UNIVERSITY-INDUSTRY LINKAGES AND UK SCIENCE AND INNOVATION POLICY

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by

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Abstract
This paper assesses the current nature of university-industry links in the UK and US using the recent unique IPC-CBR innovation benchmarking survey of the UK and the US. It argues for a more diverse approach to the complex nature of university-industry links than is currently the case. The paper in addition provides a brief overview of SET policy in the UK locating university-industry links within the overall UK policy framework. It argues for a greater degree of coordination of existing policy levers rather than new initiatives and for an effective use of public procurement in relation to SET policy.

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Introduction

In the UK as elsewhere in the industrial and developing world the role that universities can play in supporting innovative performance and productivity growth has received increasing emphasis. For example, the recently implemented UK Science and Innovation Investment Framework for the period 2004-14 is based on the proposition that

'Harnessing innovation in Britain is key to improving the country's future wealth creation prospects…(Britain) must invest more strongly than in the past in its knowledge base, and translate this knowledge more effectively into business and public service innovation. Securing the growth and continued excellence of the UK's public science and research base will provide the platform for successful innovation by business and public services'. HM Treasury et al (2004)

The idea that the translation of science into business innovation is ineffective in the UK has deep roots

'…the small band of British scientific men have made revolutionary discoveries in science; but yet the chief fruits of their work have been reaped by businesses in Germany and other countries, where industry and science have been in close touch with one another' Alfred Marshall *Industry and Trade* (1919).

A problem which is so deep-rooted as to be an issue at two periods a hundred years apart is unlikely to have an easy or straightforward policy solution. In this short paper I want to assess the current nature of university-industry links in the UK and outline the current policy approach. My comparator in this respect will not be Germany but the USA which is the current UK policy role model in this area. I have argued elsewhere that nature of that role model is often misinterpreted, with an overemphasis on one aspect of their role, namely that connected with licensing patenting and high tech entrepreneurial spin offs, and a neglect of the differentiated role of US universities, technology absorption by key user sectors such as retailing and wholesaling and important support role of public expenditure and procurement policy (Hughes (2003)). In what follows therefore I attempt to demonstrate the full range of university-industry interactions in the UK and the US. I also attempt to place those links in perspective within the overall sources of knowledge for business innovation.

Finally, I provide a brief overview of relevant policy in the UK, locating university-industry links within the overall UK policy framework for innovation and Science Engineering and Technology (SET). I argue that a key to successful policy development is to integrate existing potential policy levers as much as to develop new initiatives and that there is a potential role for more effective use of public procurement in this area in the UK.

The diverse nature of university-industry relationships

Despite abundant evidence testifying to the diverse nature of university-industry relations current innovation policy discussions tend to focus on those few directly concerned with commercialization such as patenting, licensing and spin offs. It is useful, therefore, to map out the range of actual interactions. We may identify at least four potentially separable kinds of interactions which work at the university-industry interface (LIS 2005). First, there is the basic university role of educating people and providing suitably qualified human capital for the business sector. Second there is the role of research activity and the role it plays in increasing the stock of codified knowledge which may have useful or commercial elements. Thirdly, there is a role in problem-solving in relation to specifically articulated business needs. Finally, one may identify a group of what one might term as "public space" functions. These are relatively neglected but distinctive features of the role of universities in the economic and intellectual systems of nations. They include a wide range of interaction mechanisms between university staff and the business community. These range all the way from informal social interactions to specially convened meetings, conferences, specifically convened centres to promote, for instance, entrepreneurship and entrepreneurship activities, and the exchange of personnel including the role of internships. Each of these public space functions promotes a range of activities between the business community and the university sector. These may lead to the transfer not only of codified but also tacit knowledge and the establishment of relationships which may feed back into the other three roles.

Just as we may identify these different potential areas of university-industry interaction, it is also important to recognise the different elements that individual universities may stress. This may reflect their own particular missions as well as the economic circumstances of the particular localities or regions within which some universities are located and the role they choose to play in relation to them. For instance, in a recent international collaborative study of regional patterns of university interactions, the Local Innovation Systems Project at MIT has developed a useful typology in which one can see the ways in which different dimensions of activity may develop and be most appropriate to different local economic development pathways (Lester (2005)).

One pathway focuses on the creation of new industries in which the most important interactions would be along dimensions which emphasise leading-edge science and engineering research, aggressive technology licensing policies, and the promotion or assistance of entrepreneurial businesses. Such circumstances may also lead to great emphasis on participation in standard-setting and other activities which promote the rapid diffusion of particular technologies.

A second pathway would emphasise the role of universities where the regional development strategy was focussed around the importation or transplantation of industries, for instance into formerly declining localities. In these circumstances responsive curricula to the needs of the newly transplanted or imported industries and associated education and manpower developments might receive more emphasis, along with technical assistance for the emerging sub-contracting and supplying industries that the newly emerging implanted industry may require.

Thirdly, to the extent that the local development strategy involves a diversification away from existing strengths into technological related new ones, then the university role may emphasise making bridges between otherwise disconnected actors in the local system and the filling of structural holes in the networks of activity and the creation of new industrial identities.

