the UK CIS-3 provides a large sample of responses from firms, many of which are engaged in innovation and the survey can provide some interesting insights concerning both the direct and indirect contributions of the science base to innovation in firms.

3.0 Investigating the Links between the Science Base and Innovation in Firms

We will undertake the data analysis in three parts. Section 3.1 will investigate the 'direct links' between innovation in industry and the science base; Section 3.2 will investigate some 'indirect links'; and Section 3.3 will focus on the 'factors hampering innovation', with particular reference to the extent to which firms were hampered in their innovation activities by a lack of access to technological information or knowledge, and by a lack of skilled personnel.

3.1 The Direct Links for Innovation Between Industry and the Science Base

The CIS-3 includes two questions that allow us to examine the *direct contribution* of the public science base to innovation activities in firms. The first of these is as a source of information (or knowledge) for innovation, the second is as a partner in collaborative arrangements for innovation. We examine these in turn.

3.1.1 The Public Science Base as a Source of Information for Innovation

Question 12 of the CIS-3 questionnaire asks about "the sources of information [used] for innovation activities". The firms were asked: "Please indicate the sources of knowledge or information used in your technological innovation activities, and their importance during the period 1998-2000." Eighteen sources were then listed, and the firms were asked to indicate whether these were 'not used', 'of low importance', of medium importance' or 'of high importance'.

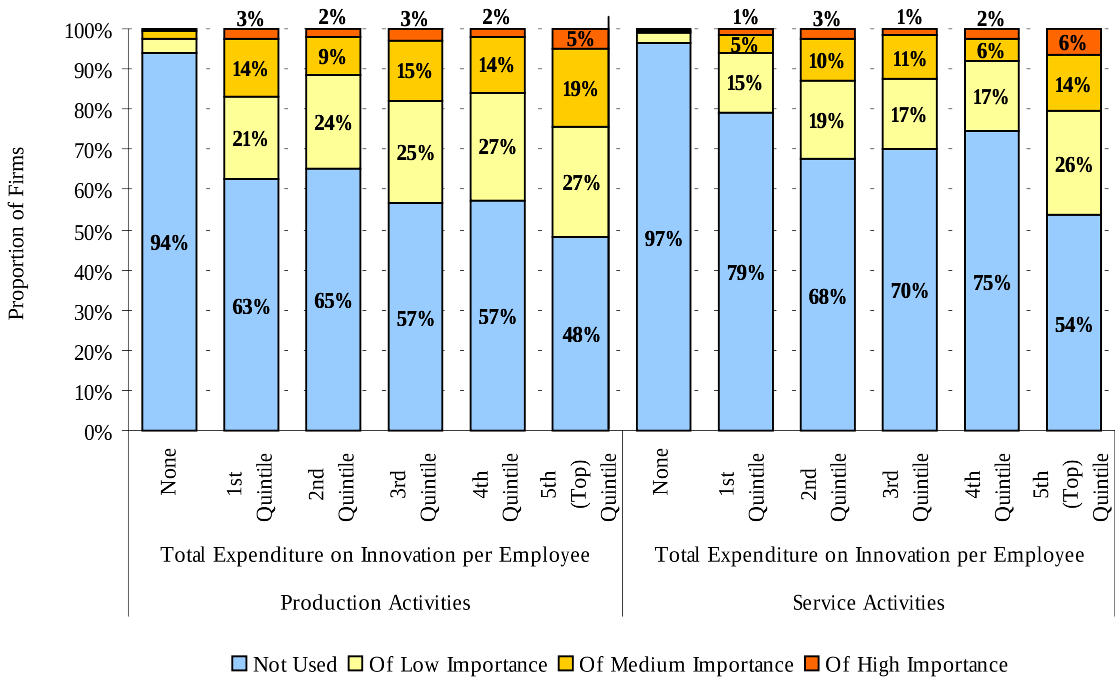
As mentioned in the introduction, the universities and government research organisations were amongst the least likely of these sources to be identified as being of 'high importance'. It is also the case that they were amongst the least likely of the sources to be used at all. About 16% of firms engaged in production activities and 12% of those in services claimed to have used the

9 The main reason for doing this is that much more is known about patterns of innovation and interaction between production firms (principally manufacturers) and the science base than is known about the links between the science base and service firms. By analysing these two sub-samples in parallel we can see whether the patterns found amongst production firms are replicated for service firms.

universities as a source of information for innovation,[10] while about 11% of production and 9% of service firms claimed to have used the government's research organisations as a source of information for innovation.[11] Combined, about 19% of production and 14% of service firms claimed to have used the science base as a source of information for innovation, but only about 1% and 1.5% respectively claimed the science base was a source of information of 'high importance' for their innovation activities.

It is difficult to know whether these figures are impressive or disappointing. On the one hand the finding that about one in six firms (with 10 or more employees) claimed to have use the science base directly in their innovation activities is impressive given the widespread perception that the science base is remote from business. On the other hand, it is also notable that very few of the businesses that drew on the science base regarded the information provided as being of high importance for their innovation activities. Certainly relative to other sources, such as sources within the firm, suppliers and customers,[12] the science base was not widely engaged and was perceived as being relatively unimportant.

Figure 1:
Expenditure on Innovation and Use of the Science Base for Information



This raises the questions, what types of firms used the science base as a source of information for innovation, and what types of firms regard the science base as being a source of high importance for their innovation activities? An examination of firms' expenditures (per

10 Whilst only 1% and 1.4% respectively claimed the universities were a source of information of 'high importance' to their innovation activities

11 With 0.3% and 0.4% respectively regarding these as a source of 'high importance'

12 All of which were identified as being used by more than 40% of both production and service firms, and were regarded as being as source of high importance by at least one in ten of both production and service firms.

employee) on innovation activities shows that those firms that themselves made the greatest commitments to innovation tended to be those that were the most likely to make use of the science base as a source of information for innovation.[13] Figure 1 shows that amongst the firms in the fifth quintile, that is those that made the greater, half of production and 45% of service firms indicated they had used the science base as a source of information for innovation. Five percent and 6% respectively declared the information provided by the science base to be of 'high importance' for their innovation activities. By contrast, amongst the firms that indicated they had no expenditures on innovation in 2000, only 6% of production and 3% of service firms claimed to have used the science base as a source of information for innovation. These patterns indicate that as firms increase their own commitments to innovation, they become more interested in directly engaging the science base to assist with their innovation activities.

A second way of illustrating how the firms' own commitments to innovation relates to the extent to which they engage the science base is shown through the construction of a 'dynamism score'. This score is intended to provide an indication of the extent to which the firm was engaged in competitive and innovation activities. It was constructed as follows:

- Firstly, those firms that that indicated they had engaged in innovative activities between 1998 and 2000 were distinguished from those that had not.[14] The former were given a score of 1, the latter 0. Overall, 46% of production activity firms, and 41% of service firms were categorised as being engaged in innovation activities.[15]
- Those firms that identified their main market as 'international' were allocated 2 additional points, whilst those that were mainly engaged in local, regional, or national markets but exported received one additional point.
- Those that claimed to have introduced a product innovation 'new to their market' were allocated 2 additional points, whilst those that introduced a product innovation 'new to their firm' (but not new to their market) were allocated 1 additional point. One point was deducted if the product innovation was 'mainly developed by other enterprises or institutions' rather than by the firm itself, either individually or jointly with other enterprises or organisations.
- Those firms that claimed to have introduced a process innovation 'new to their industry' were allocated 2 additional points, whilst those that claimed to have introduced a process

13 The firms were asked to provide information on their expenditures on innovation, including internal R&D, the acquisition of machinery, equipment and external knowledge, design, training and marketing, all for the year 2000. We divided the sum of these expenditures by the firm's employment, and then divided the sample of firms reporting expenditures into five bands, or quintiles. We did this separately for production and service activities.

14 Those identified as being engaged in innovation activities were those that had at least begun the development of a new product or new process (even if this was later abandoned), those with expenditures on internal or acquired R&D, those with expenditures on design, those with co-operative arrangements for innovation, and those that engaged in longer term innovation activities. [Technical coding: prodinov=1 or procinov=1 or longtm_r=1 or pcoop_r=1 or xextra_d=1 or xdesig_d=1 or rdcont=1 or rdocc_r=1 or aband=1 or nyettime=1 or nyetlate=1].

