Universities, Business and Knowledge Exchange

Maria Abreu, Vadim Grinevich, Alan Hughes, Michael Kitson and Philip Ternouth

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Contents

Executive summary

Universities are central generators and repositories of knowledge in our society. How that knowledge is developed, disseminated and applied affects not only the cultural richness of our society, but also our global competitiveness. To meet the challenges of the latter, we need policies that encourage and facilitate closer understanding and joint working between universities and businesses. To be effective, these policies need to be based on evidence of what works and why and the processes that need to be in place to enable the dialogue and interaction to be most productive. Our work seeks to help illuminate those issues.

This report reflects the results of semi-structured interviews with over 30 UK businesses on where they see universities most adding value in the process of exchanging and co-developing knowledge. It confirms that technology transfer is only one aspect of the knowledge exchange process; the very notion of exchange highlights the interdependent and evolutionary nature of interactions with others and particularly those in business.

Valuing relational approaches, not just transactions

There are indeed multiple knowledge exchange mechanisms and our work has again stressed the importance of personal relationships and the development of mutual trust built up over time. Our cases highlight the importance of relational rather than contractual interactions. Indeed sometimes when university intermediaries were required to formalise contracts they appeared to be pursuing their own agenda, not adding value and even distorting the project. These relationships are often built up through common networks (the most common form of interaction was via collaborative or consortia research) where the project or problem to be addressed evolved following a series of interactions rather than being specified up-front. It is the contact between individuals rather than institutional relationships that dominate the opening phase of university-business relationships.

A vital role for enabling gatekeepers to encourage collaboration

Many projects developed from a business identifying a broad problem area or challenge rather than specifying a narrow technical issue. Indeed just solving a problem does not necessarily enhance the capability of a business. Defining mutual benefit from an interaction is also most likely if the area is broad. The different value systems also need to be well understood. Hence our study reveals the vital role played by gatekeepers who sit at the interface and can both explain the issues, identify the appropriate researchers and translate the results in ways that impart knowledge throughout the organisation.

Businesses value the broad perspectives contributed by academics

There are several ways in which businesses evaluate the success of their relationships with universities. These range from the informal through formal metric based approaches and KPIs to financial returns (though there were few examples of the latter). In general the relationships which are most valued stem from the contributions of knowledge and expertise and the ability of academics to take a wider view. This is particularly the case with those larger companies that had a more mature relationship.

Variety and richness in university-business collaborations

A significant result from the fieldwork is the variety and richness of the types of impact the university-business collaborations have on the research value chain. These extend far more widely than the traditional view, whereby a technology developed in a university is incorporated into a commercial product, a view which has been encouraged by the focus

given to it by policymakers. Indeed, the cases indicate that the highest identifiable financial impacts arise from a re-engineering of the production process rather than from the sales of new products. Indeed technology-based companies may not need assistance from university researchers in the development of their technology, but may benefit from marketing and management science in the development and deployment of business processes involved in supporting their technology in the field. The complexity of the impact on the value chain is also illustrated by the fact that even when the research is described as 'applied', it may still need substantial development for incorporation into process and product; the deliverables may be in the form of prototypes which need re-engineering or redeveloping for use in different product areas.

Investing in internal capacity to embed knowledge generated

A key issue that arose in the course of our research was the extent to which knowledge became embedded in a business and the types of processes used to ensure this embeddedness. Some saw this as critical to the value that a university adds and to maintaining the relationship and hence devoted considerable resources to this effort. But in others, the embedding was seen as an additional cost rather than an investment in capacity building. Some businesses have specific structures, procedures and internal networks and appreciate that one of the success criteria for KTPs, for example, is this insistence on there being an embedding strategy.

A different view on proximity

It is a commonly held view that proximity matters; that clusters build because of the close interaction of people including from academia and business. Our work offers an added insight since it suggests that proximity may be more important for small businesses than for large and also that proximity is, at least partly a matter of perception. BT and MIT have a proximity because the former considers the relationship so important that it embeds a person in the MIT laboratory. 'Local' therefore depends on the reach of the business and the strength and excellence of the research. The relationship can be much more important than the increase in transaction costs implied by distance. This view also underlines the importance that mature businesses attach to the longevity of their relationship with academics.

Businesses want access to the possessor of tacit knowledge

The effectiveness of the relationship depends on how far the general can be translated and made specific for a particular business context. Academics generally deal with the former whether that be explicit or tacit knowledge. The process of transforming tacit knowledge into explicit or codified knowledge is particularly difficult. Businesses generally want access to the possessor of the tacit knowledge which underpins what might be explicit. Therein lies the tension with knowledge transfer and IP intermediaries and whether value is most likely to be created by the business commercialising the knowledge (and writing the patent) or the university.

Moving beyond linear metrics, recognising complexity

There is often a trade-off between the simplicity and transparency needed for policy metrics and the complexity of the processes that such metrics are attempting to measure and influence. The current policy agenda is concerned with the transfer of technology from the research base supported by a focus on STEM graduates, support for technology transfer offices in universities and the use of instruments (such as tax credits) that seek to encourage R&D. This focus, however, can too easily ignore many of the varied ways by which universities and businesses together influence innovation and business performance. Also, it ignores some of the greatest challenges and difficulties which are concerned with absorbing and embedding knowledge within businesses. This report suggests that there is now a need to broaden the knowledge exchange policy agenda.

1 Introduction

This report sets out the findings of a case-based study of knowledge exchange processes involving more than thirty UK companies and UK universities.

It provides a qualitative examination of university-business interactions which goes beyond an analysis of patterns and structures of knowledge exchange to uncover the processes by which modes of exchange emerge, develop and are assessed. It offers business views on the nature of the research value chain and the roles they see universities play in that process.

The cases cover a wide range of firm sizes and sectors including firms in the services sector. They are intended to be illustrative and are not intended to be representative samples of the UK as a whole.

The report is based on research carried out by the Council for Industry and Higher Education (CIHE) and the Centre for Business Research (CBR) at Cambridge University, and represents the UK Country Report for a Sasakawa Peace Foundation (SPF) funded project titled *'Improving the Effectiveness of University-Business Interaction'*. The project also forms the first stage of an Economic and Social Research Council (ESRC) funded project by CBR titled *'University-Industry Knowledge Exchange: Demand Pull, Supply Push and the Public Space Role of Higher Education Institutions in the UK Regions'*. The case study research was designed to ensure that critical insights affecting the dynamics of knowledge exchange practice and outcomes could be captured, a requirement which was common to each project. These insights will be included in survey instruments to be administered in large scale surveys of both businesses and academics in the UK for the ESRC project. The collaboration with its dual funding has enabled an enlargement of the number of case studies to be included in the research with consequent benefits to each project. The SPF project will go on to provide a comparison of the case results with similar work in the USA, Japan and Canada.

In order to provide an empirical and conceptual background to the cases the report begins with a brief overview of current interpretations of the state of university-business knowledge exchange and government policy initiatives in this area in the UK. This serves to highlight some unresolved questions which have motivated the research project as a whole. The insights from the cases are then set out. These provide:

- a qualitative assessment of the ways in which university-industry knowledge exchange activities are both created and successfully exploited;
- an analysis of the processes by which appropriate modes of knowledge exchange or 'paths' along which knowledge exchange can flow are chosen;
- an analysis of the interaction between the nature of research and the mode of knowledge exchange and the ways in which modes may vary across different sectors and types of business;
- an analysis of the factors affecting the geographic location of knowledge exchange partners and consequent impacts upon regional and sub-regional economies;
- an analysis of how knowledge exchange partners evaluate their success and how they interpret their impact upon their "home" organisations in business and academia.

In the cross-cutting review we will address in detail the specific SPF project objectives by combining and comparing the findings from the four country reports. This will enable us to:

- further the understanding of the modalities of relationships between universities and business and industry;
- identify and characterise the processes which aid the translation of different types of research in a range of sectors into application;
- identify modalities of interaction which may be particularly suited to open innovation models;
- develop practical interventions in policy and practice which will accelerate and improve the ability of universities and business to work together;
- guide investment in knowledge exchange support;
- guide the development of the Knowledge Transfer (TLO) function in universities;
- identify effective knowledge exchange mechanisms and therefore indicate the professional expertise, skills, training and personal characteristics likely to be most effective in knowledge exchange;
- assist the development of more "intelligent" performance indicators and measures of success;
- identify effective support networks for innovation.

On the basis of our cases we draw some suggested implications for the way that policy should approach the fostering and development of knowledge exchange between business and academia. We note in particular where these emerging findings reinforce or are reinforced by findings from earlier studies. In the main we emphasise the importance of the process aspects and co-evolving nature of the mechanisms of knowledge exchange and the learning experienced by individuals as they develop knowledge exchange activities.

We argue that attention needs to be paid to the ways in which policy can affect the likelihood of potentially fruitful interactions occurring and the most effective way in which they can be fostered. We note in particular the importance that certain '***gatekeeping***' and '***boundary-spanning***' roles play if effective information exchange between the business and the research base is to occur. We also emphasise the extent to which resources and internal structures are required to shape and embed relevant information and technical knowledge flows from the research base into business product and practice. Finally, we draw attention to the large extent to which, in our cases, knowledge exchange is concerned with processes of product and service production and delivery, and with organisational change as opposed to final new product development[1].

1 We note that in some service sectors in particular the process and product distinction may be harder to draw (see Abreu et al, 2008b).

2 UK Policy context

2.1 Interventions to stimulate business university interactions

Since 1993, with the introduction of the *Realising Our Potential Awards* report, there has been an increased focus by the UK government on the impact of interactions between universities and business. This has grown in importance as globalisation has increased the perceived importance of the UK developing an innovative knowledge based economy. More recently there has been a recognition that other domains of research and sectors such as creative, media and financial services also contribute to economic growth but the focus of policy remains on science and technology.

The White Paper *Our Competitive Future* in 1998 (DTI, 1998) committed the Government to support business in developing knowledge based competition and made specific reference to the important rôle of universities. Separate initiatives since then have provided funds for universities to invest in different types of knowledge transfer projects. For example, the University Challenge Seed Fund launched in 1998 was aimed at projects that moved technology closer to the market and acted as a springboard for spin out companies. The Science Enterprise Challenge provided funds for projects in Entrepreneurial Education and Higher Education Reach Out to Business and the Community (HEROBAC) and its descendant, the Higher Education Innovation Fund (HEIF) provided funds to universities to improve their interaction with business. HEIF is the current means of funding and its third generation (HEIF 3) provided some £200m over 2 years from 2006. HEIF 4 allocations for 2008 – 2011 were announced in March 2008, and provide funding to universities rising to £150m per annum by the third year. Initially funding was allocated on a competitive basis to stimulate ideas for novel activities, but it has increasingly moved to a formulaic basis (using a formula based on existing income from business). A review of the impact of HEIF funding will be completed in late 2008. One of the results of these policies has been the development of specialised units in universities charged with stimulating interactions with business and this report will discuss the extent to which they are able to fill the key role of "gatekeepers" identified in the discussion of our findings.

The Research Councils have also become increasingly interested in evaluating the economic impact of the research they support. They have always been accountable for ensuring that research outcomes are exploited but until recently this has received little real focus. They have for some time acted as sponsors of individual programmes such as Knowledge Transfer Partnerships and in the case of the Engineering and Physical Science Research Council (EPSRC the 'Engineering Doctorate'. However the Warry Report (Research Councils Economic Impact Group, 2006) concluded that their activities were fragmented and there was little meaningful attempt to evaluate outcomes or share good practice.

2.2 Metrics and evaluation

The metrics that have been used in the evaluation process have to date reflected a focus on stimulating transactions. Since 2002 there has been a regular survey of interactions between business, the community and universities. The Higher Education Business and Community Interaction Survey (HE-BCI) has collated data from all HEI's on the nature and extent of their relationships with business. The metrics in the HE-BCI survey to which most prominence has been given by policy makers and others are the transactions which reflect a linear mode of technology transfer – such as patents, licences and spin out companies.