Finally, in the case of upgrading existing industries, the problem-solving dimension and the use of faculty for consulting and contract-research may assume significance alongside activities designed to upgrade the skills of the educated labour force and a variety of activities concerned with global, best-practice scanning foresight exercises, and developing user supplier forums.

The first key point here is that the variety of interrelationships available allows a rich set of possible patterns of interaction. There is no one true way. Although I have emphasised here regional patterns it is also the case that the nature of these relationships are sectorally varied too, so that there too optimal patterns of relationships will vary. The second key point is that in each industry or specific regional case universities will be only one among many sources of knowledge inputs so that there potential impact must be seen in this wider systems context.

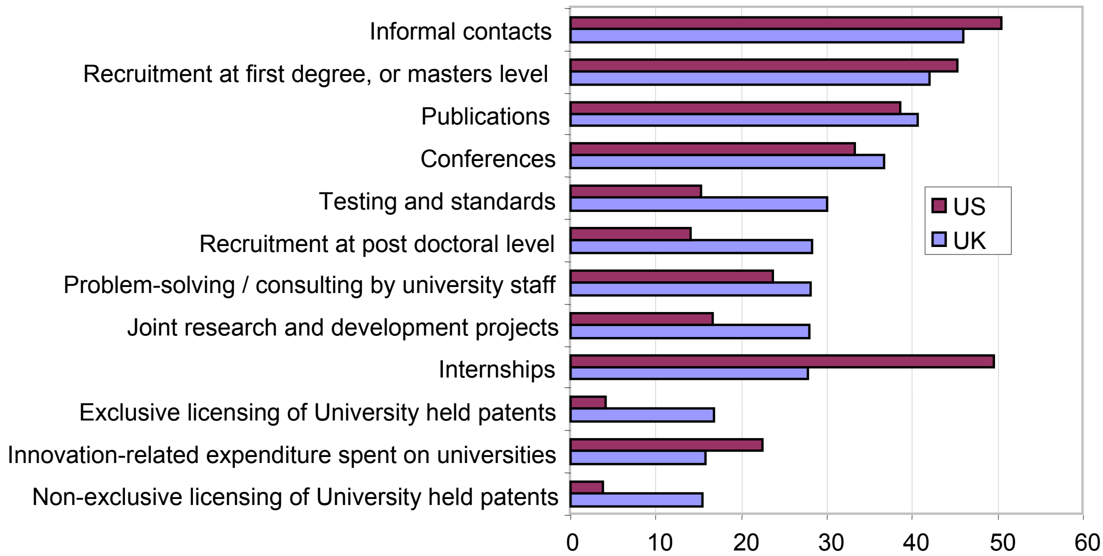
University-industry Links: A US-UK Comparison

In order to indicate the variety of mechanisms by which university activity may impact on innovative performance at firm level, I will draw upon a recent survey carried out by the Centre for Business Research at Cambridge and the Industrial Performance Center at MIT which was concerned with benchmarking innovation activity in these two economies (Cosh, Hughes and Lester 2006). This is the only survey to date which compares the UK and the US innovation systems and it provides the most recent data available for the US as well as for the UK. Here I will focus solely on those elements of the survey which deal with university-industry interactions.

The CBR/IPC US UK innovation benchmarking survey was carried out in March/November 2004. It was a telephone survey with response rates of around 19% in the United States and around 18% in the UK. In both countries a postal top-up was carried out for the larges firms in 2005. The survey instrument contains around 200 questions and generates around 300 variables per firm. The final overall sample consists of 2129 firms from the UK and 1540 firms from the US. The results reported here relate to a matched sample of 2298 businesses: 1149 from each country matched by size, sector and age. This allows us to make comparisons across the countries without having each time to adjust for possible variations which arise from differences between the two countries based on size, sector or the age of businesses.

As part of our survey document we enquired about those interactions which contributed to innovative activity. The responses of the business community on this aspect business-university links are summarised in Figure 1. They show a similar pattern of interactions in both countries. In both countries businesses report engagement with universities using a very wide range of mechanisms. Informal contacts are most frequently cited, followed by other, what may be regarded as conventional interactions involving, recruitment of graduates, use of publications and attending conferences. Licensing and patenting are amongst the least frequently cited of interactions which contribute to innovative activity across our matched sample. Strikingly, with a few exceptions such as internships, UK firms more frequently report such interactions. There is little here to suggest that, with those exceptions, the frequency of interaction is below par in the UK and that particular policy attention is required to increase it.