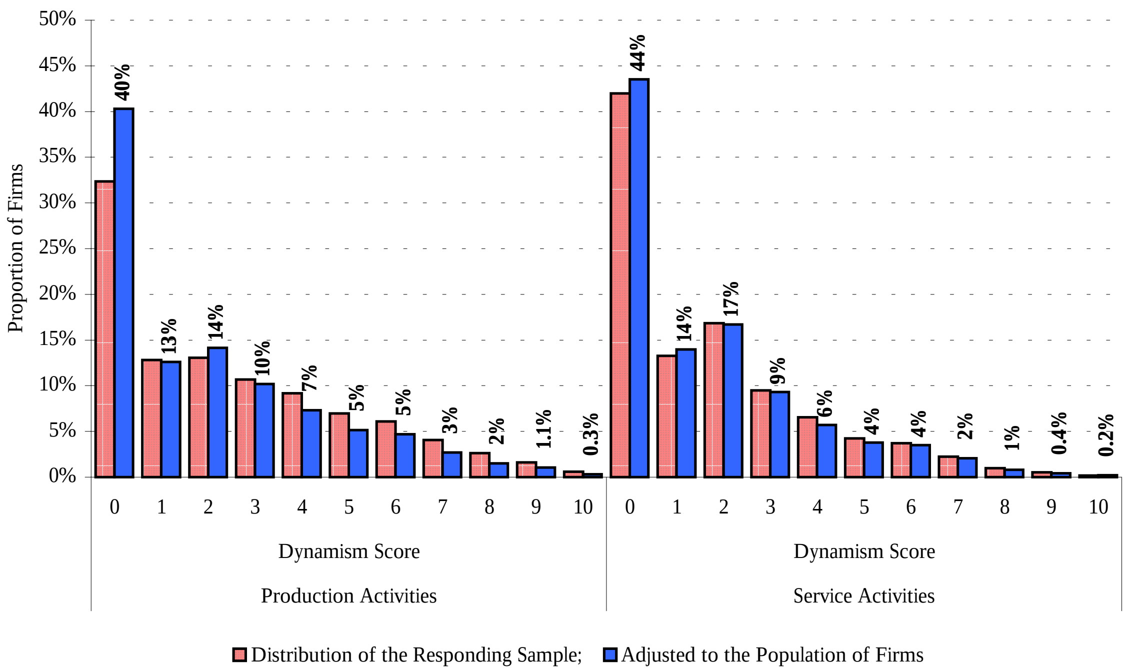
15 Stockdale (2002) reports that overall 47% of firms were innovation active. Stockdale uses a similar but slightly different definition of innovation active than that used here.

innovation 'new to their firm' (but not new to their industry) were allocated 1 additional point. One point was deducted if the process innovation was 'mainly developed by other enterprises or institutions' rather than by the enterprise itself, either individually or jointly with other organisations.

- Those firms that claimed to be engaged in R&D on a continuous basis were allocated 2 additional points, whilst those that claimed to have engaged in R&D occasionally[16] were allocated 1 additional point.
- Finally, those firms that declared they had engaged in longer term innovation activities, such as basic R&D or technology watch were allocated one additional point.

From this, it is possible for a firm to score up to 10 'dynamism points'[17]

Figure 2:
The Distribution of Firms by their 'Dynamism Scores'



Clearly the 'dynamism score' developed here, though reasonable, is arbitrary in its construction. We have developed it as a way of summarising the evidence rather than presenting the findings in the form of complex statistical models that can be hard to 'read'. Fundamentally, the 'dynamism score' provides some indication of the extent to which firms were engaged in innovation, innovation related activities, and competitive markets. We will use it to relate this behaviour to their engagement with the science base for innovation.

16 Or, failing that, declared expenditures or employment in R&D
17 Technical coding: (mkt_int*2) + dmkt_exp + (prodnov*2) + prodimit - prodin_x + (procnov*2) + procimit - procin_x + longtm_r + rd_cond

Figure 2 shows the distributions of both production and service firms by their 'dynamism scores', both for the simple unadjusted sample of responses to the survey and for UK industry as a whole, where the pattern of response has been adjusted to make it representative of UK industry. This shows that, when adjusted, 40% of production and 44% of service firms with 10 or more employees scored no dynamism points. That is, they did not engage in innovation at all and served only domestic markets. Meanwhile, only 16.5% of production and 12% of service firms scored more than 5 'dynamism points', and just 0.3% of production and 0.2% of service firms scored all 10 'dynamism points'. The skewed nature of this distribution is important, and is something to which we shall return.

How do these 'dynamism scores' relate to the use of the science base as a source of information for innovation? Figures 3a (for Universities) and 3b (for the Science Base as a whole) show that, for both production and service firms, the more dynamic the firm, the more likely it was to engage with the science base as a source of information for innovation. Whilst fewer than one in ten of the firms that – although engaged in innovation - scored only one dynamism point admitted to using the public science base as a source of information for innovation, more than half those that scored seven or more dynamism points admitted using the science base. Moreover, it can also be seen that the relative importance of the science base as a source of information for innovation also tends to increase with the dynamism of the firms. These findings clearly indicate that use of the science base as a source of information for innovation increases with the firms' own commitments to innovation (as proxied by our dynamism scores).

While the proportion of firms with high dynamism scores that regarded the universities and science base as sources of information of high importance for their innovation activities remained small, it would appear that one fundamental reason why relatively few firms make use of the science base as a source of information for innovation is that relatively few firms make substantial commitments to innovation. Other things being equal, if more firms made significant commitments to innovation, more would use the science base as a source of information.

These findings, suggest that universities and the science base more generally are more significant as sources of information for innovation than the simple proportion of firms using them would imply. Innovation is not, however, a linear process. The most dynamic firms do not simply draw ideas, knowledge or technologies from the science base. Instead, the CIS-3 and other evidence shows that they tend to use multiple sources of information or knowledge for innovation (Larsen and Salter, 2003). Table 1 shows that on average those firms with a 'dynamism score' of only 1 claimed on average to use just four of the sixteen possible sources of information for innovation asked about by the survey, whereas on average those with a 'dynamism score' of 9 or 10 claimed to have used 12 of the 16 sources.[18]

18 Furthermore, the average reported importance of these sources does not decline as the number of sources used increases. Apart from universities, and government research organisations, the other sources asked about were: sources within the firm; suppliers; clients or customers; health and safety standards and regulations; environmental standards and regulations; technical standards; other enterprises within the enterprise group;

Figure 3a:
The Use of the Universities as a Source of Information by Firms' Dynamism Scores

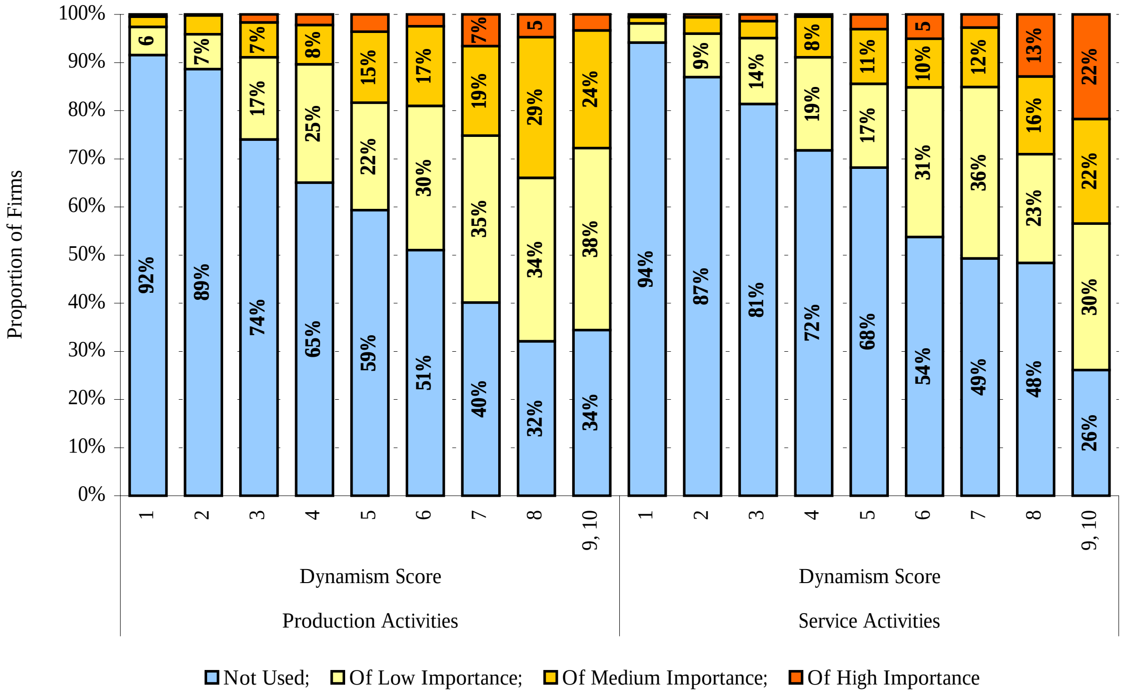
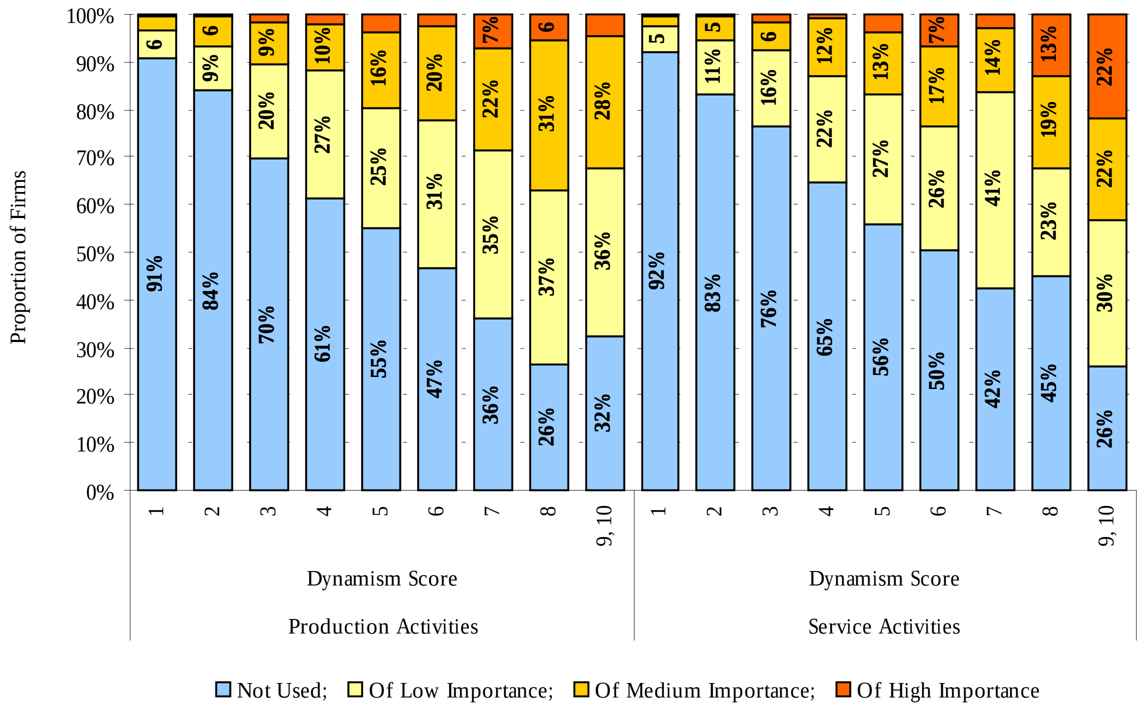