2.3 Key policy reviews and reports

Since 2003 there have been several major policy reviews in areas related to business-university relationships, including a range of specially commissioned reports to government by leading figures:-

i. the ***Lambert Review*** which examined business-university interactions and whose recommendations included providing resources for training the 'commercialisation' staff in universities and creating model agreements for sponsored research and IP licensing.

ii. the ***Gowers Review*** of intellectual property (IP) policy (HM-Treasury, 2006) which criticised the lack of a strategic approach by the UK patent office and suggested that it should take a more proactive role in considering the use of IP as one tool in the innovation process including use in specific areas such a proteomics and genomics; this resulted in the formation of the Strategic Advisory Board on Intellectual Property (SABIP).

iii. the ***Sainsbury Review*** *The Race to the Top,* (HM-Treasury, 2006) of the UK innovation system which has made a number of recommendations including doubling the number of KTP's, and adopting a formulaic approach to HEIF funding; it suggested also a very simplistic segmentation of universities (research intensive and business facing): with research intensive universities pursuing 'knowledge transfer' and business facing universities pursuing 'problem solving'. It also recommended that the UK should revise the current SBRI (Small Business Research Initiative) programme to be more closely modelled on the US SBIR (Small Business Innovation Research) programme. The current configuration of the scheme was really just a signpost to small government contracts. The CIHE published a report (Ternouth, 2007) supporting this conclusion but highlighting the key differences in implementation and staffing which will be necessary to underpin this development. This built on a previous review of the SBIR programme by David Connell (Connell, 2006).

iv. the ***Department for Innovation, Universities and Skills*** (DIUS, 2008) published a White Paper on Innovation (" *Innovation Nation")* which takes a much broader view of innovation beyond the traditional science and technology paradigm. The White Paper conceives innovation as a complex process, with far less emphasis on linearity and being just as dependent on demand as on supply. At the same time the UK's world-class research base is seen as an important component of its innovation ecosystem.

In 2008 Professor Paul Wellings, the Vice Chancellor of Lancaster University, has been asked by the Secretary of State for Higher Education to review the role of universities in managing intellectual property. John Denham's comment on the brief was quoted in Times Higher Education (Gill, 2008). *"I want institutions to reap the fruits of their own labour. But as Secretary of State for Innovation, I want to see financial benefits flow through the economy and the wider diffusion of knowledge across the country."*

These last two initiatives in particular highlight the importance of this report and the four country study which will share knowledge and experience in the area of university-business knowledge exchange in Japan, Canada, the UK and the US. Understanding the mechanisms through which business and universities actually interact and how universities actually contribute to the creation of economic value is of critical importance for developing interactions which are aligned with and reinforce those mechanisms - rather than distorting or constraining them.

3 What we know about university-business interactions in the UK

Evidence for the UK economy taken as a whole, shows that customers, competitors and suppliers are the most common source of knowledge for innovation. Universities appear low down the list (DTI, 2006). Taken at face value such evidence is not particularly illuminating, since it is not clear what an optimal pattern of interaction might be or where we might expect universities to rank. One way of tackling this problem is to compare the relative importance of universities across countries and particularly in relation to the USA which is often taken to be the aspirational target in UK and EU policy discussion.

Unfortunately relying on data covering the whole economy cannot be used to make such comparisons in a straightforward way. Countries differ in the distribution of activity across sectors, in the size distribution of firms and in the share of innovating firms across sectors and size bands. These variables have an impact on the need and likelihood of access to the research base, and hence complicates international comparisons. Moreover, there is no official survey-based innovation data for the USA comparable to the harmonised EU community innovation survey which is the most frequently referenced data for the UK. We can, however, draw on a recent study carried out by the Centre for Business Research (CBR) at Cambridge and the Industrial Performance Center (IPC) at MIT (Cosh et al, 2006). This specifically addresses comparability problems. It does this by providing an analysis of university-industry links based on a careful comparison of a size and sector matched sample of 1,149 UK and 1,149 US innovative firms in the manufacturing and business service sectors.[2]

The first key finding of this study (which is discussed more fully in Appendix 1) is that even when we focus on innovative firms and control for size and industry, universities in general remain low in the pecking order behind customers and suppliers as sources of knowledge. This finding is based on the percentage of firms which report using universities as a source of knowledge. What is more striking is that by using this measure the study also shows that contrary to much of the rhetoric in this area, UK innovative firms are *more likely* to use universities as a knowledge source than are size and sector matched US firms. The study also shows that the majority of firms in both countries use multiple sources of knowledge with UK firms much more likely to report combining universities with other sources (Hughes, 2008).

Even more striking, however, is that when businesses were asked how important each source of knowledge is perceived to be to innovation (rather than just how often it is used) an opposite result emerges. Here the research shows that US firms are more likely than UK firms to find university sources of knowledge very important for their innovative activity. Thus the much more frequent use of university sources by UK firms and their greater tendency to use multiple sources including universities in combination is not matched by a greater value placed upon the university contribution. This suggests a more diffused innovation ecosystem in the UK than in the USA with more extensive, but weaker university ties. This is reinforced by a further finding from the CBR/IPC study that US firms are more likely to be investing in training, marketing and other activities to support these university links than are UK firms (Cosh et al, 2006).

2 It must be noted that the results from a matched sample of innovative firms of this kind cannot be compared with grossed up results designed to illustrate the overall position in each country for innovative and non-innovative firms of all sizes and sectors. It is on the contrary specifically designed to control for innovation size and sector effects which make such grossed up results unhelpful in comparing results across countries.

In addition to an analysis of the relative importance of universities as a source of knowledge within and between the UK and the USA the CBR/IPC study also reveals that in both countries there is a very wide range of types of interaction with the university sector. Informal contact is the most frequent and most highly valued in both the UK and the US. Next in frequency are all the conventional modes of university activity (undergraduate and graduate recruitment and dissemination through publications and conferences). Access via patenting and licensing, though more important in some sectors than others, is much the least frequent form of interaction in both countries. One striking difference is the much higher frequency of reported use of internships in the US than the UK (Cosh et al, 2006).

In the light of this evidence a number of critical questions emerge which we address in our cases. These relate firstly to the role of informal contacts, and their inter-relationship with other aspects of knowledge exchange in the identification and development of high quality knowledge exchange relationships. Second, the finding of greater supporting investment in the US leads us to probe their importance in maximizing value from knowledge exchange. Finally, the relatively low importance attached to patenting and licensing leads us to look closely at factors affecting business attitudes to these modes of interaction.

3.1 Academic involvement in knowledge exchange

There is considerable variation in the extent to which academics are involved in knowledge exchange activities with the business sector. Taking a wide range of modes of interaction (joint research, training, contract research, consultancy, meetings, conferences and creation of physical facilities) one recent study by D'Este and Patel (2007) shows that whilst 30% of Engineering and Physical Sciences Research Council (EPSRC) grant holders have no interaction, over 50% interact using three or more modes. Most academics are, however, still relatively specialised in the modes they use. If we measure intensity of interaction as the number of categories of interaction in which a researcher has engaged most frequently than the average, it is clear from this study that most academics interact along one or two modes. This suggests that in making knowledge exchange arrangements there is some degree of specialisation amongst academics (D'Este and Patel, 2007). We explore this in our case studies by asking our businesses how they identified partners and the extent to which opportunities for interaction and modes of interaction are proposed to them by individual academics and institutions.

3.2 Not just science and technology

An emphasis on science and engineering disciplines and technological change per se runs the risk of failing to deal adequately with service innovation, organisational innovation and the contribution of knowledge fields beyond the natural and engineering sciences (Abreu et al, 2008a; Miles, 2005; Metcalfe and Miles, 2000; Boden and Miles, 2000; Salter and Tether, 2006). Recent reports on innovation and knowledge exchange, for instance, both emphasise the value placed by business on social science inputs and the significance of service sector innovation (Abreu et al, 2008b, Brown and Ternouth, 2006; Brown, 2007; CBI, 2005). There is also an important and growing body of evidence on the impact of ICT as a general purpose technology on the nature of the innovation process in both service and goods sectors (Bresnahan and Trajtenberg, 1995; Brynhjolfsson and Hitt, 2000; Hempell, 2006; Hughes and Scott Morton, 2006).

The increased use of virtual modeling and simulation techniques reduces the need for physical prototyping and experimentation, encourages the extent and value of customer/supplier/producer iteration and transforms the nature of the innovation process as a whole (Dodgson et al, 2005). It also alters the sectors in which the firm itself is able to compete as a result of the transferability of general purpose techniques across sectors (Hughes and Scott Morton, 2006). More generally it alters the balance of knowledge fields required by firms towards mathematical modelling and organisational skills, and alters the resulting nature of the expertise required by firms in the process of knowledge exchange. It is also associated with the growing importance of a range of knowledge-intensive business firms which provide key inputs into the innovation process (OECD, 2006). All of this points to the importance in our case studies of including service firms and of discussing the full range of organisational process and production changes associated with knowledge exchange activities.

3.3 The importance of the diversity of universities

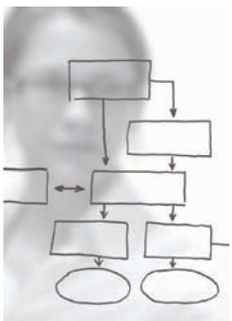
As well as the variety of knowledge-exchange channels across sectors and type of firm, it is important to recognise the different roles that individual universities may play in their local and regional economies (de la Mothe and Paquet, 1998; Cooke and Morgan, 1998; Rutten, Boekema and Kuijpers, 2005; Shane, 2005; de la Mothe and Link, 2002; HEFCE, 2006, Adams and Smith, 2004; Niosi et al, 2005; Asheim and Gertler, 2005; Corona et al, 2006; Kitson et al, 2006; Kitson, 2007).

Such diversity is more varied than suggested by the simple binary distinction made by the Sainsbury Review between 'research universities' and 'business-facing universities'. The diversity will reflect a university's particular mission as well as the various local economic development pathways, and the role the university chooses to play in relation to them (Lester 2005a, 2005b). It will also depend on the different strengths and inclinations of departments, faculties and institutes within a university and of the individuals who lead them. Universities are not homogeneous businesses. In our cases we pay particular attention to the way in which partners are sought and the extent to which this maps into existing conceptions of research intensive and business driven universities.

3.4 Barriers and hurdles to collaboration

Several potential barriers to university-business collaboration in the UK have been identified (Lambert, 2003). An often cited constraint is the lack of knowledge about potential partners and about possibilities for interaction, on both sides of the exchange. This can be due to a lack of skills and competences at the collaboration interface, where the presence of individuals who are familiar with both the academic and business environments is crucial. These highly-connected individuals, known in the literature as 'gatekeepers', may be embedded in academic or business environments. Gatekeepers are aware of the nature of the information available, are able to disseminate this knowledge throughout their organisations, and act as 'intermediators of contacts and knowledge' (Tushman and Katz, 1980). A key characteristic of gatekeepers is their ability to form and maintain informal ties with individuals in a variety of external organisations (Allen et al, 1979; Edmunds and Morris, 2000; Nikolainen, 2007; Sosa et al, 2002). Within the firm, the ability to make use of external knowledge is also dependent on the individual abilities of its workers, on the existing level of internal 'know-how', and on the quality of internal communication mechanisms, which together constitute a firm's ***absorptive capacity*** (Cohen and Levinthal, 1989, 1990; Zahra and George, 2002).

A further barrier to collaboration is a mismatch in time lines, with universities often operating on longer time scales. Differences in culture and language can also be a problem, which can to some extent be addressed by the presence of gatekeepers who are able to communicate with both the academic and business communities. Financial constraints can be a deterrent, particularly in the context of negotiations and contracts related to Intellectual Property (IP). We therefore explore each of these issues in our cases.



4 Conceptual frameworks and the case studies

4.1 Conceptualising university-business interactions

In framing our cases we have found it useful to adopt the same view of university roles that was developed for the CBR's Innovation Benchmarking (IB) Survey. This four way taxonomy is reproduced in Figure 1. It is designed to capture a wide range of modes of interaction. It identifies what we term a ***'public space'*** role in universities in which a wide range of formal and informal interactions can occur which in turn may shape and lead to activities in terms of problem solving and increasing the stock of codified and non-codified knowledge (Cosh et. al. 2006).