Figure 1. Types of University Industry Interaction Contributing to Innovation (% Companies)

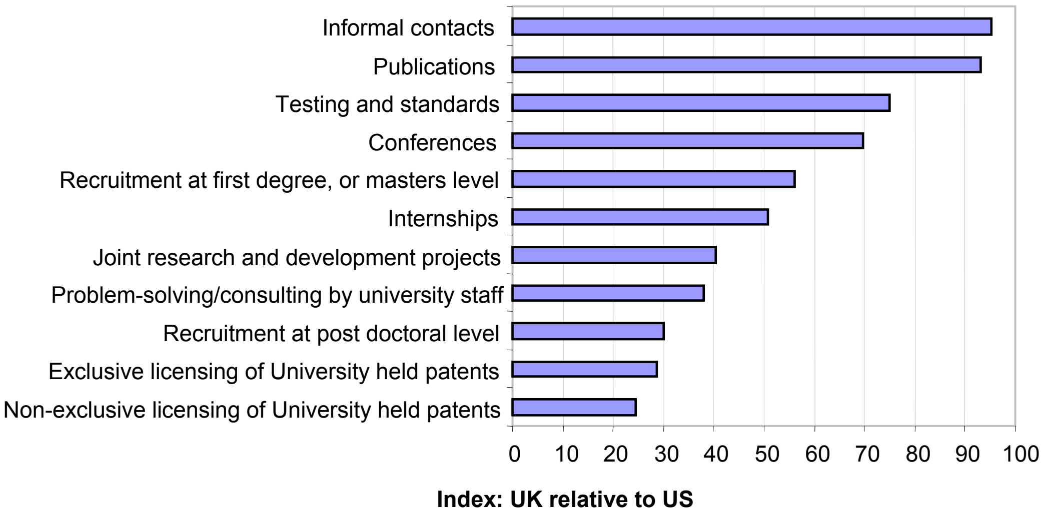


Source: A. Cosh, A. Hughes and R. Lester *UK PLC Just How Innovative Are We?* Cambridge MIT Institute 2005

In addition to asking whether a particular type of interaction occurred we also asked about the importance attached to that interaction. Here it is useful to look at the results as relatives comparing the UK and the US. This is shown in Figure 2, where a score of over 100 on the horizontal axis means the relevant interaction is relative more frequently rated as important in the US than in the UK. The first point that emerges clearly is that, whereas we have seen that UK businesses more frequently report taking part in most types of interaction, it is the US companies that more frequently rate their interactions with universities as highly important for their innovative activities (i.e. the relative score is less than 100). US companies in particular more frequently place a high importance on the admittedly infrequent licensing interaction, as well as joint R&D and problem-solving and on post-doctoral and graduate recruitment and internships. The last two of these are also quite high frequency interactions and, as we have seen, the US firms are also much more likely to use internships than UK firms. The differences between the US and the UK are less marked for the much more highly frequent activities in formal contacts and publications. Further evidence in support of the view that it is the depth and quality of the relationships that distinguishes the UK from the US is the separate finding from the survey that US businesses are more likely to make innovation related expenditures to support their university links (Cosh Hughes and Lester 2006).

The patterns revealed in Figures 1 and 2 suggest that if the US is to be used as a comparator then in terms of the frequency of interactions far more is at stake than licensing, spin-offs and R&D. Equally, the relatively high importance placed by the US on all university interactions and in particular on licensing, joint R&D and problem-solving suggests that there is a need to address the quality of these relationships.

Figure 2. University Industry Interactions Regarded as Highly Important for Innovation: % UK Companies Relative to US

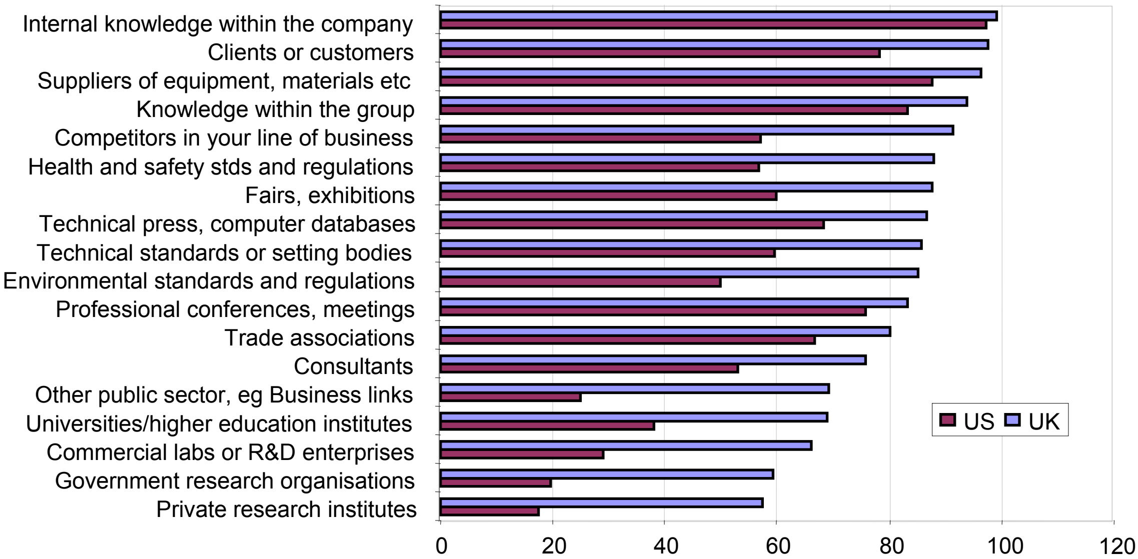


Source: A. Cosh, A. Hughes and R. Lester *UK PLC Just How Innovative Are We?* Cambridge MIT Institute 2005

In thinking about the relative weight to be placed upon university-industry interactions in the promotion of innovation and productivity it is important to look not only at those interactions themselves. They must also be located in the context of the wider system of innovation related business interactions. In the CBR/IPC survey we therefore asked the businesses about their overall sources of knowledge for innovation. The results are summarised in Figures 3 and 4. These present in turn the frequency of use of various sources of knowledge for innovation in the UK and the US, and then the relative importance attached to each by UK businesses compared to US businesses.