Figure 3b:
The Use of the Science Base as a Source of Information by Firms' Dynamism Scores



competitors; technical and trade press; fairs and exhibitions; trade associations; consultants; professional conferences and meetings; commercial laboratories; private research institutes; and other government agencies.

Table 1
Average Number of Sources of Information / Knowledge Used by Dynamism Score

	Dynamism Score								
	1	2	3	4	5	6	7	8	9,10
Production	4	6	7	9	10	10	11	12	12
Services	4	5	8	9	9	10	10	11	12

3.1.2 Collaborations for Innovation between the Public Science Base and Private Firms

The second direct contribution that the science base can make to innovation and which is asked about by the CIS-3 is as a collaborative partner for innovation. Question 13 on the survey asked the firms whether they had any co-operative arrangements for innovation in the period 1998-2000, where: "Innovation co-operation means active participation in joint innovation projects (including R&D) with other organisations. It does not necessarily imply that either partner derives immediate commercial benefit from the venture. Pure contracting out of work, where there is no active collaboration, is not defined as co-operation in this survey". The survey asked whether the enterprises had co-operative arrangements for innovation with nine different types of partners.[19]

Overall, only 8% of firms had co-operation arrangements for their innovative activities. Of these, about a third had these arrangements with universities, whilst just 13% had such arrangements with government research organisations (Stockdale, 2002). Amongst firms with co-operative arrangements for innovation, suppliers (57%) and customers (50%) were, unsurprisingly, the most widely engaged types of innovation partner (ibid).

Although few firms had collaborative arrangements for innovation with the science base, the question again arises whether or not the extent to which universities and the public science base more generally were engaged in collaborative arrangements for innovation varies with the firms' own commitment to innovation, as proxied by their expenditures on innovation and by their 'Dynamism Score'.

Table 2
Innovation Expenditures and Participation in Collaborations with the Science Base

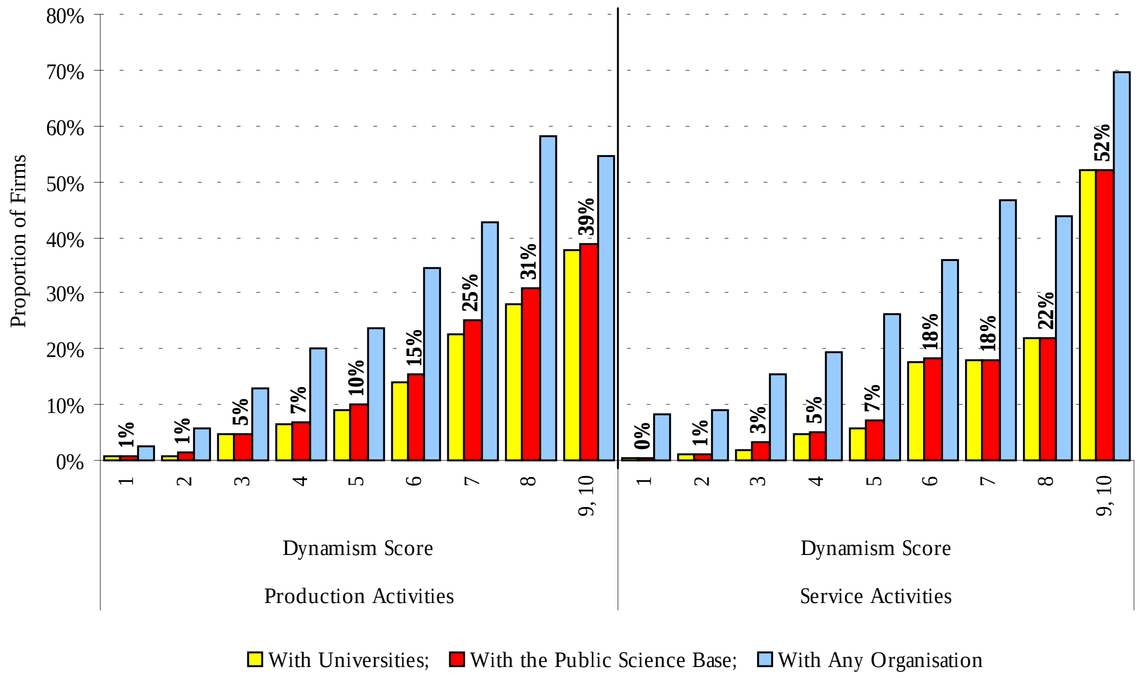
	No Innovation Expenditure in 2000	Distribution by Innovation Expenditure per Employee in 2000				
		1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th (Top) Quintile
Production	1%	6%	7%	10%	10%	21%
Services	0%	1%	7%	6%	4%	14%

Table 2 shows that amongst the production activity firms, a fifth of those in the top quintile by innovation expenditures had collaborative arrangements for innovation with the science base, whilst 14% of service firms in the top quintile of service firms with innovation

19 Apart from universities and government research organisations, the other partner types asked about were: other enterprises in the enterprise group; suppliers; customers or clients; competitors; consultants; commercial R&D laboratories or R&D enterprises; and private research institutes.

expenditures had these arrangements. Almost none of the firms that declared no expenditures on innovation in 2000 had these arrangements. Meanwhile, Figure 4 shows that those firms with high 'dynamism scores' were much more likely to have collaborative arrangements for innovation with universities and the science base than those with a low 'dynamism scores'. For instance, whilst more than a third of the production activity firms and more than half of service firms with 'dynamism scores' of 9 or 10 had these arrangements, less than 1% of the firms with 'dynamism scores' of 1 had these arrangements.