Figure 1: University roles in contributing to economy and society

Educating People
- Training skilled undergraduates, graduates & postdocs

Increasing the stock of 'codified' useful knowledge
- Publications
- Patents
- Prototypes

Providing public space
- Forming/accessing networks and stimulating social interaction
- Influencing the direction of research processes among users and suppliers of technology and fundamental researchers:
  - Meetings and conferences
  - Hosting standard-setting forums
  - Entrepreneurship centers
  - Alumni networks
  - Personnel exchanges (internships, faculty exchanges, etc.)
  - Visiting committees
  - Curriculum development committees

Problem-solving
- Contract research
- Cooperative research with industry
- Technology licensing
- Faculty consulting
- Providing access to specialised instrumentation and equipment
- Incubation services

Source: Cosh, Hughes and Lester (2006)

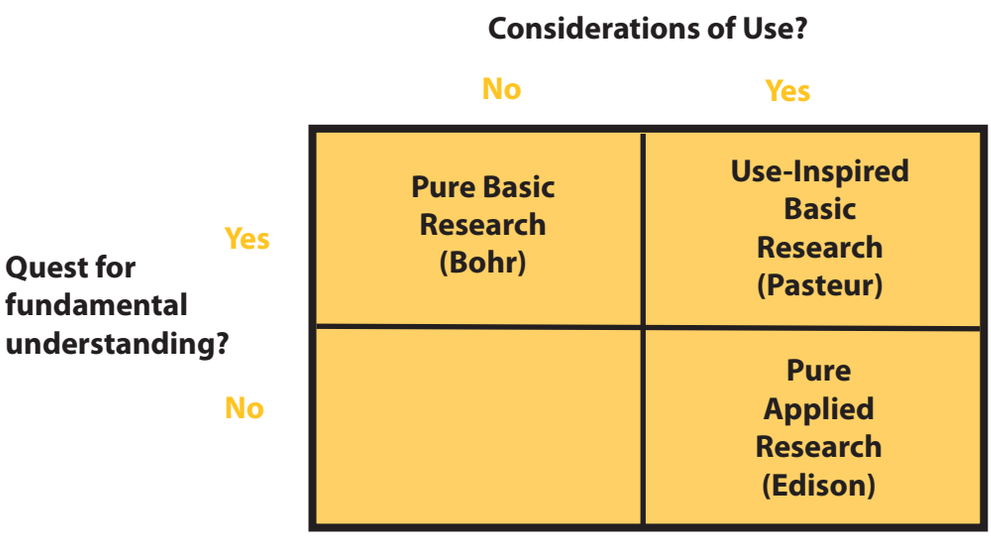
The specific composition of university-business interactions in a particular business context can encompass one or more of these interactions and are reflected in the wide range of reported interactions which, as our review of evidence shows, occurs in the UK. In our cases prior to an examination of a particular successful interaction we probed for the full range of modes in which the firm is involved.

In discussing the interactions between these four broad categories of university roles we have found it useful in our case analyses to emphasise the inevitable and essential interplay between basic and applied research.

In doing this we draw in particular on the work of Stokes (1997) (which is discussed more fully in Appendix 2). He showed that there was a dynamic interaction between *considerations of use* and *fundamental understanding* within the conduct of science itself. His well known quadrant representation shown in Figure 2 plots combinations of research motivated by consideration of

use (Edison) or fundamental understanding (Bohr) or both (Pasteur). Knowledge flows must, can, and do move across the quadrant boundaries. The extent to which these boundary spanning flows involve university-industry interactions is an empirical matter that we address in our case studies whilst recognising the iterative process by which technological knowledge, fundamental understanding and applied research develop.

Figure 2: Spanning quadrant boundaries



Source: D. Stokes (1997) Pasteur's Quadrant, Brookings Institute, Washington

4.2 The case studies

The analysis presented in this report is based on 33 case-study interviews, which were carried out with the help of a semi-structured questionnaire. The cases were selected to enable a rich understanding of the expected variability in the ways in which interactions arose and proceeded, and the perceived or assessed nature of their impact upon the company value chain to be captured. The semi-structured questionnaire was developed by the project team based upon the project's objectives and information gained from earlier studies (Brown and Ternouth, 2006; Cosh, Hughes and Lester, 2006), and is attached in Appendix 3. 19 case studies were based on large companies and 14 on SME's.

The cases were selected to provide evidence on a range of university-business interactions covering a range of sectors, including the primary sector (2 companies), manufacturing (15), construction (1), utilities (2) and services (13). In addition, the cases were chosen to ensure coverage of both high-technology (8 in manufacturing, 9 in services) and low-technology firms in both the manufacturing and service sectors, where high-tech and low-tech are defined in terms of reliance on technology to produce products or deliver services[3]. Two procedures of case selection were adopted, one for large companies and one for small and medium-sized enterprises (SMEs):

i. for large companies (with more than 250 employees), the cases were individually selected to provide a spread of sectors;
ii. for small and medium-sized companies (with fewer than 250 employees), the cases were selected at random from a database composed of SMEs that had been identified as collaborating with universities in the National Small and Medium Sized Business Survey carried out by the Centre for Business Research in 2004 (Cosh and Hughes, 2007), together with one additional SME that was chosen to ensure an example of a university-associated start-up.

3 See Butchart (1987) for a detailed classification of high-tech and low-tech businesses, by SIC code.

Companies were asked to identify both the range of interaction types in which they participated and to identify one particular example of an interaction with a university which they considered was successful. This case then formed the basis of the remainder of the interview and the subsequent analyses and observations set out in this report.[4]

The fieldwork was carried out on a relatively small number of cases and was not sampled to be proportionately representative of the structure of British industry. Instead, the companies were selected to provide a rich range of qualitative descriptions of the characteristics of interactions with universities which have been regarded as successful, and to cover a range of sectors, size classes and production technologies. Because the sampling framework used in-depth qualitative analysis techniques, any extrapolation from this to the business population as a whole must be approached with caution. However, interpreting the characteristics of the cases in light of a synthesis of the literature helped us to understand how the relationships arose and developed to give rise to successful interactions. This understanding will provide guidance on how policy might be developed to foster such interactions in the future.

4 In some cases companies described more than one case example in sufficient detail for each to be included in the analysis described later in the report.

5 Key motivations and objectives for collaborating

The ways in which companies decide to collaborate with a particular university are heavily influenced by the process through which the company went in deciding to collaborate with a university in the first instance. This decision is unlikely to result from a clear sales proposition by the university. There is no common decision tree across the cases studied and the process does not necessarily follow a linear sequence which starts with a decision to collaborate followed by the selection of partners through a process analogous to tendering and selection.

5.1 Company motivations

Case Study: Emergent Project Objectives – Open Innovation

BT has for some time practiced open innovation – a collaborative business model that enables BT to connect with the best minds in business, industry and academia. Throughout the development of new services BT engaged its university partners to contribute ideas and technological research to identify and develop service and product opportunities. Such interactions demonstrate the properties of emergence in which opportunities and objectives may arise out of discussions with no original shared objectives other than to explore the opportunities of working together.

In the case of BT's collaboration with MIT to predict the performance of fibre optic network, the details of the project - which included the need to develop some of the key components - arose out of a discussion of the issues facing BT with the team at MIT. This started as a planning exercise to explore any future projects to be carried out as part of a long term strategic research collaboration programme between BT and MIT. This identified the ability to model both the financial performance and the cost in use of the as yet non-existent components as one critical issue where the university could assist the company. Notably BT did not wish to exercise proprietary control over the components but have them adopted as widely as possible both to keep the procurement costs low and to ensure that their services are based on the forefront of mainstream rather than niche technologies.

Openness to and adoption of ideas generated by interactions with other businesses and academe requires action by any company to secure and internalise the benefits. BT is supported by an embedded company team of two people actually in MIT itself, and the BT university liaison team spends a substantial amount of its staff resource on ensuring that the 100 senior managers in BT are aware of, and can appreciate the significance of developments with the company's open innovation partners. This is done via the intranet and the publication of an internal journal.

Company motivations for university interactions can be conceptualised in a variety of different ways:

- Interaction with university academics (especially if they are familiar with the company and the market) may enable a company to identify issues of which it was previously unaware. In such cases the selection of the partner is strongly determined by existing relationships.
- A recognition by the company that its industry faces serious challenges; it seeks to respond to these by accessing a broad spectrum of expertise relevant to the industry.
- The motivation may be driven by a need for additional capability or from a problem to which a solution is required.

The cases demonstrate that the selection of partners may proceed along different paths depending on prior history. The route followed by the company may be to contact a researcher already known to the company from previous interactions and with whom mutual trust and understanding already exists.

Case Study: Developing Project Objectives & Absorption – BAE Systems

The FLAVIIR project did not start with a specifically defined deliverable as an objective but a challenge by the key industrial sponsor, BAE Systems: "To develop technologies for a maintenance free, low cost UAV without conventional control surfaces and without performance penalty over conventional craft". The project was given form from this 'Business Grand Challenge' and the managing university partner was chosen through having a critical mass of expertise in the broad area of aeronautical engineering rather than an individual specific expertise.

A pan BAE team identified key areas (Aerodynamics, Control systems, Electromagnetics, Manufacturing, Materials/Structures, Numerical simulation and Integration) and the corresponding technical focus groups identified technical issues and key university partners in each of their domains to propose a network with the required breadth and depth of skills. A strategic partnership was formed with the EPSRC to agree the university partners and to put together a programme which would have real scale and impact. The integrated research programme is managed through the Strategic Partner, Cranfield University, including management and integration of the research outcomes from the networked partners as they mature.

Dependencies and integration across the technical themes is considered from the start of the five year programme with developments in each theme and a gradual ramp-up in the integration of the technologies. The final two years focuses on technology demonstrators including a flying demonstrator vehicle. Steering and exploitation are achieved through a BAE Systems programme manager supporting the academic director and interfacing BAE staff from different businesses with university staff. In excess of 30 technology exploitation routes and knowledge transfer opportunities have been aligned with product and capability needs. Formal quarterly meetings involve explicit project management and deliverables include a technical liaison facility so that the company can absorb and translate (including reverse engineer) what has been done.

This mode of engagement to develop a programme which would have "real scale and impact" and consider systems integration from the early stages of research was developed by the company to address the existing diversity of contacts between the company and its university partners. Previously the company had over 90 university relationships which were managed more tactically and which were not able to address the big challenges with inter-dependent multidisciplinary threads sufficiently. It had also proven difficult to integrate the different research threads as they matured. It was with these concerns in mind that the company approached the EPSRC at the inception of the project. As well as delivering over 30 technologies that can be more easily integrated into products and capabilities the programme is delivering a high profile flying demonstrator showing the new technologies working together.

5.2 Identifying mutual benefits

Prior to any project activity commencing some expenditure of effort is required to identify the ways in which the university may assist the company, determine how the company may benefit from the outcomes, and establish precisely how the knowledge exchange will be effected. It is unlikely that these tasks can be carried out by intermediaries. Ideally it requires the active engagement of those with a detailed understanding of the research domain. This understanding will include: potential opportunities for creating value in the business; existing research outcomes in the domain; the performance of research within it; the ways in which possible outcomes may be absorbed and used in the business to realise the opportunities to create value.

Arguably this process, even prior to any commitment, is the first phase of the knowledge exchange process as it is likely to be a learning experience for both the company and academic contacts. In one of the cases involving BT, discussions on the potential project helped the company to understand and narrow the objectives of the project. For example in the one spin-out case studied it was only the key researcher who could actively discuss potential applications of the technology with potential customers. Matching the interests of the company to the research done by the academic partly requires a highly granular understanding of the research and this understanding is likely to be in tacit form. Even where contact is made through intermediaries or power brokers the project configuration itself requires significant input by the domain expert.