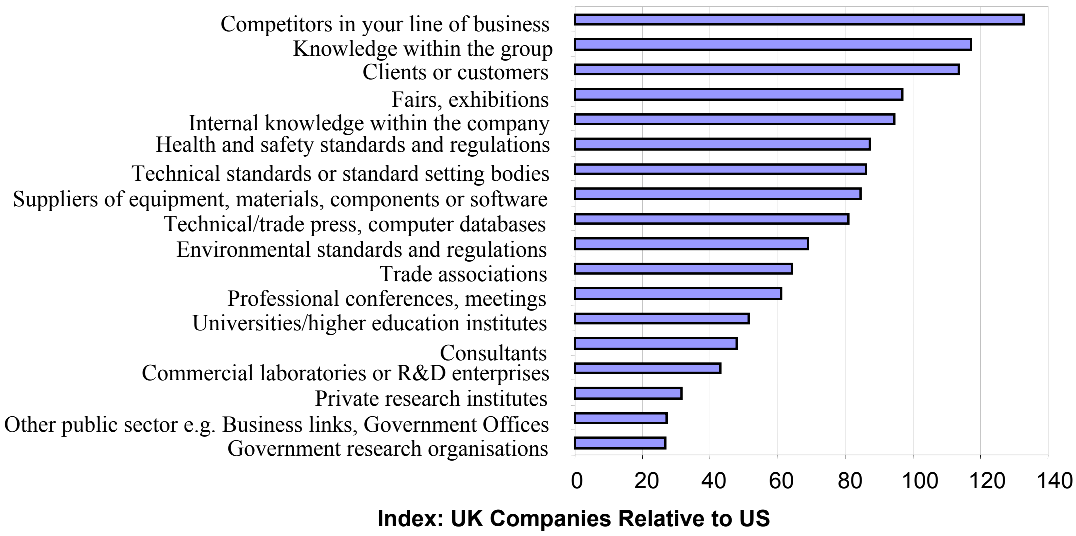
Figure 3 shows that in both countries universities are ranked very low in frequency of use. Customers, suppliers, competitors and internal knowledge within the organisation are the dominant sources of knowledge for innovation. In all cases the UK businesses claim to be more frequent users of external sources than is the case in the US. However, Figure 4 shows that as with university interactions, the US companies more frequently placed more importance on external knowledge sources than was the case in the UK. In all but three cases (competitors, in-house knowledge, clients and customers) US companies were more likely to rate the knowledge sources as highly important than the UK. This was, in particular, the case for the public sector, university and private research institute sources, even though these, as remarked earlier, were somewhat lower down the list in terms of frequency of use.

Figure 3: Use of Sources of Knowledge for Innovation: All Companies %



Source: A. Cosh, A. Hughes and R. Lester *UK PLC Just How Innovative Are We?* Cambridge MIT Institute 2005

Figure 4. Sources of knowledge for Innovation regarded as Highly important by Users of that Source: % UK Companies Relative to the US



Source: A. Cosh, A. Hughes and R. Lester *UK PLC Just How Innovative Are We?* Cambridge MIT Institute 2005

In general, these findings imply that although external source use appears to be more important in the UK, the value or the importance placed upon those relationships is more important than the US. This suggests that the US places greater importance on open innovation system sources beyond the industrial context.

A further analysis of the survey data has been carried out which looks at variations in the importance attached to particular university interactions and the frequency of use of sources across size-classes. This shows that the US firms in all size-classes appear more likely to rate universities highly as sources of knowledge. However, it also shows that the smaller firms in the UK lag most behind US counterparts in attributing significant importance to universities as a source of innovation-related knowledge (Cosh Hughes and Lester 2006).