Figure 4:
Engagement in Collaborative Arrangements for Innovation by Dynamism Scores



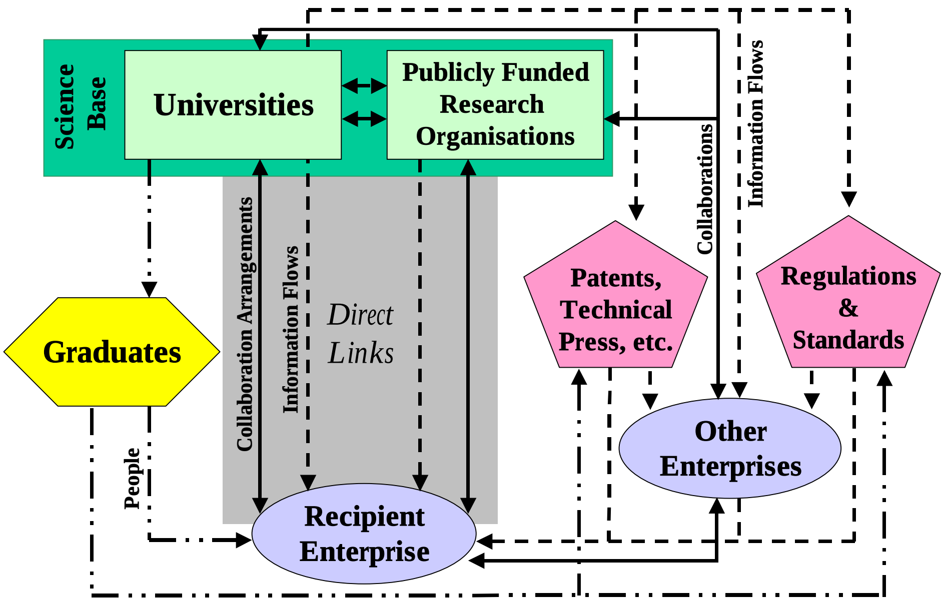
Unfortunately, the CIS-3 does not ask how important these collaborations were for the firms' innovation activities. Nevertheless, the finding that collaborations with the science base tend to be associated with firms that themselves make substantial commitments to innovation again suggests the significance of the science base as a collaborative partner in the innovation process is greater than the simple proportion of firms with these arrangements would imply. Furthermore, this finding suggests that, other things being equal, if firms increased their own commitments to innovation, they would be increasingly interested in engaging in collaborative arrangements for innovation with the science base as well as with other firms.

3.2 The Indirect Links for Innovation Between Industry and the Science Base

So far we have examined the direct or immediate contribution that the public science base makes to innovation in both production and service firms, as a provider of information (or knowledge) for innovation and as a collaborative partner in the innovation process. It is important to appreciate that the science base also makes indirect and non-immediate contributions to innovation in firms, contributions that are easily overlooked. The most obvious indirect contribution is through the education of graduates who are then employed in firms to apply the knowledge or skills they have acquired at university.

Other indirect and non-immediate contributions follow from the circulation of information or knowledge in the economy. In short, other sources of information or knowledge such as other enterprises (including competitors, customers, suppliers, etc.), regulations or standards, and the trade and technical press, may draw directly on the science base, and at least some of this information will then reach other firms through indirect links (see Figure 5). As these sources of information are one or more stages removed from the firm's immediate interactions with regard to innovation, it is unlikely to recognise their contribution in responding to a survey such as the CIS-3. To clarify, consider this homely example: If we were to ask shoppers which were the most important sources of their groceries and household goods they buy, most would probably respond "Sainsbury", "Tesco" or another retailer. Few would say "Unilever" or "Proctor and Gamble" even if many of their purchases originated from these companies. Respondents will tend to name the immediate provider – the retailer – rather than those behind the scenes, such as the manufacturer, even if the respondents know that those behind the scenes play an important role (Swann, 2002).

Figure 5:
Links between the Public Science Base and Industry



There are a number of ways in which information or knowledge from the science base may diffuse indirectly into firms without this being recognised. These include:

1. Through the imitation of innovative products, services and processes. We have seen that the science base is more likely to be drawn upon directly by firms with high dynamism scores. Such firms includes those that introduced 'new to the market' product innovations, and/or 'new to the industry' process innovations. Collaborations with the

science base are also more frequent amongst the more dynamic firms. The competitors of these dynamic firms will, in time, probably have to respond to these innovations (or perish), and it is likely that they will try to develop similar product or processes – learning directly from their rivals without recognising the indirect contribution of the science base. In this way, knowledge from the science base diffuses from those that use it directly, to those that do not.

2. A group of enterprises has emerged which act as 'knowledge intermediaries'. These include R&D enterprises, private research institutes and technical consultants, and such firms are more likely than other firms to engage the science base as a source of information for innovation and to have collaborative arrangements for innovation with the science base. Such firms make their living from assisting others with innovation, so that while many of their customers will not work directly with the science base, they will often benefit from it indirectly through engaging these 'knowledge intermediaries'.

3. For many firms, suppliers are a significant source of innovation – providing both information and new knowledge embodied in capital goods. Many suppliers will have developed their own products (as both capital goods and services) with (direct and indirect) contributions from the science base. Again, these contributions will not be recognised by surveys such as the CIS-3.

4. Environmental, technical and health and safety standards and regulations are a significant source of information for innovation in many firms. Indeed, these are much more likely to be cited as sources of information of 'high importance' for innovation than the science base (Stockdale, 2002). However, the science base, and in particular government research organisations, are likely to play an important role in the development of these standards, a role which is not recognised by the firms which draw on standards and regulations as a source of information for innovation.

The above is not intended as an exhaustive list of the indirect contributions that the science base makes to innovation in firms,[20] nor is it to advocate a linear – 'science push' - model of innovation. Our point is simply that the indirect and non-immediate contributions of the science base are unlikely to be recognised in a survey such as the CIS, but these indirect links are likely to be at least as significant as the direct contributions. Unfortunately, it is very difficult to determine the extent of that contribution, particularly as knowledge from the science base can take some considerable time to diffuse into industry.

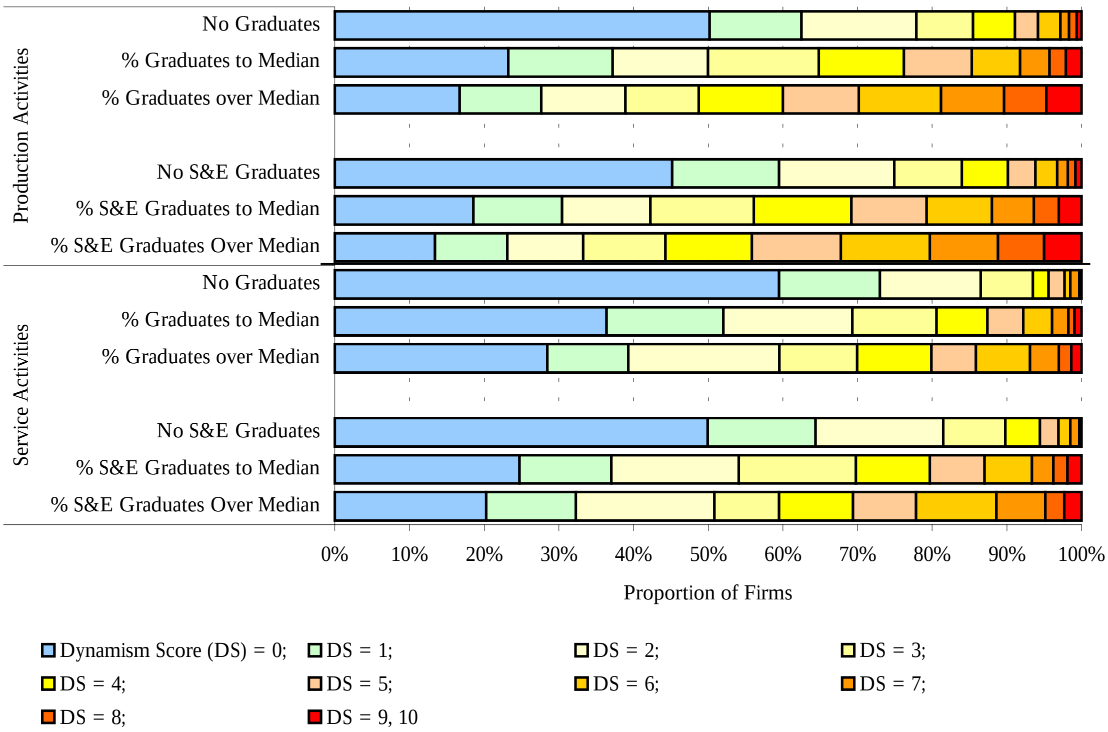
We can, however, undertake a fuller investigation into the impact of the employment of graduates on the innovation performance of firms. It is to that that we now turn.

20 For example, the trade and technical press is likely to draw on the science base to some extent, as are professional conferences and meetings

3.2.1 The Employment of Graduates

Firms employ graduates – generally at a higher cost to themselves than the employment of non-graduates – for the capabilities that such people bring, including, where necessary, scientific and engineering knowledge and skills. From our perspective, what is interesting is how the employment of graduates impacts on the firms' innovation performance. In Figure 6 we divide both production and service firms into three groups: those that did not employ graduates; those that employed graduates but to a proportion no greater than the median proportion for their particular industrial sub-sector (e.g., the 'textile and clothing' sub-sector amongst production activity firms, or the 'informational services' sub-sector amongst the service firms) - labelled '% Graduates to Median' in the figure; and those that employed graduates at a proportion of their workforce greater than that of the median of their particular sub-sector - labelled '% Graduates Over Median' in the diagram. We undertook this analysis twice, first for all graduates, then for the sub-set of science and engineering graduates - labelled 'S&E' in the figure.