Case Study: Transitive

This spin out company from Manchester University was based on the research of its founder, Alasdair Rawsthorne. Prior to the founding Alasdair had been a lecturer in computer science for over 20 years, this after a spell in hardware product development in industry. But the challenge addressed by Alisdair's research which led to the founding of the company was the product of 3 years spent both full and part time on sabbatical in a company developing supercomputers. Changes in target processor architecture and consequent rework led him to ask the question as to whether or not it was both theoretically and practically possible to develop an approach to developing computer instruction sets which was generic, transportable and of high performance.

This direct engagement with a market challenge led to a body of research and feasibility studies by Alasdair and a series of student and post graduate research projects which he supervised and led to the development of the technology platform. Alasdair himself played a major role in dealing with potential investors. However the 'killer' application which would attract the seed investment needed to form the company proved hard to identify. A history of poorly performing 'emulators' had created a poor product perception; this needed a detailed understanding of the technology to overcome discussions with potential investors and early stage customers. It was finally through the direct interaction between Alasdair, the lead investors (Pond Venture Partners and the ManTech Fund) and potential major US customers in which Pond were instrumental in making the introductions and setting up the early presentations that significant traction was obtained from the market. Although the company gained the legal right to exploit the technology through the licence and then assignment of the original inventions from the university, the real knowledge transfer took place through Alasdair himself and the hiring of several of his ex-students and colleagues into the company. The company set up its development centre in Manchester in order to continue to recruit from the university, although the commercial HQ was established close to major customers in the US, in California.

Douglas Hague (2006) in 'Oxford Entrepreneurs' described the frequent need for small start up companies to "wiggle" (rather than drift) in the development and implementation of their strategy.

This applied to Transitive. After the seed investment the final nature of the "killer application" which spurred the growth of the company through several rounds of investment needed several modifications before the first major revenue earning contracts were agreed. The company now has major commercial partnerships with significant market constituents such as IBM, Sun, Apple and Intel and in February 2008 celebrated the milestone of achieving 10,000,000 commercial shipments worldwide.

The Transitive case demonstrated the development of a product strategy and development plan through direct engagement between the founder and the key market constituents. In this case there was a strategic objective – the development and commercial exploitation of a toolset to provide a high performance means of making computer applications portable between different processor architectures. Interactions between business and universities may also exploit the freedom of academic researchers from the assumptions made by companies about technologies, markets and product development as illustrated by the BAE systems and to an even greater extent by the BT cases.

5.3 The importance of relational rather than contractual interactions

Some cases were identified where companies engaged in informal interactions which were successful in achieving at least immediate objectives for the company or where an objective is achieved through connection with other parties through a university network - value realised purely through informal contacts. A 'project' may be implemented through a deepening of the engagement and successively greater commitment by each partner without any formal relationship. This occurred in at least one case studied and it tends to stress the importance of relational rather than contractual interactions. This analysis indicates that informal interactions are at one end of a continuum characterised by an increasing need for formal commitment along the continuum as the formulation of a project proceeds to implementation.

5.4 The costs of contractual obligations

Where the commitment is sufficiently substantial to require formal contracts then other parts of organisations become involved. It is important that these additional contacts share the same expectations and motivations as they will need to operate in, what is from an organisational perspective, a co-ordinated series of contacts (Cunningham and Homse, 1986). Several interviewees noted concerns about university intermediaries adding additional complexity to relationships when they were required to formalise contracts. Sometimes they appeared to be pursuing their own agenda, were not adding value and were even distorting the project. This resulted in delays which were frustrating both for the company and the researchers. Where there were problems, valuation of intellectual property (IP) was often cited as the most typical problem. This arises because the university often perceives a direct connection between the IP it has generated and the creation of value by the business in the form of a product. This is, in the company's view, rarely the case for a number of reasons which are discussed below in relation to value chain impact and evaluation. This problem has been observed by David and Metcalf (2008) and attributed to a mismatch between the institutional expectations of the contracts staff (TTO) on the one hand and the motivations of the academic researchers who 'own' the project on the other. A limited number of the cases actually involved formal IP. Where this was involved and the contractual terms had been negotiated and settled at an early stage, or were part of a framework agreement, few problems arose.

6 Developing university-business interactions

6.1 Choosing institutional partners

When institutions are the objects of selection (as opposed to individuals), this can evolve in a number of different and contrasting ways. Institutions are often the 'hosts' of individuals with whom the company wishes to work based on prior history or because they are identified as leaders in their particular field. Institutions may be selected because they have a critical mass of expertise and are likely to continue to do so because of their international pre-eminence and the consequent expected longevity of the critical mass of relevant expertise.

6.2 Modes of interaction and project objectives are co-determined

In the cases studied there are no examples of individual projects where we can identify that the selection of the mode of interaction was considered separately from the formulation of the objectives of the project, except where a company decided to join an existing consortium. There may however be a strategic assessment of the modes of interaction based on experience which predisposes a company to interact in a particular way.

Case Study: GlaxoSmithKline

GlaxoSmithKline (GSK) is one of a number of major pharmaceutical companies in a long term multi-participant collaboration for which the Protein Phosphorylation Unit at the University of Dundee acts as the research hub. It now has substantial 'gravity' to continue to attract collaborators with over 100 scientists in eight research groups. The participant companies include AstraZeneca, Boehringer-Ingelheim, GlaxoSmithKline, Merck & Co Inc, Merck KGaA and Pfizer.

Protein phosphorylation is a control mechanism that regulates most aspects of cell life. Abnormal protein phosphorylation is a cause or consequence of cancer, diabetes and inflammatory disease. Several of the systems that the unit is studying have the potential for therapeutic intervention. When the Unit was set up in October 1990, the possibility that protein kinases and protein phosphatases might represent important drug targets was considered to be a remote idea, but almost every pharmaceutical company now has a major programme in this area. The Unit's research programme is of interest because aspects of it have the potential to speed up the development of compounds which can intervene in protein phosphorylation with therapeutic potential.

It would have been unlikely that single companies would support the research programmes because it was unclear at the inception that specific targeted interventions in phosphorylation were possible in a predictable timescale. The research outcomes of the Unit do not impact on companies' key competitive advantage (which is the IP in compounds) but the speed at which they can be developed – which applies equally to all participants.

6.3 The importance of trust and mutual understanding

Developing trust and understanding between individuals is a key component of university-business relationships. Investigating with whom and how such contacts originate and develop has been one of the key elements of this study. How did the contact between the university and the company initially arise? A range of different approaches is possible:

- In a large number of cases (13) the relationship between companies and universities was formed through common networks, or the contacts were already familiar with each other (8 cases).
- Companies approached universities in 6 cases, whereas universities took the initiative in only 3 cases. It is important to note that these statistics include only those contacts which eventually led to interactions regarded as successful by the companies.

6.4 The importance of personal contacts

The way in which contacts originate seems to be influenced more by personal history and contacts rather than company type, although organisational history may influence such history and contacts. In the few successful cases of interaction which originated with a university driven contact there was a good *a priori* reason to expect a successful interaction

Case Study: Waitrose / Lancaster University Collaboration

The collaboration incorporates a framework agreement under which Waitrose, its supply chain and the University through the Lancaster Environment Centre (LEC) join in research projects and staff training focused on issues concerning climate change and environmentally sensitive agronomy. This is a domain core to both Waitrose known brand values and the LEC's work. The approach introduced the potential of working together rather than a particular project which provided a strong basis for a developing partnership. It originated in an approach from Lancaster not with a specific project in mind but indicating a willingness to collaborate on projects of mutual interest. The collaboration is in its second period and this time has allowed the university, the company and its supply chain to identify how best to work together for mutual benefit.

6.5 How projects are formulated

There is also a spectrum of processes by which university-industry projects are formulated including either the university or the company or both specifying the project deliverables at the outset. The category in which the university specified the project included two cases in which the university offered technology for licence at the outset. In terms of projects originating within the company we can distinguish three types of interactions:

- the company identified business challenges it faced and encouraged universities to respond with solutions (13 cases);
- the company identified technical objectives or problems to which universities responded (5 cases);
- the company defined the characteristics of a solution and the types of action by the university which would meet its criteria (2 cases).

It should be noted that in 2 cases it was difficult to identify whether the company or the university took the lead in framing the project.

Overall, it is unusual for a project to be specified in its entirety either by a company or by a university; most projects are a result of a series of interactions between the two partners. For example, there was only one case where a license followed an offer of technology developed by a university without the company's involvement. The company contacts who have experience working with universities explicitly indicated that they value the wider range of understanding and approaches academic researchers can bring to a problem in comparison with internal company staff. It should be noted that academics are valued for their specialised expertise and they are not considered as a simple means of expanding the company's own R&D capacity.

Project conception typically starts with a discussion between key individuals in the company and the university. How these individuals meet and 'contract' to discuss the potential of working together is highly variable and may be an emergent rather than a deliberate process. In the formulation of projects the ways in which the academic and company gatekeepers identify and develop opportunities seem to demonstrate the characteristics of effectual behaviour often associated with entrepreneurs in the broad sense as described in Sarasvathy (2001).

There is strong indication from the cases that it is ***contact between individuals*** rather than institutional relationships which dominate the opening phases of university-business interactions. In fact, as evidenced by several cases, the process can be disrupted as different individuals with different priorities become involved.

6.6 Broad challenges or technical problems?

Many projects developed with the company identifying a broad problem or challenge rather than specifying a narrow technical problem or a project. A common feature of the cases was that neither the company nor the university could precisely specify the project, the service and the way in which the two organisations will interact.[5] In only 5 out of all the cases did the company specify a technical problem which they wanted the university to address and in at least 2 of these the company may have limited its potential gain from the project. Solving a specific problem does not necessarily enhance the capability of the company. Conversely, in at least one case it was only once the project was well underway that the potential gain of the project was identified and this coincided with a substantial increase in capability of the company. In the two cases in which the company was able to specify the project, the university academics joined in a service delivery activity in a role specified by the company but the nature of the service was such that it naturally allowed a high degree of discretion to be exercised by the individual service provider.

Case Study: BBC and Dovenest

Both BBC and Dovenest (a management development company) collaborate with universities not necessarily only to increase their permanent capability but also in order to enhance their services through the inclusion of academic staff in their service delivery. In the case of the BBC this is achieved by involving academic staff in the development and delivery of programmes. This is done frequently through the inclusion of academic specialists as commentators and contributors on news and public affairs programmes but may be more intensive in more specialised programmes. For example, much of the development and delivery of the recent BBC Radio 3 series on the classical authors was done in collaboration with academic scholars and the anchor presenters were themselves academic experts in research, teaching and communication in the field. This may be seen as a minority interest but commanded an audience in excess of the attendance at an international football match.

In the case of Dovenest academic teachers were frequently included, for example where the client needed formal input of the nature of an MBA course, and in the deeper collaborations it has involved using universities to provide accreditation for courses developed and delivered by the company.

The nature of the high value services each company provides is such that it is important that the people who are involved in the delivery of their services have the necessary in-depth expertise which can enable them to develop highly customised and specialised contributions. They then need to be able to make those in such a way that they can respond flexibly in presentation and discussion to the immediate requirements of the service situation, and do so in a way that commands authority and respect for their contribution and their views.

5 In the case of KTP and to a certain extent Eng.D projects there is a standard model but it still needs to be localised to the specific partnership.

6.7 Relationships evolve and adapt

At the outset, unless the individuals in the companies and the academics have worked together before, they will not necessarily be familiar with the resources and degree of commitment available to the other. This results in an adaptation and formulation process which may involve some considerable expenditure of resources by each party. For the interactions to continue it is important that each party is able to develop an expectation of mutual benefit from the interaction and to understand the culture and values system of the other party even if they are not required to adopt it itself. It follows that company staff need to understand the type of benefit they might expect from a university and the different value systems which naturally apply in an academic context.