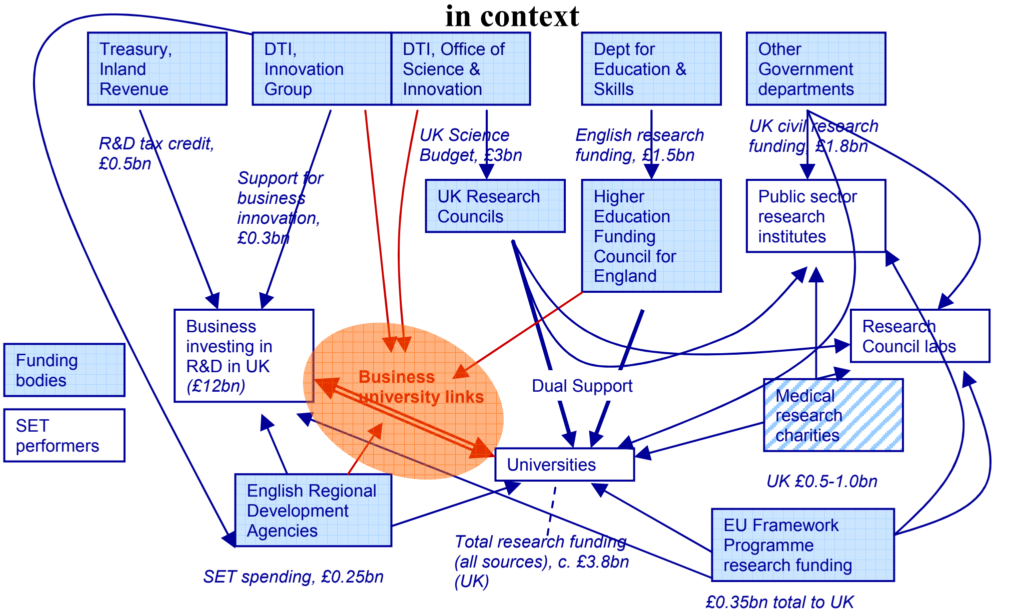
This brief overview of a selection of the key findings of the CBR/IPC survey has a number of implications for policy. In both countries university business innovation related interactions are a small part of the overall innovation system and must be seen in that light. This is not to deny that for some sectors such links may be much more significant than for others. Rather it is to emphasise the need to craft university focussed innovation policy with close attention paid to the full set of relevant interactions. The second policy implication arises from the observed depth of, and degree of importance attached to, business-university interactions in the US compared to the UK. This finding implies that if the US is to be the policy role model then attention should be paid to raising the quality of interactions rather than increasing their incidence. Finally it appears that in the UK the smaller businesses are less likely to be involved in and place importance on university interactions. These findings and the importance of focusing beyond spin offs and licensing confirm qualitative arguments to the same effect in the recent influential innovation policy review carried out by Richard Lambert (HM Treasury (2003)).

The main conclusions of the Lambert review relevant this paper were that the principal challenge facing the effective exchange of knowledge of the university-industry frontier in the UK lay in raising the effectiveness of good quality business demand for research from all sources including universities. The report also argued that there was a case for making greater business inputs into the nature of university courses and curricula in the UK. The report also made a strong plea for the switch of R&D support policy to promote interaction between universities and smaller firms.

UK SET Policy and University-industry Links: A System Overview

To understand the nature of policy intervention in university-industry links in the UK it is useful to set them in the wider science policy and R&D system. To avoid complications of detail which arise when considering the nature of policy in the devolved national administrations the analysis shown in Figure 5 is for England[ii]. This provides a schematic overview of the public and major charitable organisations which fund SET activity and those organisations that carry it out. Funders are shown in the shaded boxes along with an indication of the scale of funding in 2002 levels. SET performers in the public and private sectors are shown in unshaded boxes and cover the business sector, universities, public sector research institutes, and the UK Research Council laboratories.

Figure 5: Funding and Performing SET in the UK: University Industry Links in context



Source: HM Treasury CST Briefing Document 2005

It is apparent that there are many actual and potential, and direct and indirect influences on business university links. The most important route is through the dual support system which provides core university funding through two mechanisms which, along with charitable funding of medical research, account for around £3billion of the total university research funding spend of around £3.8 billion. The first mechanism is direct block grants from the Department for Education and Skills via the Higher Education Funding Council for England (HEFCE). This supports research activity with allocations linked to university size and performance in a periodic Research Assessment Exercise (RAE). The extent to which these funds are linked to university business related activities is essentially a matter for individual universities. The second leg of the dual funding system is provided by the Office for Science and Innovation via the 7

UK Research Councils[iii] where project or programme specific funds are allocated on the basis of scientific peer review of competing bids to universities (as well as research council labs and public sector research institutes). The extent of specific university business interaction here depends on respective council policy initiatives in relation to the award giving process. Government policy concern at the extent to which this dual flow of funds was too dominated by scientific peer review in both legs and too little connected to business uses has led to periodic attempts to revise both (e.g. HEFCE 2003a 2003b). It has also led to a series of initiatives such as the Higher Education Innovation Fund (HEIF) which has been designed to provide resources to develop a so called third leg of university funding. These initiatives are based on encouraging entrepreneurial spin offs and raising income from commercialization activities such as licensing and patenting and are discussed in more detail in the next section.

In addition to these primary funding sources universities attract research funding on a smaller scale from the DTI to support innovation activity and from the 9 regional development agencies (that are themselves funded by the DTI). Universities also compete for funds under a variety of European Union programmes. These funding routes are frequently linked respectively to schemes designed to promote specific national or regional university interactions, or European wide research collaboration. Finally out of total university research spend of £3.8 billion funding of around £300 million came directly from the business sector.

Business carried out around £12 billion in R&D. The main direct policy support here is the R&D tax credit (worth around £500 million a year) alongside a range of business support policy programmes delivered regionally or nationally by DTI worth around £300 million in 2004/5 which are discussed further below.