Figure 6:
The Employment of Graduates and Firms' Dynamism Scores



What this shows is that – within the same industrial sub-sectors - those firms that employed graduates tended to have higher dynamism scores than those that did not employ graduates. Moreover, those firms that employed graduates at a proportion above their sub-sector's median tended to have even higher dynamism scores. This finding applies to graduates in general and to science and engineering graduates in particular. In more detail, half or more of both production and service firms with no graduates in their workforce had dynamism scores of zero, compared with 24% of production firms that employed graduates to a proportion no greater than their sub-sector's median proportion, and 18% of production firms whose employment of graduates exceeded their sub-sector's median proportion (i.e., those with relatively high proportions of graduate employees). The corresponding proportions for services were 38% and 31%. The message is simple and clear, those firms that employ graduates – in general and science and engineering graduates in particular – are more likely to engage in innovation activities and/or in competitive international markets.[21] Quite simply, the employment of graduates allows firms to 'raise their game'. It also increases firms' absorptive capacity (Cohen and Levinthal, 1989) – that is their ability to learn from the work of others, such as the science base.

3.3 Factors Hampering Innovation

So far, we have examined the direct and indirect links between the science base and innovation in firms, including both production and service firms. We have seen that, on the whole, direct links between the science base and firms are not widespread, but they tend to be associated with firms that are themselves making substantially greater commitments to innovation than 'the average firm'. This, in turn, suggests the true significance of the science base as a source of direct support for innovation in industry is rather greater than the simple share of firms that drew from it would imply. There is also good reason to believe that the indirect, non-immediate contribution of the science base to innovation, although unrecognised by surveys such as the CIS-3, is at least as significant if not considerably greater than the direct contribution. Consequently, the 'true significance' of the science base is rather greater than the headline finding of the survey might imply.

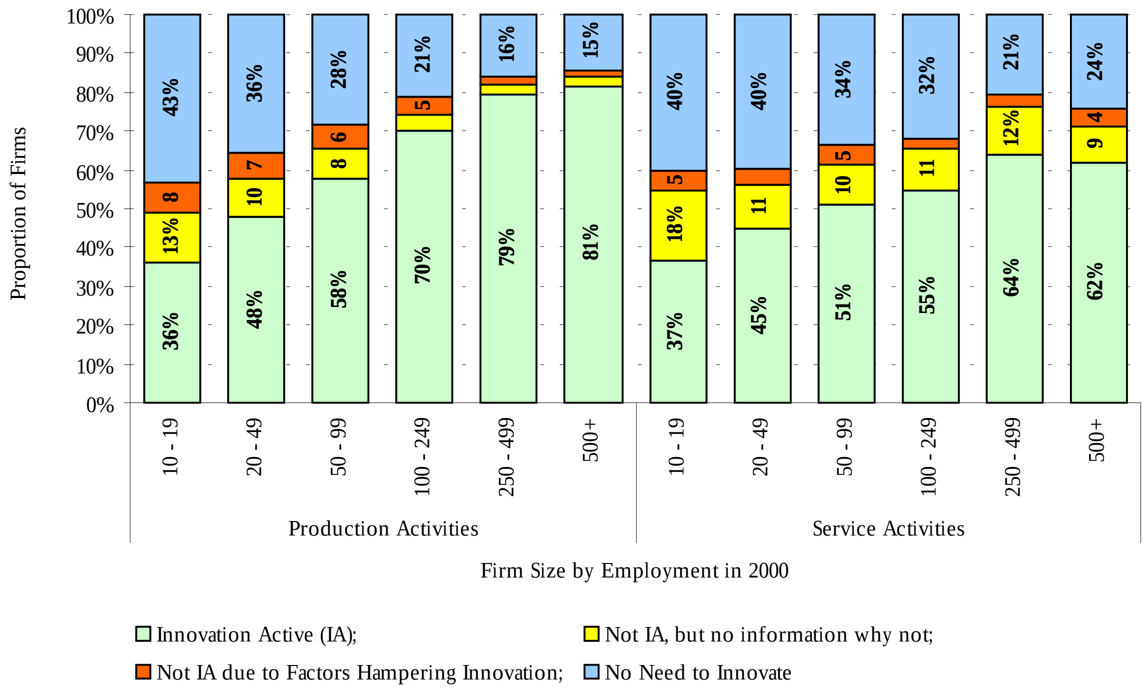
Fundamentally, one reason why relatively few firms engaged the science base directly in their innovation activities is that relatively few firms made substantial commitments to innovation. Indeed, our analysis of the CIS-3 data shows that less than half of firms in the UK engaged in innovation activities, and fewer had successfully introduced innovations. It is difficult to judge whether this is a low proportion or not. It could be that most firms did not engage in innovation because it did not make commercial sense to them to do so. Alternatively, it could be that those firms that did not engage in innovation did not do so because they were unable to gain access to vital resources, such as information about technologies or skilled personnel. The CIS-3 allows us to investigate whether such firms were indeed hampered in their innovation activities, and by which factors. Those firms that did not engage in innovation were asked why it was not possible or desirable for the firm to innovate? Perhaps surprisingly, about two thirds of both the production and service firms that did not innovate declared that they did not because they had no need to, either because of 'market conditions' or because of previous innovations (introduced before 1998). Quite simply, most of the non-innovators felt – rightly or wrongly – that they had no need to innovate. They therefore did not seek to innovate and were not hampered in their

21 The employment of graduates, particularly at high intensities in the workforce, also tends to be associated with higher expenditures on innovation activities.

attempts to do so. Only 12.5% of the production firms, and 9% of service firms that did not innovate claimed they had not engaged in innovation because of 'factors impeding innovation'.[22]

Figure 7 shows the distribution of production and service firms by their size and engagement in innovative activity. Engagement in innovative activity increases with firm size, and more markedly amongst production than amongst service firms. However, substantial proportions of firms of all sizes claimed no need to innovate, either because of market conditions or because they had innovated previously (prior to 1998). Over two fifths of both production and service firms with 10 to 19 employees made this claim, as did 15% of large production firms and nearly a quarter of large service firms with 500 or more employees. Meanwhile, the proportion of firms of all sizes that claimed not to have engaged in innovation because of factors hampering innovation was small, at no more than 8%, but generally around 5%. The remaining firms were not innovation active but provided no information as to why this was the case. The important message is that most firms either engaged in innovative activities or decided not to; relatively few claimed to have been prevented from engaging in innovation activities by factors impeding innovation.

Figure 7:
Innovation Activity and Inactivity by Firm Size

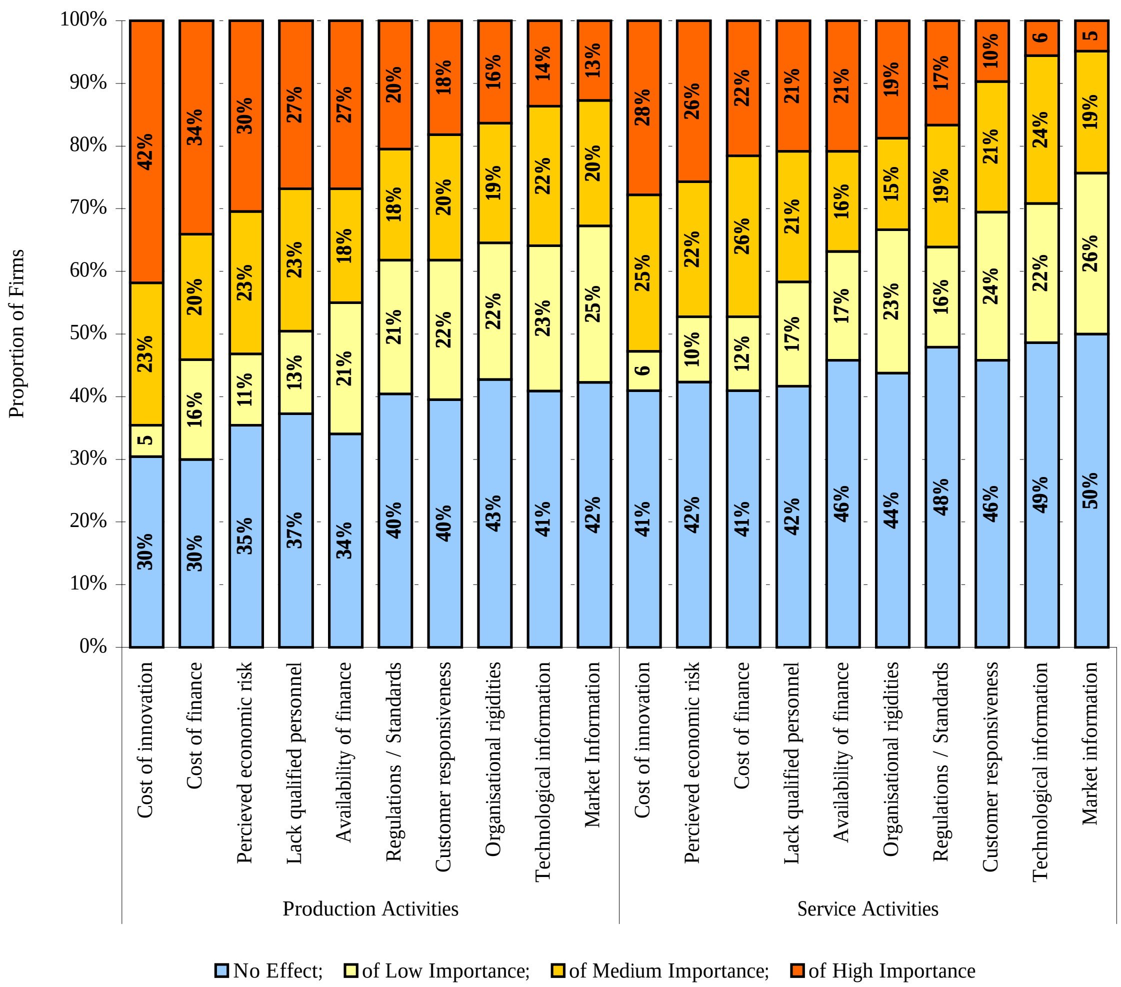


Elsewhere, the survey asked the firms to grade the importance of ten factors that might impede the firm's ability to innovate.[23] In Figure 8 we examine how those firms that claimed not to have engaged in innovation activities because of factor hampering innovation scored these