6.8 The role of Knowledge Transfer Partnerships

In Knowledge Transfer Partnership (KTP) projects (of which a number featured in the cases) the development and configuration of the projects is deliberately facilitated by a specialist advisor and in Engineering Doctorate (Eng.D) projects there are formally designated roles (company and academic supervisors) which are expected to negotiate the project contents at an early stage of the project. These roles require the development of understanding and distinctive expertise. For example induction training is provided for the supervisors as part of KTP programme and a key role of the advisor is to assist them in the original formulation process. That the role of academic supervisor in Eng.D projects is one in which academics can and will benefit from gaining expertise was a conclusion of an EPSRC review of the programme in 2007. Even in the facilitated projects the active engagement by the company through an internal champion on the process of the project is critical. To quote the Chairman of one KTP industry partner: *"... they need the intellectual capacity to relate to the academics."*

7 Factors that affect the choice of mode of interaction

We identified a very diverse set of university-business interactions which included technology licensing, collaborative or sponsored research, and consultancy. Some projects also involved students or graduates spending time working within a business, or a business sponsoring research students to work on topics of interest to them and bespoke or company specific education programmes.

Case Study: ARUP

The company is a technical services company, a global, innovative professional design and consulting firm which combines a variety of areas of technical expertise with a well developed strategic project management capability. It has a substantial engagement with universities. For example it is very active in recruitment, sponsoring research and encouraging staff to become active as faculty in universities. Research might cover issues specific to individual markets through its local offices, such as methods of construction which are sensitive to local environmental issues. The company is particularly interested in integrative research which crosses domains, such as aesthetically pleasing as well as sound construction.

ARUP has a substantial portfolio of work in China which includes work on the Chongming island project for the masterplan of Dongtan eco-city. This is a very environmentally sensitive area. The island was extending by 1 metre per annum through silt deposition and the width of the island at its eastern end is a very rich wildfowl habitat. The plan is to place an eco-city of half a million people alongside this habitat based on sustainability best practice. In seeking out best practice the company identified a number of serious research challenges, and as result it stimulated the development of a network of Chinese and UK academics to address these. The company put out a paper on research issues to the EPSRC and UK academics, so the company acted as seeder and hub, and the EPSRC responded by offering £1.5m to help fund the network. The nature of the challenge and the company are such that it is pulling researchers from different disciplines from the UK and China together.

7.1 The use of collaborative and consortium research

Of these, collaborative and consortium research was observed in 14 cases. Collaborative research refers to a process in which the company and university join in a research project which is of interest to the company and usually supported by public funding such as that from the Research Councils. Where technology arises from this research which is applicable to the company it may take a licence. Consortium research is similar except that there is more than one company involved. The evolution of consortia is interesting because they enable companies to access pre-competitive research outcomes on a highly leveraged basis. Consortia may arise where the project is pre-competitive and/or capability is not critical to competitive advantage or have complementary interests. They are an extended case of a one-to-one engagement where the university acts as a 'hub' to attract companies with a common interest; in some cases companies may provide the initial seed idea or motivation which is then handed to an institution or umbrella body (such as a Research Council) to take forward.

Consortia may form on an indefinite basis particularly where companies share problems of a generic nature; it is not worthwhile for an individual company to fund the work because of the high risk and unclear perception of value. Waitrose brought its supply chain into a consortium.

7.2 Consultancy projects

In 6 cases there were consultancy projects where an academic researcher worked on a project of interest to the company usually to address a problem specified by or identified with the company and this is done on a personal basis rather than being configured as a research project with the institution as the collaborator.

7.3 Graduate and student placement

Graduate or student placement in companies was given as an example of successful interaction by 5 cases. This mode of interaction is characterised by a large proportion of the time spent by the individual in the company usually with an academic supervisor to provide access to university knowledge during the duration of the project. Student projects and Knowledge Transfer Partnerships fall within this category.

Sponsored PhD / Eng.D were reported by 3 cases. Here the company is paying a contribution to the costs of a research student working on an original research topic of interest to the company; in the Eng.D some 50% of the time may be spent in the company and the research will have a more overtly commercial focus than with a conventional PhD. As the research student will have an academic supervisor there are similarities in terms of access to a body of academic knowledge with the Graduate or Student Placement mode, particularly in the case of the Eng.D.

7.4 Recruitment and staff development

The Recruitment and Staff Development mode was observed in 4 cases where the project had a strong educational content. This differs from the normal context of graduate recruitment in that there is a strong projective element motivating the programme in which the company has a deliberate role in developing and specifying the content of the programme oriented towards its objectives.

7.5 Networks

In 2 cases companies are joining in and participating in formal or informal networks in which there is strong academic involvement which appears formative in the emergence of the network and facilitates academic and non-academic contacts.

7.6 Licensing of technology

Finally, the licensing of technology offered by the university is observed in one case only. This refers to a process in which the university volunteered technology to a company which owes its origins to research conducted by the university; this is contrasted with collaborative research or consultancy which may produce technology to which the university takes title or rights as part of the agreement.

7.7 Choice of mode

The choice of mode is influenced by the nature of the project and company objectives. There are no examples in the cases in which a company deliberately selected from all the possible modes but implicit comparisons of two similar modes are frequently made. For example, where there is a perceived research interest with the potential for leveraging public funding then the project may be steered towards collaborative research, although without public funding the research may be conducted via a consultancy arrangement. Several cases cited the active processing of potential research council funding as an influence on mode selection and in one case the mode was changed from consultancy to collaborative research when it became apparent that there was the potential to leverage public funds. Similarly, the modes available to a company with the objectives of targeted staff development or the recruitment of staff with particular skills are limited.

Case Study: United Utilities

United Utilities is one of the major water and waste water treatment companies in the UK. The identified a number of research themes in which they were engaged with universities largely concerned with the optimisation of processes concerning waster water treatment and the recovery and recycling of nutrients in the form of fertiliser. The nature of the projects which concern the deliberate development and acquisition of expertise as well as the use of the collaboration with a university to produce key deliverables (such as optimisation software) has led the company to conduct many of these projects through the modality of Knowledge Transfer Partnerships.

In these cases typically the company has sought a partner from its existing network with whom a project objective and outline programme of work has been developed as a key first stage in the interaction. The recruitment of an Associate (a good graduate who takes responsibility for undertaking R&D on the project and works within the company, with the company staff and who is supervised by a dedicated academic supervisor from the university) is the means by which the project is undertaken. In one such case the close interaction between the associate and the company staff has led to a company staff member undertaking a PhD in a related area. United Utilities has adopted KTP as a strategic vehicle for its university collaboration programme.

7.8 The pathways of collaboration

The emergence of the mode of collaboration may proceed along different paths:

- Prior experience may influence mode selection and there is evidence that some companies will actively process the effectiveness of different modes in achieving effective transfer and as a result deliberately adopt a particular way of implementing collaborations.
- A strategic collaboration may implement a succession of projects and the question addressed might be to test whether or not a new project is suited to the collaboration rather than search for a new partner to carry out the project.
- Companies may decide to join an existing collaboration where the mode has already been determined.
- Where a consortium is formed to address high risk pre-competitive research this may be the only mode attractive to a company partner so that progress with the project is dependent on obtaining support and membership for the consortium.

7.9 Perceptions of different modes of interaction

How a particular mode of interaction is perceived by a company may have a bearing on how they interface with universities. Some companies view KTP as a response to a recruitment or capability need, as a means of solving a particular problem or achieving a required deliverable and this appears to influence the way in which it is evaluated. In at least one case the Eng.D mode was selected because of its apparent strategic value as a way of engaging with university research. Costs may also influence mode selection. The adoption of full economic costing by universities was cited by at least one interviewee as a reason for moving towards academic consultancy as a fee for service and away from sponsored research where no research council funding was available.

Our analysis also reveals that companies which might be regarded as having a low reliance on technology may nevertheless engage in projects involving university-based research through small research active units. For example, the water industry might be regarded as capital intensive rather than knowledge intensive but is now faced with a broad range of issues for which university research has relevance beyond the conventional domains of water and sewage engineering. In the cases studied, only high technology service or manufacturing companies sponsored PhD students.

Case Study: Electronic Arts – Engineering Doctorate Programmes

This global company started as a games publisher but developed into a games developer with a number of studios worldwide, one of which is in the UK. The industry has evolved from reliance on hobbyist game developers to one in which there is a premium on leading edge software and systems engineering and this puts an emphasis on graduate recruitment. EA did a tour of UK universities in 1999 and identified 3 as major strategic recruitment and research partners. One in particular, UCL, was closest to software application areas of key interest with the research of the Virtual Environment & Computer Graphics in the Department of Computer Science. They also located at UCL a key academic staff member who was also a keen games player, he spent a sabbatical at EA from which he gained a greater understanding of the company and its production processes. As a result the company and the university developed a strong mutual understanding that they needed more of these close relationships. They recognised that the Engineering Doctorate programme, in which a research student of doctoral calibre worked on a problem of key interest to the company was an ideal way of achieving this.*

The EngD offered the advantage of the student spending time both in the company working alongside its own staff, and in the university to take advantage of the facilities and interactions with other researchers. The company has a 12-18 month development and publishing cycle so a university collaboration was more suited to long-term strategic technical issues than short-term tactical deliverables. Thus a programme of doctoral substance and calibre was a good basis for collaboration. There are a number of really difficult problems now in the games industry which are of genuine academic interest; ranging from supporting high quality graphics through to understanding how users interact with games. Ten such high-level problems were described and two research engineers were appointed to work on two of these challenges.

Exposure of the academic researchers involved company talks which were very popular with the company's software engineers. Formal documentation included published papers but also regular internal reports for the EA journal. This spread the contribution of EA's Guildford studio to the global knowledge base around the business and made the knowledge transferred explicit in a context familiar to the company. As of the date of writing some five other people in the company could apply the technology developed into a live game.

8 Measures of success

There are several ways in which companies evaluate the success of their interactions with universities, ranging from informal or subjective measures, to formal metrics-based approaches. Several of the companies interviewed (7) are able to attribute a calculated financial impact to the interaction, and trace it back to a specific project contribution. This type of financial benefit was described by one interviewee as "line of sight" to a financial impact.

In several cases (7) the company evaluated the project using an internally defined Key Performance Indicator (KPI) which is non-financial, while a number of companies (6) used subjective or informal evaluations, which are typically based on some form of internal review which incorporates a subjective assessment of projects without the use of pre-determined KPIs. A few companies (6) used a post-implementation form of evaluation, where success was assessed in terms of the extent of adoption or use within the company of the product, service or process innovation that the knowledge exchange has enabled.

8.1 Financial measures are rarely used

The proportion of companies which evaluated the outcome of the interaction in financial terms was lower than expected; this may in part be due to the variety of value chain impacts of the interaction, the majority of which are not directly associated with individual financial metrics. Conversely, where production processes have established KPIs (such as scrap or re-work costs) with a direct financial component, a pre- and post-project evaluation will give a direct computation of benefits.

Companies may value university collaborations for reasons connected directly with company operations and their financial performance but also for reasons which are not susceptible to direct measurement. Evaluation is, however, important to determine whether or not university collaboration is developed as a strategy. Only if collaborative activities are directly connected in "line of sight" with specific products is a financial evaluation easy to achieve and in other cases the evaluation of collaboration with universities may be subsumed in the internal evaluation of the collaborating unit.

A feature of the traditional patenting / licensing model of technology transfer is that a contribution of technology to a product should attract a royalty fee based on product sales. The cases demonstrate a number of reasons why this model might be less frequent than the deliberate focus currently placed on it implies.

Firstly, a project which delivers technology into a product or service usually requires active engagement and a significant contribution by the company to produce the technology, so that any license arises as part of the agreement of the project rather than as a university-initiated license agreement. In two cases in which a university-developed technology made a direct contribution to a product without direct company involvement the inventors were very close to the market application. Secondly, the degree of dilution makes it difficult to assess the value of a single contribution. Companies are less likely to value university "armchair" patents which do not protect particular applications; claims that are conceptually distant from the application may not be drafted as to provide good protection.

8.2 The value of knowledge

In general, the contributions which are most valued by the companies are the contributions of knowledge and expertise, and the ability and perspective of academics to take a wider or different perspective from the company's own staff, particularly in the larger and more experienced companies. In such cases academic researchers are not regarded as an extension of the company's own R&D resources but as sources of knowledge as emphasised in open innovation models. Where the contribution affects the way in which management makes decisions on strategic issues then a subjective rather than objective /quantitative evaluation of the contribution is easier to achieve. Where major strategic collaborations deliver a succession of projects then a formative evaluation may take place. Smaller companies have a greater tendency to view collaborations as a "fee for service" consultancy, but even in some small companies a different and more strategic perspective prevails, particularly if a long-term view is taken on the way in which multiple collaborative projects have made successive contributions.