Civil public sector expenditure on R&D shown in the diagram (amounting to around £1.8 billion) was augmented by around £2 billion of defence related public sector R&D (which is not shown in the diagram). Only around £400 million of this combined total was channelled through Higher Education or Research Council Institutions. The rest was either carried out inside the relevant department (around £900 million) or in the UK business sector (around £900million), with a small balance carried out overseas. The impact that publicly procured R&D could have on university-industry links from the business demand pull side is thus considerable. For instance an element of this procurement could be linked to promoting knowledge based firms linked to the science base. At present this aspect of UK innovation policy is underdeveloped. I discuss it further in the next section.

The complexity of this system poses obvious coordination problems. In developing SET policy and business university links the UK government has, therefore developed a long term programme designed both to strengthen the science base, rationalise business support policy, raise the overall R&D effort and strengthen commercialisation activity and university links.

The Science and Innovation Investment Framework for 2004-2014

The Investment Framework for Science and Innovation for the period 2004-2014 sets a target of raising total UK R&D from 1.9% of GDP to 2.5% of GDP by 2014. The broad structure of the target is shown in Figure 6. The year-on-year growth of the public science spend was 10% from 2003-04 to 2005-06 in the UK. The commitment in the science and innovation framework is that the level of public spending on the science base will grow faster than the rate of growth of GDP over the framework period, rising from 0.7% to 0.8% of GDP. In order to reach the 2.5% target nationally by 2014 it is clear there must be a substantial matching investment by the private sector, which must raise its R&D from

Figure 6. The 10 Year Science and Innovation Framework R&D Target

	R&D investment as percentage of GDP	
	2004	**2014**
Science Base	0.4	0.5
Other Government R&D	0.3	0.3
Private sector	1.2	1.7
UK total	**1.9**	**2.5**

Science and Innovation Investment Framework 2004/14, HM Treasury, DTI, DfES July 2004

1.2% to 1.7%. This is against a background of stagnant or declining levels of private sector R&D in the UK. It is important to note that UK R&D in the private sector is heavily concentrated with only a handful of large firms in a few sectors with intensive R&D expenditure. (DTI 2005). Pharmaceutical and aerospace account for 23% and 10% of private sector R&D respectively and the share of overall private sector R&D and GDP fell from 1.4% in 1985 to 1.2% in 2002. There is little sign that the target will be met by existing large UK R&D spenders. Moreover, R&D is internationally mobile. Increasing attention has therefore focussed on the potential role that newer technologically based UK smaller and medium-sized enterprises (SMEs) can play in fill the void. There is however an order of magnitude problem here. Data on independent SME R&D data is subject to considerable margins of error but even generous estimates suggest it is only between £400 and £600 million a minor fraction of the total £12 billion 2004/5 private sector spend in 2005.

Whatever the likelihood of meeting the target it can be argued that it is far less important than other aspects of the framework. First, R&D is an input and what matters for commercialisation issues is how effectively it is converted into outputs. Second, this conversion requires major complementary investments in design, marketing and human capital developments, (Cox (2005)) effective access by business to the full range of knowledge sources described earlier, and the design of a 'public space' architecture to enable universities to play their part across the full range of interactions identified earlier in this paper (Lester and Piore (2004)).

It is worthwhile highlighting a few of the more important elements here. First in relation to university spend in particular, a basic commitment in the science investment and innovation framework is to the full economic costing of university research projects. This is an important element in maintaining a sustainable science base since it prevents the under-costing of projects and the cross-subsidisation of them from other sources of university income typically at the cost of essential overhead infrastructure. Secondly, in relation to third-leg funding there has been a realignment of the Higher Education Innovation Fund (HEIF) and a rationalisation of the DTI innovation support policies, (or 'products' as they are now known). Thirdly the introduction of a new Technology Strategy Board designed to play a key intermediary role between science and technology projects which are near to market and the business sector.

HEIF in its realigned third phase will from August 2006 to July 2008 involve approximately £240m worth of funding to higher education institutions. The intention is to promote activities of direct and indirect UK economic benefit in the university sector. The fund is designed to support knowledge transfer activities which would be unlikely to generate a large net income for universities and therefore not be attractive investment propositions by the universities themselves. It is a national scheme but encourages bids with regional involvement so that the connection between the university sector and the regional economies can be fostered. In order to avoid the problem which has faced many newly introduced schemes of a lack of sustainable human capital to support them, the new funds under phase three of HEIF will be allocated on a formulaic and predictable basis. This should allow the recruitment and retention of skilled staff on the basis of the more predictable funding available. A minority of the funding is reserved for a competitive allocation. This portion is designed to encourage particularly new and innovative approaches and to encourage collaborative activies across higher education institutions so as to get scale gains from knowledge transfer activities and to capitalise on best practice. The nature of these changes is designed to encourage an increased degree of quality and depth in university-industry relations which our survey suggests is required.

Prior to the science and innovation investment framework the DTI innovation support programme was characterised by a plethora of separate schemes and products, with varying or ill-defined objectives and different modes of operation and delivery. As a result of an innovation review (DTI (2003) carried out prior to the development of the science investment framework, the DTI innovation "products" have been rationalised into three. First, there is the grant for R&D which used to be called the SMART programme. This will provide around £30million per annum to support small and medium-sized enterprise funding for innovation activities in the early development stages prior to commercialisation. This is a continuation of a very successful scheme which has operated for many years in an effective manner (Cox et.al. (2002). This programme is part of the useful underlying support system for small and medium-sized enterprises R&D activity linked to early stage commercialisation from the science base.