22 The remainder did not provide answers to this question.
23 Question 8 of the CIS-3 survey asked the enterprises about the factors that might impede their innovation efforts. It stated: 'A range of factors may inhibit your ability to innovate. Please grade the importance of the following [10] constraints during the period 1998-2000'.

impediments. This shows that the principal impediments to innovation were economic factors, such as the perceived excessive economic risk of innovation, the direct cost of innovation, and the cost and availability of finance for innovation. Indeed, 80% of production firms and over 70% of service firms that had not engaged in innovation due to factors impeding innovation cited one or more as important, and more than half regarded one or more of these factors as being of 'high importance' in inhibiting their engagement in innovation. By contrast, access to information on technology was amongst the least widely cited inhibiting factors, being identified as an impediment of some importance by 60% of production and half the service firms, but this factor was identified as being of 'high importance' by just 14% and 6% of these firms respectively. Also notable is that the vast majority of the firms that identified this as a factor of high importance also identified other factors, such as the economic factors, as impediments of equally high importance. Consequently, when a lack of information on technology was an impediment of high importance it was rarely the only impediment of high importance.

Figure 8:
The Factors Hampering Innovation amongst Impeded Non-Innovators



A lack of qualified personnel was more widely identified impediment to innovation amongst these firms, being identified as of some importance by over 60% of the production firms and by nearly this proportion of service firms. This factor was cited as being of high importance by a quarter of the production activity firms that did not engage in innovation due to factors hampering innovation, and by a fifth of the same group amongst service firms. We do not know the nature of the skills that these firms lacked. They may have missed graduate or professionally skilled personnel, or they may have missed vocational and technical personnel. However, again most of the firms that complained that a lack of skilled personnel had hampered their innovation activities also claimed that other factors were impeding their engagement with innovation. For example, three quarters of the production and two-thirds of the service firms that cited this factor as being of high importance impeding innovation also identified one or more of the economic factors as an impediment of high importance.

Stockdale (2002) has shown that the economic factors (the direct cost of innovation, the perceived economic risk of innovation, and the cost and availability of finance for innovation) were, along with the impact of regulations and standards, the most widely identified factors hampering innovation amongst both innovation active and innovation inactive firms. A lack of qualified personnel was a middle ranking factor, whilst access to information on technology was the least likely factor to be identified as a factor hampering innovation. Interestingly, Stockdale also shows that almost all of these impediments were more likely to be identified by the firms that engaged in innovation than those that did not. In light of this, we investigate further the relationship between firms' dynamism scores – a proxy for the extent to which they engaged in innovation – and the extent to which they identified a lack of information on technology and a lack of qualified personnel as factors inhibiting innovation. We examine these factors further as they are those that the science base might provide assistance with.

Figure 9:
Access to Technological Information as a Factor Hampering Innovation

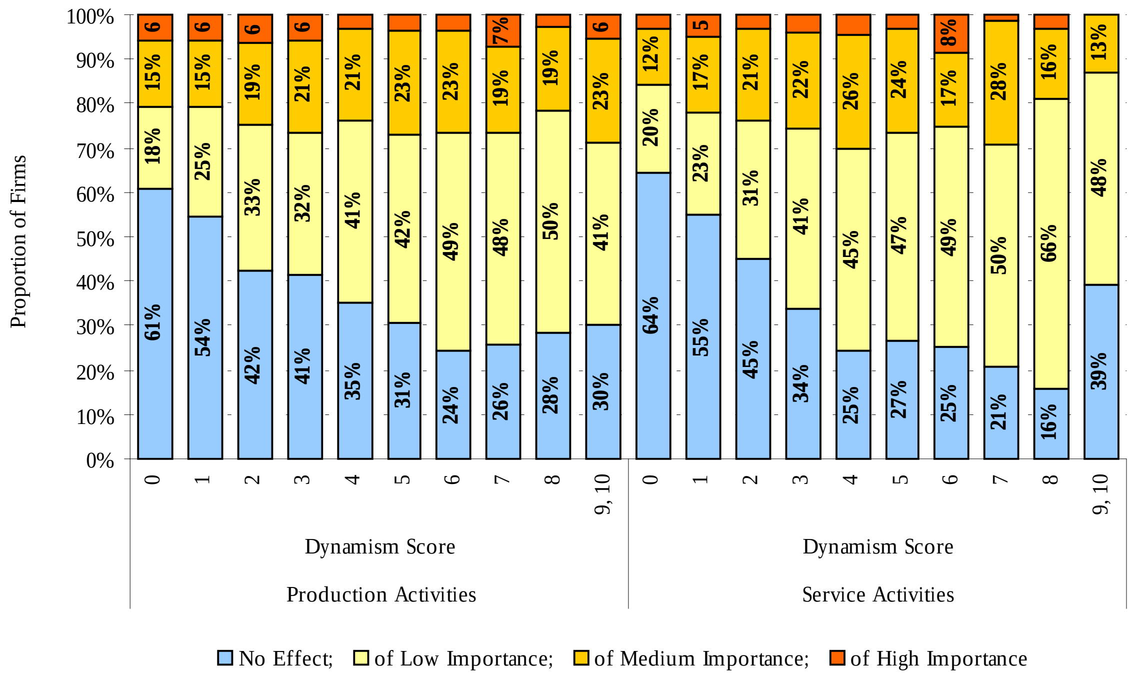


Figure 9 shows that a lack of information on technology is more likely to be identified as an impediment to innovation amongst the firms with high dynamism scores than those with low dynamism scores, and those that did not engage in innovation. This suggests that information on technology is rarely the reason why firms did not engage in innovation, but that accessing information on technology is an increasingly important impediment as firms deepen their commitment to innovation. This finding is unsurprising. Any firm that engages in research and development – which itself is an indication of a deeper commitment to innovation – is seeking to know more than it currently does about the technologies it is using or might use. It does not follow that because firms admit to being hindered by information on technology that this is necessarily a role that an external agency, such as another other firm or the public science base, should step in and assist with, particularly at a subsidised rate. Being hindered by a lack of information or knowledge about technologies is 'a fact of life' for any firm with a deep commitment to technological innovation activities, and it is notable that most of the firms that claimed to be hampered by a lack of information on technology regarded this as an impediment of low importance.