Where projects are associated with company operations that have established KPIs, or where the project itself involves university expertise in establishing them, value can be demonstrated and this may have the effect of reinforcing the tendency to commit resources to collaboration. Some of these KPIs may be directly associated with financial measures. The KPIs may also concern issues of strategic importance to the company but not necessarily be financial.

9 Business evaluation of the impact on innovative activity and value-added

9.1 Impact on the business value chain

A significant result from the fieldwork is the variety and richness of the types of impact of the collaboration on the business value chain. These extend far more widely than the traditional view, whereby a technology developed in a university is incorporated into a commercial product, a view which has been encouraged by the focus given to it by policymakers. Indeed, the cases indicate that the highest identifiable financial impacts arise from a re-engineering of the production process rather than from the sales of new products.

Companies with a low reliance on advanced technology incorporated into the products themselves may see substantial benefits through advanced analysis and simulation of production processes. Conversely companies which manufacture products with highly advanced technology content may collaborate with university researchers from a different domain to develop their business processes. In some cases the companies also highlighted an increase in their market profile and position which arises from the association with either specific issues or individuals, occurring through high profile and well publicised collaborations.

Case Study: Inca Digital

Inca Digital is a specialised company producing high volume production line printers for packaging using specialised piezo electric print technology. It is a spin out company – not from the nearby Cambridge University but from Cambridge Consultants where the founders conceived the technology on which the products are based. This is an example of the effect of universities on the creation of economic value not directly but indirectly via the attraction of talent to the area. Inca Digital does collaborate with universities, for example, in order to acquire an understanding about future developments in print technology. Another most notable example to date of its collaboration with universities has been in the development and implementation of customer support systems.

The products it supplies are critical elements of its customers' production systems and therefore in field support to ensure rapid reaction to problems on site, minimising down time, and customer confidence in these processes are important competitive elements of the company's augmented product offer. The expertise to develop, implement, monitor and evaluate these processes was gained through a collaboration with the University of Cambridge Manufacturing Centre. The processes themselves generate the key KPI's used in the evaluation such as time-to-fix and engineer response times and it is the trends in these which demonstrate the success of the project.

We have found a range of value chain impacts arising from different types of research. However the cases reveal a complex series of relationships in which what occurs in the interaction and the company strategy themselves play a significant role.

Case Study: Jones Stroud Insulation (JSI), Blairs, Anglo American

In several cases studied companies took advantage of academic expertise specialised in the understanding and evaluation of production processes. In the case of Jones Stroud Insulation (JSI) and Blairs this was prompted by the identification of the opportunity or need to change. For JSI this arose from an internally conducted industry benchmarking exercise which suggested that there was an opportunity to improve their profitability through addressing the manufacturing mix and process. In the case of Blairs, a company which makes wooden doors and windows, it arose from a desire to increase capacity and tighten the integration of the sales and ordering process with manufacturing. In each of these cases the stimulus from which a university collaboration arose was a recognition that in order to achieve its objectives the company needed to acquire a capability which it did not currently have and by applying that capability to the highest priority project it could also develop internal capability within the business. Understanding precisely how that capability was to be applied and localised was the first stage in the project formulation and implementation.

Anglo American identified the opportunity to join a project managed and delivered by an industry specialist research team which was developing a means of simulating the type of specialised extraction and production processes it used in many of its precious metals plants. It was able to join in the project when it identified that progress was being made which promised to deliver an improvement compared with its existing operations.

In each of these cases the research outcomes which were focused on the specific processes used by each company were absorbed and embedded by the company's own staff working alongside university staff. In the case of JSI and Blairs the projects used the KTP modality which involved dedicated staff members working in the company supervised by the university. On the other hand Anglo American adopted an approach which saw a dedicated team from the company working with academic researchers and then themselves localising what they had learned to each plant they visited, thereby developing their own internal expertise specific to company operations. In each case these key staff members had access to the university staff on their own initiatives.

Central to each of these projects was the identification of Key Performance Indicators. A standard feature of the KTP modality is the identification during the project formulation process of how the project's impact will be evaluated. In the case of Anglo American the KPI's were core to the project methodology as these were the object and dependent variables of the simulation. These project features in each case enabled the impact to be converted into financial metrics which reinforced the company's engagement with the project.

9.2 The importance of different disciplines

The cases demonstrate how a variety of different research types can find value in different ways in business. The subject domain of the academic research and the technology central to the company's business may not be necessarily related. Thus technology-based companies may not need assistance from university researchers in the development of their technology, but may benefit from marketing and management science in the development and deployment of business processes involved in supporting their technology in the field.

9.3 The importance of co-production

The complexity of the impact on the value chain is also illustrated by the fact that even when the research is described as 'applied', it may still need substantial development for incorporation into product; the deliverables may be in the form of prototypes which need re-engineering or redeveloping for use in different products. Even this is likely to be a simplification of reality,

because it neglects the substantial degree of co-production and iteration which occurs. Co-production arises when the processes, from identifying the project to delivering the desired outcomes, require substantial intellectual input from the company. The company's staff may perform part of the project activities and transfer knowledge back to the university team.

9.4 The importance of Pasteur's quadrant

Research motivated primarily by a quest for fundamental understanding is sometimes mediated through considerations of use. Research partnerships achieve this by a process of working through the original research outcomes to develop further outcomes localised to a point at which the company is able and willing to absorb them and develop them further. Even applied research is shown by some of the cases to require further localisation. For example, where fairly abstract university research in production management or simulation needs to be applied to highly company-specific production processes and technology, there will be a distinct investigation phase involving research within the company before interventions are designed which may affect both production methods and the product mix offered. This indicates the need for company specific localisation of the research. A process of iteration may also occur between the application and the existing fundamental research.

9.5 The role of corporate strategy

A company's R&D strategy will also affect the nature of the research sought. If a company wishes to exercise control over as many aspects of product innovation as possible, it may wish to engage in supporting and absorbing a variety of outcomes from basic research so that the entire R&D process is carried out in-house. An alternative strategy is to source the technology closer to its application in the market, and encourage university researchers to produce deliverables in the form of prototypes. The ability of university researchers themselves to iterate between underlying theory and practical application is noted in cases where unexpected results in the incorporation of technology into product has revealed an incompleteness in the domain of the understanding of underlying theoretical processes.

One case in particular demonstrated the use of academic scholarship as a means of locating, understanding and localising research outcomes achieved in other institutions where an analysis by the academic partner demonstrated that this was the best way of addressing the company need. The academic partner's main role as the partnership developed was to locate, absorb and then re-interpret the findings of research carried out elsewhere in a way which the partnership could assimilate and apply. At least two other cases demonstrated the application of scholarship either to re-purpose the original output of the research or to identify suitable research partners to join a consortium in circumstances in which detailed knowledge of, and the capability to 'peer review', the research domain was important.

Case Study: Rolls Royce: Application and Fundamental Understanding

Rolls-Royce adopts a policy of directing the majority of its academic research into selected University Technology Centres (UTCs) by establishing long-term strategic partnerships with high calibre university departments with leading expertise in selected fields. One such UTC is a strategic partnership between Rolls Royce and Loughborough University for developing advanced technology and research concerning combustion and materials science associated with engine casings and coatings. Experimental work includes detailed investigation into the aerodynamic features within gas turbine combustors, and research into compressor outlet guide vanes and compressor interconnecting duct flows.

During the in-house testing of one research engine the company identified a series of oscillations which could not be explained or addressed by current theories. Although the damping of such oscillations is common practice in engine design the challenge was to provide a rigorous method of design which could be combined with the use of film cooling to maintain a satisfactory operating temperature for the damping devices. The pressure waves from the oscillations had a tendency to disrupt the cooling gas flows. Study of these effects by the university has developed the new discipline of Unsteady Fluid Dynamics within Computational Fluid Dynamics.

The original project took approximately 6 months from start to finish. As for the collaboration between the UTCs and the company there were regular project related meetings through which design theories developed and tested by the university together with the design definitions arising from them were discussed with and passed to the company engineers. From these they created new designs which would be checked by the university. "Once you understand it you don't need to go back and the test of embedding is to know when you need to." The company knows enough to know when it needs to ask.

Rolls Royce has a practise of assisting the university and its own knowledge transfer by putting new UTC inventions through its own disclosure process even where the university retains ownership. This ensures that the engineers involved in the company understand the relevance of the application and arguably produces stronger and better patent protection.

The company has an internal mechanism for sharing information from these collaborations – including informal networks between internal scientists – any one of whom is only 2 or 3 connections away from any other scientists. There are also formal annual reviews of UTC's shared with other scientists in the company. Each UTC creates an annual report which summarises the projects shared (as with BT, also on a company intranet). The approach taken to the development of solutions in this particular example came to the attention of a different part of Rolls Royce, and resulted in the university being approached to establish whether or not the same approach could be taken with an analogous problem in a completely different part of the business, also involving oscillation in fans.

9.6 Innovation, knowledge diffusion and embedding

Corporate strategies for absorption and embedding of the knowledge generated by the interaction vary substantially. There are cases of pure technology transfer, where a technology deliverable is produced and the rights transferred, without apparent embedding of the knowledge to develop and use it further, potentially limiting the gain by the company. This may also be the case where the academic staff form part of a customised service delivery, where it is accepted (albeit implicitly) that no retention is intended. If the identity of the academic partner is a key part of the service mix, there may be little additional gain to be made by attempting a substantial degree of embedding.

9.7 Absorptive capacity

Some of the cases demonstrate action by the company to plan and take action to absorb and apply the knowledge created. This may take the form of processes explicitly designed to achieve this or a way of working in partnership or co-production which enables and facilitates this absorption. Deliberate planning may include the development of structural capital which makes the outputs more widely available throughout the company. Substantial resources may be expended on this process, for example in one case over 50% of the staff time of the relevant liaison group was spent on deliberate embedding and diffusion and in another case, 1% of the company's resources was spent on internalising the knowledge gained.

KTP is a mode of interaction in which diffusion and embedding of knowledge is an explicitly stated aim of the project as now identified by the funding agents. The arrangements for KTPs and the Eng.D involve a close working relationship between the agents of knowledge creation and transfer, i.e. the supervising academic and the Associate in the case of KTP, or the supervising academic and the Research Engineer in the case of the Eng.D, respectively. In both cases there is a cost to the company in terms of staff time and contribution to project costs.

The perspectives of company interviewees on these arrangements, particularly in relation to KTPs differed considerably. For example, in one case these arrangements were seen as a cost and not an investment which might suggest that the embedding was not actively sought by the company. This in turn appears to be related to the company's perspective that the project was concerned with problem solving (to produce a specific deliverable) rather than capability development.

In two cases the requirements to acquire and embed knowledge constitute a major element of the project, and in one particular instance had a determining impact on the location of the UK arm of the business. Alternatively, the way the project is designed may explicitly include elements which are deliberately designed to at least facilitate or achieve embedding; this may be seen, for instance, in projects which involve embedded teams where company staff work alongside university researchers. These arrangements may be a part of specific modes of implementation, such as the use of joint teams. Projects which do not involve embedded teams may make specific provision for this by detailed project management arrangements. Where the project involves work by academic teams and contact primarily through reports and regular meetings, companies may take particular care to arrange these with a degree of intensity and formality that enables close contact and discussion between the teams in each party. Patenting by the company of university inventions using company-employed or retained agents may also be a deliberate part of the embedding process.

9.8 The diffusion of knowledge

Diffusion of the results throughout the business may be achieved by contact arrangements which are shared between different parts of the company other than those directly engaged in managing the collaboration. They may involve separate arrangements by the business which are incorporated into its formal structural capital such as its standard operating procedures or deliberately managed by project teams. This may also be enabled by the operation of internal networks where engagement is encouraged by internal recognition systems or the interest of motivated staff. Rendering the knowledge transferred into explicit form[6] and in terms in which it is accessible to key individuals in the business may be an explicit feature of the arrangements for diffusion. Deliberate use of university agents (such as KTP Associates) elsewhere in the business may also be part of the diffusion process.