The second DTI innovation product is the Knowledge Transfer Network. This consists of groups of knowledge transfer organisations were formerly known as Faraday Partnerships. They are intended to strengthen the relationship between sector based businesses and universities specialising in relevant technologies. They develop pooled source of knowledge on technology developments and foster collaboration between business partners and universities on a national rather than regional scale. This includes a range of metrology and related issues and the creation of standards for effective network activity. This product is designed to help address an important issue wed identified earlier which is the tailoring of specific university-industry relationships to sector needs as well as the encouragement of open system in the connections between the relevant partners in the sectoral framework. There is however a clear, and as yet unresolved, tension between this national sector based approach and the various attempts to develop a regional focus in university-industry links. The third central product is based on Knowledge Transfer Partnerships. The Knowledge Transfer Partnerships programme is worth £20m per annum and was formerly known as the Company Teaching Scheme. It is a substantial scheme with around 1,000 projects underway which place universities and individual firms in partnership in the resolution of particular technology-based projects. This too is an important initiative which links through human capital relations and internships the university base with individual firms wishing to solve particular problems. This relates directly to that dimension of university-industry links which was identified in the UK US survey results which emphasises customised problem solving contract research. It also has a successful track record behind it (SQW 2002). Taken as a whole these products address a number of potential problems which were highlighted earlier in this paper. They have, however, been in place for some time and the commitment of resources remains similar to previous levels. Notwithstanding their merits it would appear that additional impact must come from more focused commitment to them as part of the overall technology strategy embedded in the long term framework.

A new addition to the architecture designed to enhance pull through from the science base has been he creation of a new Technology Strategy Board (TSB 2006). The Technology Strategy Board is designed to play a key role in the selection of priority areas for innovation support expenditures through the DTI Collaborative Research and Development project programme. Around £250m/annum will have been committed by TSB in 2006 with the amount rising in subsequent years. The Technology Strategy Board consists of members largely from the private business sector including the venture capital community. Its role is to encourage the developments of technology emerging from the science base which are closest to market possibilities through collaborative bids for funding. Those market possibilities are to be chosen with a view to the likely scale of potential markets available in global terms, and where the UK has potential for augmenting or developing world-class competitive capacity. In its initial activities the Technology Strategy Board programme is focusing on seven key areas. These are electronics and photonics, advanced materials, ICT, bioscience and healthcare, sustainable production and consumption, emerging energy technologies, and design engineering in advanced manufacturing (TSB 2006). The Technology Strategy Board and its programme represent an important new initiative in terms of focusing expenditure in relatively key areas seen from a business and combined technology perspective.

The size of the budgets committed in these areas is substantial in public policy terms. Their impact on the pull through from the science base by small and medium sized firm could, however be considerably enhanced if a more effective use of public sector extra mural R&D could be made. The opportunity to effectively enlist those expenditures to pull through technologies from the science base has been relatively neglected in the UK compared to successful schemes using public procurement measures in the United States such as the Small Business Innovation Research (SBIR) scheme in the USA (http://patapsco.nist.gov/ts_sbir/). Attempts in the UK to develop a similar programme have so far failed to generate significant results. The reasons are closely related to a few key factors. First, the extent to which opportunities are available and the terms on which they are accessible are relatively opaque and intermittent. In addition, in the past there has been a strong element of co-funding required in obtaining UK public sector procurement support through the existing scheme. This is in contrast to the United States where full cost contracts are awarded. The potential benefits of extending and making more effective this scheme in the United Kingdom are twofold. First the amount of funding potentially available to pull through technologies from the science base would be substantially enhanced. Second and more significant the contract nature of the relationship helps develop reputation and competence in the early stages of companies start-up. The existence of a contract as opposed to a grant both helps harden up the development of early stage businesses and also makes them more attractive propositions when they seek funding for further development from the financial sector and other sources (Connell (2004). This potential role for public procurement which was relatively neglected in the original Science and Innovation Investment Framework report has been given more emphasis in the follow-up programme (HM Treasury et al (2006)). Thus in the budgets of 2004 and 2005 moves were made to make it mandatory for Government Departments and Agencies to place 2.5% of their extra mural R&D contracts with small and medium sized enterprises through the Small Business Research Initiative (SBRI) programme, as well as to develop a new NHS research strategy to encourage the attraction of business related health R&D (HM Treasury et al (2006)). The latter proposed change is too early to evaluate. The former, where the target implies around £50 million worth of Government research to be bought from smaller firms (http://www.sbri.org.uk/aboutus.php), still faces concerns about how effective delivery will be in practice given the lack of effective simple procedures and coordination in the delivery of the initiative compared to the SBIR programme in the USA (Connell (2004)).

Conclusions
University-industry links and their potential role in innovation must be seen as part of a complex system. University-industry links are only one part of the sources of knowledge from which the business sector derives information on technologies relevant to their production process and competitive position. . In developing university it is important to recognise the distinctive 'public space' role that universities can place and not just focus on those particular issues relevant to licensing, spinouts and R&D expenditure.