Figure 10:
A Lack of Qualified Personnel as a Factor Hampering Innovation

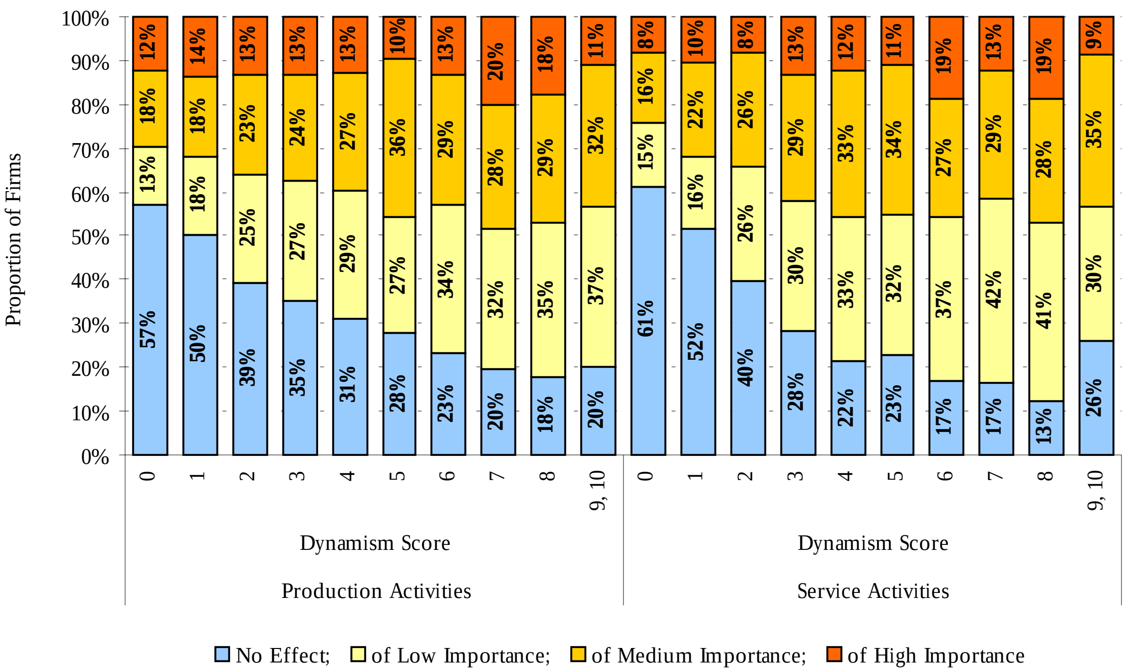


Figure 10 repeats the analysis for a lack of qualified personnel as an impediment to innovation. Again, this factor is more likely to be identified as an impediment by those firms that had a strong commitment to innovation – as revealed by their high dynamism scores – than by those with little or no commitment to innovation. A lack of qualified personnel appears to be a more serious problem than a lack of information on technology, with almost half of both production and service enterprises with moderate or high dynamism scores (i.e., greater than 3) identifying this as a problem of medium or high importance. We do not know which skills the firms were lacking, but it is reasonable to suppose that those with high dynamism scores lacked graduate or professionally skilled personnel rather than those with technical or vocational skills. We can report that most of the firms with high dynamisms scores which identified a lack of qualified personnel as a factor hampering innovation did undertake at least some training of personnel, presumably as an attempt to alleviate this problem.

4.0 Discussion

In this paper, we have examined the information provided by the UK's version of the third European Community Innovation Survey (CIS-3) with respect to the use of the science base by industry, with particular reference to firms' innovation activities. We have undertaken this analysis in the context of the politically inspired debate which suggests that the science base 'could do more' to assist the innovativeness of British industry. Before discussing our findings, we briefly summarise the main points.

Firstly, we confirmed the finding that relatively few firms have direct links with the science base to support their innovation activities. These direct links include the use of the science base as a source of information for innovation and as a collaborative partner in innovation activities. This finding is true for both production and service firms. However, the evidence also shows that those firms that themselves made substantial commitments to innovation – measured either by their expenditures on innovation activities or by their 'dynamism score' were much more likely to engage the science base in undertaking their innovation activities. Fundamentally, one reason why such small proportion of firms use the science base is that only a small proportion of UK firms make substantial commitments to innovation. Relatively few, therefore, have a need for the kind of information or skills generally associated with the science base.

Secondly, we argued that the contribution of the science base to innovation is often indirect and non-immediate, and is therefore not captured by surveys such as the CIS-3. We used the analogy of asking shoppers to identify the most important sources of the groceries or household products they purchased. Most, we predict, would identify their supermarket of choice, be that Tesco or Sainsbury or another. Few, we contend, would identify the primary or secondary producers of these goods, such as Unilever. By the same token, there are a number of ways in which information or knowledge from the science base can and does flow indirectly to firms, which then influences their innovation behaviour. Because these contributions are indirect, they are not acknowledged by the headline findings of surveys such as the CIS-3. Unfortunately, this indirect and non-immediate contribution is very hard to measure – although we believe it is substantial, and greater than the direct contribution outlined above. One indirect contribution that we were able to investigate further was how the employment of graduates impacts upon the innovative performance of firms. We showed that those firms that employed graduates (in general and science and engineering graduates in particular) were more likely to engage in innovation and we more likely to have substantial commitments to innovation. Moreover, those firms that employed more than the average proportion of graduates for their particular sub-sector were still more likely to innovate and have high commitments to innovation. Essentially, those firms that employ graduates tend to 'play a higher game' with respect to innovation activities.

Thirdly, we examined why those firms that had not engaged in innovation had not done so. We found that the majority of non-innovators did not claim to have been prevented from engaging in innovation because of one of more factors hampering innovation, but instead declined to engage in innovation because they felt there was no need to, either due to 'market conditions', or because they had innovated in the period prior to 1998 and were still reaping the rewards of that initiative. Only a small proportion of firms claimed not to have innovated because of factors hampering innovation. Amongst these (and indeed amongst all firms) the most widely cited factors impeding innovation were economic factors – such as the direct cost of innovation, the perceived excessive economic risk of innovation, and the cost and availability of finance for innovation. A lack of access to technological information was, after a lack of market information, the least likely factor to be considered of high importance (especially on its own, without other factors also being given this status). A lack of qualified personnel was a more widely identified factor than a lack of access to technological information, but was less widely identified than the economic factors discussed above.

How do these findings relate to the current debate about the role of universities and the science base in 'knowledge transfer', and stimulating innovation in industry? Our analysis might be read as confirming the view – prevalent in government – that the UK has a first order problem: too few firms make significant commitments to innovation, whilst too many are content to rest on their laurels and claim there is no need to innovate. We have seen that over 40% of both production and service firms did not engage in any technologically innovative activities between 1998 and 2000 – these firms had little if any need to interact directly with the science base. Beyond this, the majority of firms that did engage in innovative activities do not appear to have made large commitments to innovation. Half of those that declared expenditures on innovation activities in 2000 spent no more than £1,000 per employee on these activities. By contrast, the average expenditure amongst the top quintile was about 10 times that. In terms of our 'dynamism scores', a firm which, in the three years between 1998 and 2000 developed (either by itself or jointly with another enterprise or organisation) a new or significantly changed product, and a new or significantly changed process, both of which were new to itself but not new to its market or industry (i.e., they were really imitations, not innovations), which engaged occasionally in R&D, and which had some exports - would have achieved a 'dynamism score' of 5. This does not appear to be the description of a highly innovative firm, yet 84% of production and 89% of service enterprises with 10 or more employees failed to achieve this 'dynamism score'.

This 'demand side' problem – if indeed it is a problem – has been identified before. Coombs and Metcalfe (2000, p. 3), for example, observe that 'the real problem with the sub-optimal utilisation of the UK's science base for commercial ends lies not with the universities, but with private firms in the UK who still underspend on R&D and innovation, and therefore have underdeveloped capability and ambition with respect to innovation as a competitive weapon'. Lambert (2003) also states that that too few UK firms place innovation at the heart of their activities, and identifies the small and highly concentrated proportion of 'research led' businesses in the UK as a problem: 'relatively few British companies and companies based in Britain are research led. A number of those businesses which once had big research activities have run into difficulties, leaving an even greater concentration than before on the pharmaceuticals and defence/aerospace industries' (Lambert, 2003, para 1.8). Lambert also notes that UK businesses perform less than half the R&D per worker of the US, Japan and Germany.

The government is concerned that British industry does not commit enough to innovation, and has recently introduced tax credits for R&D (for smaller firms). The clear intention is to stimulate innovation through the development of new products and processes. If other things remain constant, and if this fiscal instrument has the desired effect, then the 'dynamism scores' of firms should increase, which will increase the number of firms seeking to use the science base as a source of information for innovation and as a collaborative partner for innovation projects. One view of the government's current strategy is that, like a good chess player, it is looking several moves ahead. It has anticipated the impact of the tax credits on the innovation performance of firms and hence on the demand for interactions with the science base, but it is doubtful that the science base has the capacity or institutional arrangements to deal with this increased demand. By providing (limited) funds to the science base to increase this capacity, the government is simply being prudent in seeking to ensure that the momentum generated by its tax credits initiative is not diminished by an ill prepared science base.

We do not know whether the above is indeed the case. It may be that the government simply thinks that the science base should move closer to serving the needs of industry, or even that the science base constitutes a treasure trove of commercially exploitable ideas. With that in mind, and reflecting upon our own findings, we make the following comments:

- Firstly, beware of broadening access for the sake of broadening. It is not clear what scale of interaction between the science base and industry the government would consider 'successful', or 'optimal'. Although it notes that industry academic links have strengthened in recent years, the White Paper also notes that 'less than one in five businesses taps into universities' skills and knowledge' (DfES, 2003 – Executive Summary). We have tried to show why this is the case, but the tone of the statement is clear: there is "room for improvement". But what would constitute success – one in four, one in two, or all businesses having interactions with the science base? We consider all such targets inappropriate, particularly as they imply a broadening of links between the science base and industry, whereas a deepening of links with those that can benefit most is likely to be a more beneficial development. Quite conceivably, broadening interactions in response to pressure to increase the number of firms engaged may reduce the quality of the interactions with those that can make the most appropriate use of the science base. Targets and performance indicators, by their very nature, distort behaviour. In the past, universities have shown themselves adept at meeting 'performance indicators'. A recent example of this is the number of spin-off companies, which seems to have become a performance indicator. The government boasts that the UK achieves one spin off for every £9 million spent on research, compared with one per £53 million in the United States. But is this really a measure of success? There is concern that many of the UK's spin offs are marginal, and that the technology might have been better commercialised through licensing agreements (Lambert, 2003). If the government sets a volume based target for interactions with industry, it is likely to be met, but quite probably at the expense of negative consequences elsewhere.