6 For definitions of explicit and tacit knowledge and a discussion of the relationship see section 10.3 (below).

9.9 The effectiveness of absorption, embedding and diffusion

The effectiveness of absorption, embedding and diffusion may influence the selection and management of collaborations. The feasibility of achieving effective embedding is part of the selection criteria for eligibility for grant funding under KTP and the project management arrangements explicitly highlight the appointment of a company member on the management committee who is responsible for identifying opportunities for applying the embedded knowledge in different parts of the business. A change in mode of interactions with universities at BAE systems, for example, from a large number of small projects to a limited number of major strategic alliances with deliberate management and diffusion processes - arose from a realisation that the outcomes from previous projects seemed to be too fragmented to take them into use. Decisions on the extent to which collaborations may be developed may take into account and be affected by the transaction costs of achieving effective absorption and embedding. Companies may themselves test the extent to which embedding has been achieved.

Case Study: BP and ARUP

ARUP and BP evaluate the success of collaborations by evaluating the extent to which they are used in the business. For example, at ARUP success in collaborative projects is measured by the implantability of the research outcomes into professional practice guides within the company – the ARUP collaborator would take reports, presentations etc from academic partners and translate these into these guides. Assessment of the effectiveness is based on observed change in practise.

In the case of the BP Institute at Cambridge, a project will typically produce as an outcome fresh awareness of the nature of the problems, challenging accepted assumptions and questioning whether there are more fundamental scientific or mathematical approaches which would be better. The results are an improved understanding of the problem. This makes it hard to track the stand-alone impact of individual projects as the work of the Institute would often simply be incorporated into the company's thinking and thereby affect different types of activities, from further research through development to operations within the business. The best and most effective evidence seems to be to to have as many anecdotes as possible to demonstrate the utility of engaging with the Institute and expanding the number of groups in BP who wish to work with the Institute – as this is their own decision. This open-ended approach to the value of 'use' has been increasing.

10 Geographical determinants and knowledge-exchange relationships

10.1 Does proximity matter?

It has often been argued that proximity may have an effect in the process of partner selection. It may have an impact in cases where the company comes into contact with potential collaborators through the university's ***'public space'*** activities or when, motivated by a search for capability, the company contacts the nearest university as the default option. In such cases, the transaction costs are processed implicitly by the company and where the capability that is sought appears readily available, it would be reasonable to expect that local partnerships would tend to form more frequently than distant ones.

However, there is little evidence that the transaction costs involved in the interaction are important for partner selection, except for smaller companies. It is more likely that where world-leading expertise is deemed critical in the interaction, a pragmatic decision will be made on how the interaction will be managed although the extent to which it might be developed might be limited or the threshold on how beneficial the interaction needs to be to proceed might be raised. Transaction costs have a larger impact on the decisions of small companies, who will generally not have staff dedicated to dealing with university interactions. Proximity may therefore be a more relevant factor for small companies compared to larger firms. Proximity is also important where the project is of a sensitive nature or where the outcome is needed at short notice; in these instances companies place a greater value on frequent personal contacts, and are more likely to approach a local university.

10.2 What does 'local' mean?

"Local" has a variable meaning depending on the reach of the company. For instance, for a large multinational company, local to the company may be taken to mean a location in Europe, or a place where it has an embedded infrastructure (e.g. the embedded BT staff who work at MIT). In the case of KTPs, partnerships are scrutinised to ensure that they occur with the most conveniently located university to minimise transaction costs. However, the strength of the partnership which arises during the development of projects, and the relative strength of the research expertise that is available locally versus at the expertise at locations further away, can outweigh the impact of transaction costs. An example of this includes the key partnerships which have been formed between United Utilities (in the North West of England) and Cranfield University (in South Central England).

10.3 The role of universities as local economic 'anchors'

It has been argued that Universities are one of the few economic actors that do not move. In a number of the cases studied the influence of the university as an attractor of talent is both visible and informative. For the Toshiba Research Centre based in Cambridge, which spun out the company Terraview, the University was not only a source of talent for the new business but it attracted supporting organisations and investors. The presence of the company in Cambridge and the development of the embedded laboratory resulted from a deliberate decision to develop a close relationship with the University. They become part of the 'innovation ecosystem' in which the university has a strong influence.

11 Discussion

The cases studied reflect the importance of collaborations and the diversity of interactions and value chain impacts. They also illustrate the iterative process of innovation and show active company participation not only in the interactions which give rise to projects but also active participation in the assimilation and application of university derived knowledge.

11.1 The importance of gatekeepers

The ways in which the cases evolved may be understood using a synthesis of some of the relevant literature. These emphasise the importance of the ***relational aspects*** of the Interaction Model (IMP Group, 1982) and describe the formation and development of business relationships between organisations. In particular they note the development of social interactions in the adaptation process and the important influence of prior relationships on future interactions. The relationship between a university researcher and a company is frequently a series of interactions which must be viewed in a long-term context. The individuals involved in these interactions are key, particularly in the early stages of a relationship. The role they play is akin to those of gatekeepers who mediate the contrasts between scientific academic knowledge on the one hand and technology as it is applied by companies. Allen (1979) highlights the importance of this role in the early stages when the opportunity for a company deriving benefit from a university collaboration needs to be identified by the company. The lack of a suitable gatekeeper in the company may be a limiting factor in identifying how academic expertise may be connected to the needs of a company. Similarly, this Interaction Model describes how these contacts are important in fostering a mutual understanding of the cultures and practises of different types of organisations; such contrasts clearly exist between the missions and values of universities and companies.

The formative influence of entrepreneurial behaviour by the gatekeepers in Knowledge Transfer projects is consistent with the evidence reported by the expert panel on a recent collaborative project on developing enterprising and entrepreneurial graduates (CIHE, NESTA and NCGE, 2008). The report indicated that entrepreneurial activity by academic faculty in US universities benefitted from external relationships with industry, and using these as exemplars in the classroom was crucial to demonstrating the relevance of entrepreneurship in a range of academic disciplines.

11.2 Translating knowledge into application

As well as acting as the agents for introducing the company to the university and vice versa gatekeepers play a key role in the introduction of external knowledge to a company. This is both described in the literature and revealed in the cases. Academic knowledge is expressed in a common language such that scientists, for example, anywhere in the world may communicate with and understand each other when they occupy the same specialism. The use of scholarship to source knowledge for use in a collaboration provides an example of this. However incorporating knowledge into application in a particular business context requires a translation and transformation so that it can be understood and used within a business context. The function of recognising the opportunity to do this, and then engaging company resources is the role of the gatekeeper. Some gatekeepers in the cases studied also linked companies to external organisations through their role on bodies such as research councils and university-industry liaison boards. These may be particularly effective as promoters of interactions with universities where those external organisations (e.g. Research Councils) have an interest in engaging with university research.

11.3 Explicit and tacit knowledge

The form in which knowledge subsists and the properties of that form are significant.

Explicit knowledge is commonly defined in the Knowledge Management literature as being articulated into formal language, including grammatical statements (words and numbers), mathematical expressions, specifications, manuals, etc. Explicit knowledge can be readily transmitted and shared with others.

Tacit knowledge is personal knowledge embedded in individual experience and involves intangible factors, such as personal beliefs, perspective, and the value system. Before tacit knowledge can be communicated, it must be converted into words, models, or numbers that can be understood.

The process of transforming tacit into explicit knowledge is 'codification' – hence the references to 'codified knowledge'. However, there is an inherent difficulty in the use and transfer of tacit knowledge; subject experts rarely know what they know' so that codification in the absence of a specific application for the knowledge and experience may be insufficient to capture the key components for transfer. Furthermore, Polanyi (cited in Grant, 2008) argued that there could be no firm separation between tacit and explicit knowledge; while tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Hence all knowledge is either tacit or rooted in tacit knowledge and Grant (2008) further argues that this is one of the reasons why capture and codification is often insufficient to achieving an effective knowledge sharing process.

11.4 Solution space and problem space

This 'positioning' of the knowledge in either ***'solution space'*** (as a generic capability) or in ***'problem space'*** (against a specific application requirement) is analogous to the variable considerations of use in the Stokes model. It is described here as a positioning[7] phenomenon rather than as a motivational state to emphasise that it requires activity by the gatekeepers to effect the repositioning rather than simply relating to the concept of motivation. It may also require work to achieve outcomes local to specific needs to realise the opportunity for the company. Obtaining company understanding and commitment may require the company gatekeeper to act as a project champion in the company.

If codified academic knowledge is expressed in 'solution space' rather than in the 'problem space' specific to a potential user it will not be effective in transferring the codified knowledge to the user. The case interviews revealed that codified university knowledge is used more by companies to identify researchers of interest rather than as forming the vehicle for knowledge exchange. The different forms of knowledge exchange described in this report makes it clear that the knowledge exchange process is iterative, it involves a variety of forms and requires strong relationships at the level of the individual to ensure full exchange. If tacit knowledge is likely to be required for the use of codified explicit knowledge then the potential user requires access to a possessor of the tacit knowledge which underpins the codified knowledge. This is consistent with the requirements of a patent specification to be workable by someone 'skilled in the art'. Furthermore, if access to tacit knowledge related to company specific technologies, processes or culture is needed to effect this repositioning, then it follows that the interaction between the two gatekeepers is an important component in the conception and formulation of projects.

The comparative attraction of patents drafted by companies over university drafted patents that we detected in some of the cases needs to be understood in this context. They are drafted against company specific application requirements – in other words in 'problem space', rather than to protect non-company specific technology, (i.e. in 'solution space'). Patents also represent the knowledge in explicit form for rapid diffusion through the company. The exceptions arose where the academic inventor was in close contact with, and motivated by, the specific application challenges.

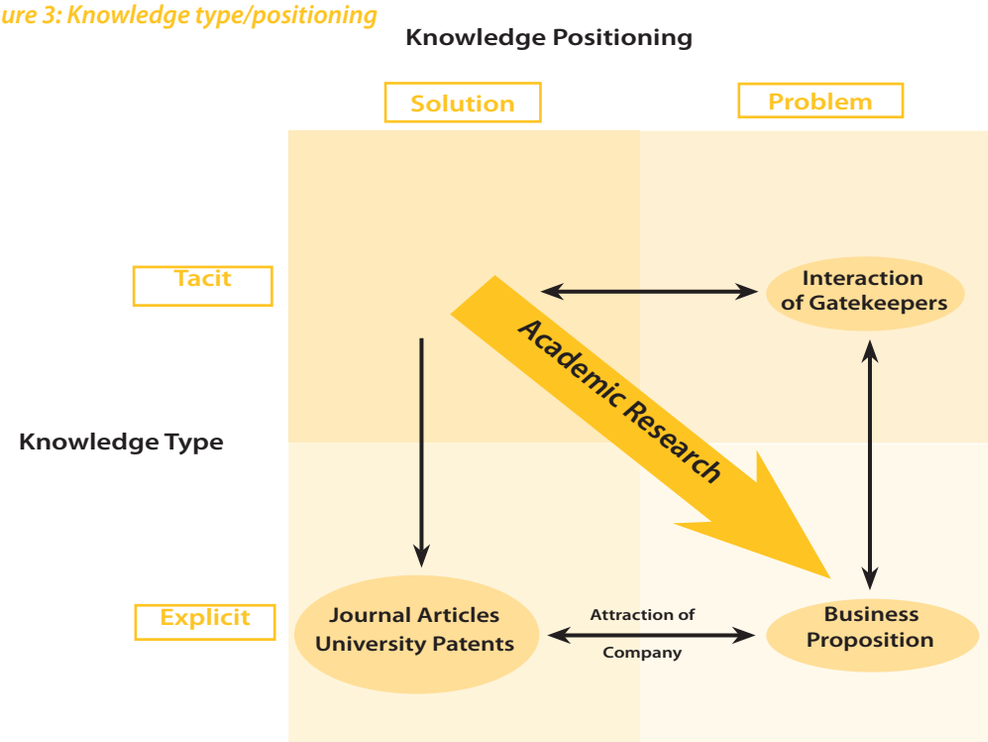
7 (Market) Positioning is the act of intellectually connecting an existing asset (product, capability) with a requirement likely to motivate interest in the mind of a user; (Ries & Trout, 1981, Positioning, Battle for the Mind, McGraw-Hill, New York p5). It is important in the assimilation of a message to connect it to something already actively processed by the recipient – such as an issue of current importance to the company.