Insofar as the US is seen as s a role model for the UK, it appears that within those university-industry relationships that do exist, it is not the frequency with which they occur in the UK, but the depth and quality which is attached to them which is the most significant difference. These problems appear to be exacerbated as far as smaller firms are concerned. This suggests that policy towards these links should attempt to ameliorate weaknesses in quality and at the same time improve access for smaller firms. The range of patterns of these interactions is both very wide and likely to vary systematically across sectors. Therefore policies need to develop which bear in mind the specific needs of different sectors. In a regional context they need to be located in specific regional development strategies. In a small open economy such as the UK the tension between promotion national sector-based schemes and those operating at regional level requires careful management.

Our brief overview of the nature of the science, engineering and technology policy system in the UK highlighted the complexity of the system and the diversity of actual and potential intervention routes. Effective policy intervention in relation to university-industry relationships requires an overall holistic view to be taken of this policy framework. It also requires a long-term perspective in order to enable a degree of predictability to occur in the underlying functioning of the system. The ten year framework for investment in science and technology for the period 2004-20014 is clearly a welcome step in providing a long-term perspective within which to work. A number of elements of the framework have been looked at in this short review and the positive contribution they can play in relation to existing evidence on university-industry relationships highlighted. A central problem for the science and innovation framework is the likelihood that the private sector component of the R&D target will not be met given the structural features of R&D spend in the UK. However, I would argue that the target *per se* is one of the less important aspects of the framework. Instead those aspects which concentrate on developing the quality of university-industry relationships and business pull through are likely to be most fruitful in the longer run. In reviewing the elements of policy which address these aspects the underexploited potential of public procurement for small high technology businesses stands out.

Notes

[1] Alan Hughes is a member of the Council for Science and Technology (CST) the senior advisory body to UK government on science and technology policy. The views in this paper are his own and should not be interpreted as those of the CST.

[ii] I am very grateful to Daniel Storey of HM Treasury for this diagrammatic exposition. In 2006 the Office for Science and Technology was renamed the Office of Science and Innovation. Its new name is used in the diagram.

[iii] The seven councils are ESRC (Economic and Social Research Council), EPSRC (Engineering and Physical Sciences Research Council), AHRC (Arts and Humanities Research Council), PPARC (Particle Physics and Astronomy Research Council), BBSRC (Biotechnology and Biological Sciences Research Council), MRC (Medical Research Council), CCLRC (Council for the Central Laboratory of the Research Councils).

References

Cosh, A., Hughes, A. and Lester, R. (2005) *UK PLC Just How Innovative Are We?* Cambridge MIT Institute.

Connell, D. (2004), *Exploiting the UK's Science and Technology Base: How to Fill the Gaping Hole in the UK Government Policy,* TTP Ventures, Cambridge, December.

Cox, G. (2005), *Cox Review of Creativity in Business: Building on the UK's Strengths*, HMSO, London, November.

Cox, M., Hughes, A. and Spires, R. (2002) *Evaluation of SMART (including SPUR) 2001: final report and appendices* DTI Evaluation Report Series No.3. Sheffield: Small Business Service. (www.dti.gov.uk/about/evaluation/smart.pdf and smart_appen.pdf)

DTI (2003), *Competing in the Global Economy: The Innovation Challenge,* DTI Innovation Report, HMSO, London, December.

DTI (2005), *R&D Intensive Businesses in the UK*, DTI Economics Paper No. 11, DTI, London, March.

H.M. Treasury (2003), *Lambert Review of Business-University Collaboration: Final Report*, H.M. Treasury, London, December.

H.M. Treasury, DTI, DfES (2004), *Science and Innovation Investment Framework 2004-14*, HMSO, London, July.

H.M. Treasury, DTI, DfES, DOH (2006), *Science and Innovation Investment Framework 2004-14: Next Steps* HMSO, London, March.

HEFCE (2003a) *Review of Research Assessment: Report by Sir Gareth Roberts to the UK Funding Bodies*. http://www.ra-review.ac.uk/.

HEFCE (2003b) *Statement by the UK higher education funding bodies on the review of research assessment*. http://www.hefce.ac.uk/news/hefce/2003/review_ra.asp.

Hughes, A (2003) 'Knowledge Transfer, Entrepreneurship and Economic Growth: Some Reflections and Policy Implications' in *Entrepreneurship in the Netherlands: Knowledge Transfer, developing high tech ventures.* EIM Business Policy, and Dutch Ministry of Economic Affairs The Hague.

Lester, R.K. (2005) "*LIS Project - Phase I Findings: Overview and Discussion*" MIT IPC Local Innovation Systems Working Paper 05-004 December

Lester, R.K. and Piore, M.J. (2004) *Innovation. The Missing Dimension* MIT Press Boston, Mass.

Office of Government Commerce (2004), *Capturing Innovation: Nurturing Suppliers' Ideas in the Public Sector*, Office of Government Commerce, London.

SQW (2002) *Evaluation of Teaching Company Scheme (TCS). Executive Summary and Main Report.* SQW Limited, September DTI Evaluation Report Series No.7 September, London, DTI**.**

Technology Strategy Board (2006), *"Technology Strategy – A Call to Action"*, London.