- Secondly, and in relation to the above, the government needs to be clearer about what business can expect from the science base and on what terms. Businesses, it seems, are being encouraged to interact with the science base were the latter is seen as a problem solving resource which is expected to provide these services either free of charge or at well below their true economic cost. Meanwhile, cash-strapped universities have been increasingly keen to charge for these services. Lambert (2003) observes that firms often object to paying at all, feeling they have already paid through taxation, or to paying the full costs, including overheads, of the services undertaken. Whilst the government may be right in encouraging greater innovation by firms, it should be wary of encouraging a dependency culture. At the extreme, it is possible to envisage the science base becoming a kind of 'National Health Service' for solving firms' technological problems. We are not suggesting this is what the government has in mind, but it would help if it were clear about just what businesses can and cannot expect from interactions with the science base and on what terms. The question of the extent to which interactions between business and the science base are effectively subsidised is also controversial given that there are a substantial number of private companies in the business of 'problem solving' and 'knowledge transfer'. If interactions between the science base and industry are subsidised this is likely to diminish the provision of similar services within the private sector, even though those current arrangements might be quite satisfactory.

- There are certainly areas in which the science base can work closely with industry and where those interactions are appropriate and mutually beneficial (e.g., work placement schemes). Moreover, the 'science base' is composed of a diverse set of institutions. What may be an appropriate form of interaction with industry in one institution may not be appropriate in another. But in general we warn that the opportunity costs to the core mission of the science base must considered before there is a headlong march to expand the interactions between the industry and the science base. Much of the science base and universities in particular is an investment in the future. Its two principle products are graduates and advances in scientific and technological knowledge. This contribution is largely indirect and non-immediate – it is hard to measure but substantial. We should be very wary of expanding direct interactions at the expense of the indirect and longer-term contributions of the science base.

- In this context, it is vital that the universities and science base continue to undertake independent and long-term research, most of which will be remote from the current needs of industry. There are two issues here. The first is the need to undertake long-term research, which is exactly the sort of research that industry will not fund because of the uncertainties involved and because of the difficulties of appropriating the returns to the new discoveries (Nelson, 1959, Arrow, 1962). Many highly significant technologies, such as the binary number system (now used in digital technologies), lasers and microwave, were initially developed without thought of their industrial application. The opportunity cost of pushing the science base closer to industry may be a reduced availability of fundamentally new knowledge in the long run. Secondly, there is a need to undertake – *and to have the capacity to undertake* – independent science that serves the public interest. R&D is undertaken by firms in their own private interests, which do not necessarily coincide with the public interests of society at large. The case of genetically modified organisms is pertinent here. The public is sceptical, but it is likely to be much more sceptical if the research and development were left solely to the biotechnology firms like Monsanto. Equally with pharmaceuticals and the development of new drugs. In this context, we should remind ourselves of the scale of the activities undertaken by the science base and in industry. The UK government spends about £2bn on science through the research councils, and public expenditure on universities is about £8.3bn. Total income to universities is about £13.5bn – they receive about £3.7bn from the private sector to undertake research projects. According to official statistics (ONS, 2002), expenditure on research and development in UK universities totalled £3.6bn; but this is only one fifth of the UK's Gross Expenditure on Research and Development. Industry spends more than three times as much (at £11.5bn). Meanwhile, GlaxoSmithKline, the largely UK-based pharmaceutical giant spent £2.9bn on R&D in 2001, from income of £21bn. AstraZeneca, the other largely UK-based pharmaceuticals giant, spent £2.1bn on R&D from income of £12bn in the same year. Combined, these two companies spent more than twice as much on R&D as did the UK government on science through the research councils. There is good reason to maintain a scientific capability that works in the public interest, quite separate from the private interests of firms. This is especially the case as firms have been known to suppress scientific findings that are not favourable to their interests. The growing interaction between science and industry threatens the culture of openness and free sharing of information that has been fundamental to the growth of knowledge (David, 1999; Florida, 2000).

- With regard to graduates, it is certainly a concern when employers find the skills of graduates inappropriate or cannot find enough of certain types of graduates and are thereby held back. But it is also sad that the government increasingly seems to see higher education in narrow economic terms. That is, in essence, as training. This view is expressed by the House of Commons Select Committee on Education and Skills (HCSCSE, 2003 para 213), who write: 'A significant conclusions that can be drawn from the White Paper is that the Government sees universities and colleges principally as economic agents; there is very little in the document about intellectual and cultural life in higher education, or the broader development of the individual. The economic role of universities is significant, but it would be wrong to suggest the only benefit of higher education for society in general or for individuals in particular is an economic one'.[24]

- At a broadest scale, the UK government's conceptualisation of universities as 'engines of economic growth', or as hubs of the knowledge economy is worrying. Perhaps such terminology is just hyperbole and is generally understood as such – nobody believes the rhetoric. But there is a danger that many will, and expectations will rise. In encouraging industry and the science base to interact to form the 'engine of economic growth', the UK seems to be following the path set by the United States in the 1980s and 1990s. But, as Florida (2000) and others observe, the US may have gone too far. Expectations were raised and have not been fulfilled: 'state and local governments are becoming disillusioned that universities are not sparking the kind of regional growth seen in the classic success stories of Stanford University and Silicon Valley in California and of MIT and the Route 128 beltway around Boston' (Florida, 2000, p. 364). Moreover, 'Some of the [US's] largest and most technology-intensive firms are beginning to worry aloud that increasing industrial support for research [in US universities] is disrupting, distorting, and damaging the underlying educational and research missions of the university, retarding advances in basic science that underlies these firms' long term future' (Florida, 2000, p. 368). Those who consider that the UK science base 'to do more' to help innovation in industry and who hold up the 'US model' as the ideal should inform themselves of how restricted this model is to a few universities and scientific disciplines in the United States, and moreover of its negative consequences, not just its short term benefits.

5.0 Conclusions

In this paper we have investigated the links between the public science base (i.e., universities and government research organisations) and innovation in service enterprises. We have summarised our findings in detail at the start of the discussion in Section 4, but we reiterate them here very briefly:

- Few firms have direct links with the science base related to their innovation activities. However, those that do tend to be firms with much deeper commitments to innovation that the 'average firm'. Fundamentally, one reason why so few firms make use of the science base for innovation is that few firms make substantial commitments to innovation.
- The indirect and non-immediate contribution of the science base is easily overlooked, hard to measure, but probably significantly greater than its direct contribution. One important

24 Further evidence of this economic instrumentalism is found on the government's web page on 'the benefits of higher education' (http://www.dfes.gov.uk/highereducation/benefits.shtml). This gives six benefits, the first five of which are all about employment, pay and career prospects. Only the last hints at something more: 'Universities and higher education colleges are thriving social and cultural centres with much to offer students of any age, nationality or social background.'.

indirect contribution is the provision of graduates. Firms that employ graduates tend to have a greater orientation and commitment to innovation than those that do not.

- Few firms are sufficiently hampered by factors impeding innovation that they do not engage in innovation activities at all, but amongst this small group, economic factors (such as the cost and risk of innovation and its financing) are more important than access to information on technology, which is rarely a very important barrier to innovation. A lack of qualified personnel, though less important than the economic factors, is more important than a lack of access to technological information.

These findings suggest an inability to access the science base is not a major impediment to innovation in British industry. This is not to say there may not be difficulties, such as with the financing of these interactions, or with the allocation of intellectual property rights, but on the whole other issues, such as a lack of willingness to take risks, a lack of innovative competition, and intermediate and final consumers that are insufficiently demanding are more significant. For a number of reasons that we discuss in Section 4, the government should consider carefully the costs as well as the benefits of encouraging greater direct interactions between business and the science base. The benefits may be easy to identify and publicise, but the largely hidden costs may be substantial, and will be concentrated in the long run. Overall, there is increasing concern that the science base and universities in particular are under-resourced. Lambert (2003, para 5.12), for instance, notes: 'Universities are all under-capitalised and operate on vary narrow margins between success and failure". For too long the UK has sought to provide higher education 'on the cheap'. The present government claims its ambition is to ensure that the UK has a higher education system matching the best in the world (DfES, 2003), but whilst it is increasing its expenditure on higher education it is also demanding yet more from the sector. What is needed is greater consensus about what it is reasonable to expect universities and the science base to contribute, and to fund those activities appropriately.

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