11.5 The importance of relationships and interactions

The development of the interaction, formulation and implementation of a project requires access to tacit academic knowledge so that it can be positioned against and then worked to address a company requirement. This requires direct engagement between the academic and the company gatekeeper and explains why the companies interviewed failed to mention university intermediaries as key contacts; key relationships are primarily with the academics concerned.

Conversion of the repositioned tacit knowledge arising from the interaction to explicit knowledge may be necessary for contractual purposes. Because explicit knowledge is capable of rapid replication and transmission, this conversion will aid diffusion within the business and has been observed as one of the functions performed by the company gatekeeper. Where the repositioned explicit knowledge is in a manner framed within the shared tacit knowledge framework[8] of the potential company recipients, it will be more susceptible to voluntary assimilation and interpretation by them. This diffusion may be carried out through formal and informal networks and in both explicit and tacit forms. This also explains the use of company drafted patents arising from university inventions, as such a practise is a potentially more efficient and effective way in which knowledge may be converted for assimilation by the business. Such embedding is not achieved unless the patents actually work by the company. This analysis is presented in the form of a two dimensional analytical framework below:

Figure 3: Knowledge type/positioning



The diagram shows the effect of the interaction as a movement between the top left (tacit/solution) quadrant and the bottom right (explicit/problem) quadrant. However, as the diagram also illustrates, this is mediated through a dialogue which occupies the top right quadrant (tacit/problem) through which the project objectives and modality are formulated and which interacts with the actual performance of the project.

11.6 Absorption and the embedding of knowledge

Active use of the knowledge now available to the company is an important part of the process. Apart from providing feedback to the university on the effectiveness of the project and identifying the need for any amendments on an iterative basis, it is an important part of the embedding process of developing an asset usable by the company because it provides for the development of tacit knowledge specific to the application by the company ('learning by doing'). This is a part of the absorption process deliberately practised by some companies and recognising its importance

8 Grant (2008) describes this as "implicit knowledge" – tacit knowledge which could be made explicit but need not be because it is part of a shared "professional" culture.

may help to differentiate companies in their capacity to absorb and apply knowledge. In the case of Roll-Royce, for example, there is an explicit recognition that knowledge needs to be worked to be localised and absorbed effectively. This factor features strongly in the development of KTP work plans. Deliberate processes to promote absorption and embedding will be important in cases where the university and company staff do not work in close proximity.

These observations allow us to characterise some of the operational components of the ***'absorptive capacity'*** of companies:

- the need for gatekeepers in the company to have a familiarity with universities and their value systems and the willingness and ability to understand and explore the potential of a collaborative interaction, the intellectual capability to understand and assist the repositioning of university knowledge against company requirements, and sufficient status within the company to act as a 'sales coach';
- the willingness within the company to invest time and effort in the localisation and embedding process;
- management having the ambition and perspective to view the engagement with the university as a knowledge and capability opportunity as well as a problem-solving opportunity;
- the company having the internal structural capital to diffuse the acquired intellectual assets throughout the business and recognise other opportunities to exploit them; this includes the acceptance by internal influencers and decision makers that collaboration with university academics and the necessary investment of resources to embed and apply the results is in the interests of the company.

11.7 Explaining the contrasts between the UK and the US

This issue of the differences in absorptive capacity may shed light upon why there may be lower quality interactions between universities and businesses in the UK as against US businesses working with US universities (as discussed in Appendix 1). These differences might reflect a difference in absorptive capacity in UK firms related to both the experience of working with universities, and exposure to qualifications from universities, along with a combination of attitude towards and ability to understand and relate to university academics. Companies need a reason and rationale to develop such a capacity. This observation from our research findings forms the basis of some of the policy initiatives and interventions which may be developed as a result of our analysis.

11.8 The performance of KTPs

Several cases used Knowledge Transfer Partnerships (KTPs), and three in particular were regarded as very successful; an evaluation by these case businesses led to further KTP-based projects. The identification of similar features between KTP projects (in which the features are implicit) and non-KTP projects (in which they are explicitly designed) suggests an approach which is supported by the findings from the literature and the cases. We suggest that success is at least partly due to the following features:

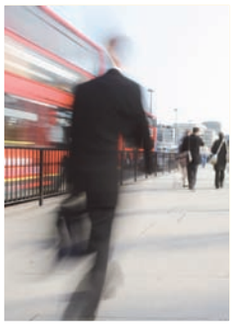
- the choice of mode fosters a relational rather than transactional approach – unlike other 'reach out' activities there is no specific university deliverable, but the intention is to identify and evaluate the opportunity; what is offered is actually a process rather than a product;
- there is a specialist diagnostic/facilitation activity (the Advisor) which can assist in identifying the opportunity in the absence of a well qualified company gatekeeper, and who can encourage the necessary interactions; whilst the advisors may not be specialists in the research domain they are specialists in university–business interactions;
- there is an implicit embedding mechanism which is implicitly well-grounded in sound Knowledge Management principles; the Associate is developed to act as a company gatekeeper and diffuser;
- project plans are developed with deliverables as exemplars reinforcing the perspective on capability development;
- there is an evaluation mechanism which looks for a context sensitive means of identifying value in terms of impact on the company value chain reinforcing the company's investment in the project.

12 Conclusions

In recent years there has been an increasing focus on the role universities play in the economy and impact they make in promoting innovation and raising international competitiveness. But until recently there has been a prescriptive view of university-business interactions with a narrow focus on technology transfer. Although technology transfer may be important, it is also necessary to focus on the more diverse and varied impacts of business-university knowledge exchange relations. A number of key issues have arisen from this and earlier research which questions the conventional wisdom and have implications for policy. This study has shown that:

- Individual universities, and the academics within them, play different and varied roles in national and regional economies; the university's strengths, where it is located, and the business structure in which it is embedded are all important and interdependent.
- Technology transfer is only one aspect of the knowledge exchange process and in the cases in this study their role is relatively minor; this study's findings stress the interdependent and evolutionary nature of interactions.
- There are multiple knowledge exchange mechanisms; the most important of these involve people.
- Knowledge exchange is not easy; it may be costly, difficult to implement and take a long time to succeed and these issues may be particularly difficult for small and medium-sized enterprises.
- There are many potential barriers to collaborations, such as the lack of knowledge about potential partners and about possibilities for mutual interaction.
- 'Gatekeeping' is an important activity and the way that the gatekeeping role is designed and filled is a vital one. Individuals or groups playing this role need to fully understand and have experience of both the academic and business environments as well as the skills to overcome barriers and foster relationships.
- Aligning the interests of businesses and academics can be problematic and requires mutual understanding and trust; this takes time to develop.
- Modes of interaction and project objectives are most likely to yield economic and social benefits if they are co-determined and they co-evolve; in some cases it is the ***co-creation*** or knowledge or the ***co-fostering*** of solutions that adds most value and reflects the respective strengths of the players.
- Academics are valued for their specialist expertise and, in general, they are not considered as a means of expanding a company's own internal capacity; in some cases it is the wider complementary capabilities which may range from providing 'thought leadership' and management science to continuing professional development that are of value.

The current policy agenda increasingly recognises that the transfer of technology from the research base, a focus on STEM graduates, support for technology transfer offices in universities and the use of instruments (such as tax credits) that seek to encourage R&D is too narrow. This study reinforces recent moves to encourage a wider view on how universities and businesses together influence innovation and business performance. It also stresses that some of the greatest challenges in broadening the knowledge exchange policy agenda concern absorbing and embedding knowledge across businesses.



13 CIHE Policy Recommendations

The CIHE is a policy influencing partnership and accordingly **recommends that DIUS, the Funding Councils, the Technology Strategy Board (TSB) and the Research Councils (RCUK) should take this report and its conclusions into account in the development of this agenda and should reflect the report's insights in future policy developments.**

Our conclusions have been reviewed against the policy context and recommendations set out in the DIUS White Paper '*Innovation Nation*' and our findings have particular relevance for the development of many of the themes in the White Paper.

Our study supports the conclusions set out in the White Paper on the importance of a demand-led approach to extracting research value, and the complexity of the knowledge exchange process. But we go further in stressing that ***economic and social impact is more likely to result from collaboration*** than from the adoption of a simple demand and supply approach. We also emphasise the variety and emergent nature of many of the interactions and the breadth of knowledge exchange which goes well beyond science and technology. In the recommendations below some of the policies in the White Paper are further developed. In particular we stress the importance of the gatekeeping role in identifying and developing opportunities for knowledge exchange. We also note that policies and practices need to consider how businesses can be encouraged to increase their internal knowledge exchange and absorptive capacity. Innovation is a function of skills, management aspiration and business repositioning as well as knowledge exchange.

Implications and CIHE Recommendations:

For DIUS and the Technology Strategy Board apropos businesses and intermediaries, we affirm that the different ways that businesses at different stages in their evolution can benefit from interacting with a university should be taken into account in the development of policies to support and promote these interactions. Such policies, including those which seek to stimulate innovation in small companies through public procurement, should recognise that their success will depend on the capacity of companies and their ability to respond. Hence policies in DIUS and programmes at the Technology Strategy Board should develop opportunities whereby such absorptive capacity in firms can be encouraged.

Rationale: There are a number of different ways that knowledge can be exchanged. These range from student placements and projects through to formal research collaborations. Some of these (such as KTPs, mini KTPs, Eng.D's, and collaborative research) may be supported by formal products managed by the Technology Strategy Board (TSB), the Research Councils and the Regional Development Agencies (RDAs). Our findings suggest that the ways in which organisations may benefit from these products depends on the capability and capacity of the organisation. This will depend in turn on the stage of a organisation's evolution, the nature of the business and the awareness of management of the products and services that a university or college might be able to offer. Independent and university gatekeepers can only help an organisation if they in turn are better aware of these opportunities and products from public agencies.

Recommendations in the White Paper also seek to stimulate innovation in small companies via procurement programmes, e.g. through the redeveloped Small Business Research Initiative (SBRI). But the R&D capability of small companies may limit their ability to respond. The experience of the SBIR/STTR procurement programmes in the US that support university/business collaboration may be of particular relevance to develop appropriate policy solutions procurement practices in the UK (see Ternouth, 2007).

Implications and CIHE Recommendations:

For DIUS, the Funding Councils and RCUK apropos Universities we affirm that policies to encourage universities to work with businesses should stress the *relational* rather than the *transactional* aspects. They should reflect the breadth of the types of interactions and the ways in which they evolve, are formulated, implemented and assessed. They should encourage the development of the *'public space'* activities of universities in creating and developing relationships, the critical nature of the gatekeeping roles as described in this report and the opportunity to improve university-business relationships through better aligning the roles of the various 'boundary-spanners' inside universities.

Rationale: There is often a trade-off between the simplicity and transparency needed for policy metrics and instruments and the complexity of the processes that such metrics are attempting to measure and such policies are attempting to influence. Current policies and metrics mainly reflect a linear model of technology transfer. This contrasts with the ways in which many productive interactions emerge and are formulated through interactions which often arise through the ***'public space'*** activities of universities. This project has increased our understanding of the processes which create value from the links businesses have with universities through the research value chain. As the HEIF funding framework has moved towards a formulaic approach to funding, universities have the opportunity to use these findings to better stimulate productive interactions with business and evaluate the outcomes. As they evolve their interactions and approach they will want to align the activities of all the stakeholders involved in this process of generating value so that a more holistic approach is developed. Formulaic funding works best when there is an improved market understanding on how value is most likely to be added and through having the appropriate processes in place. We hope that this project and this report will help improve the evidence base and contribute to better informed policy.

Appendix 1

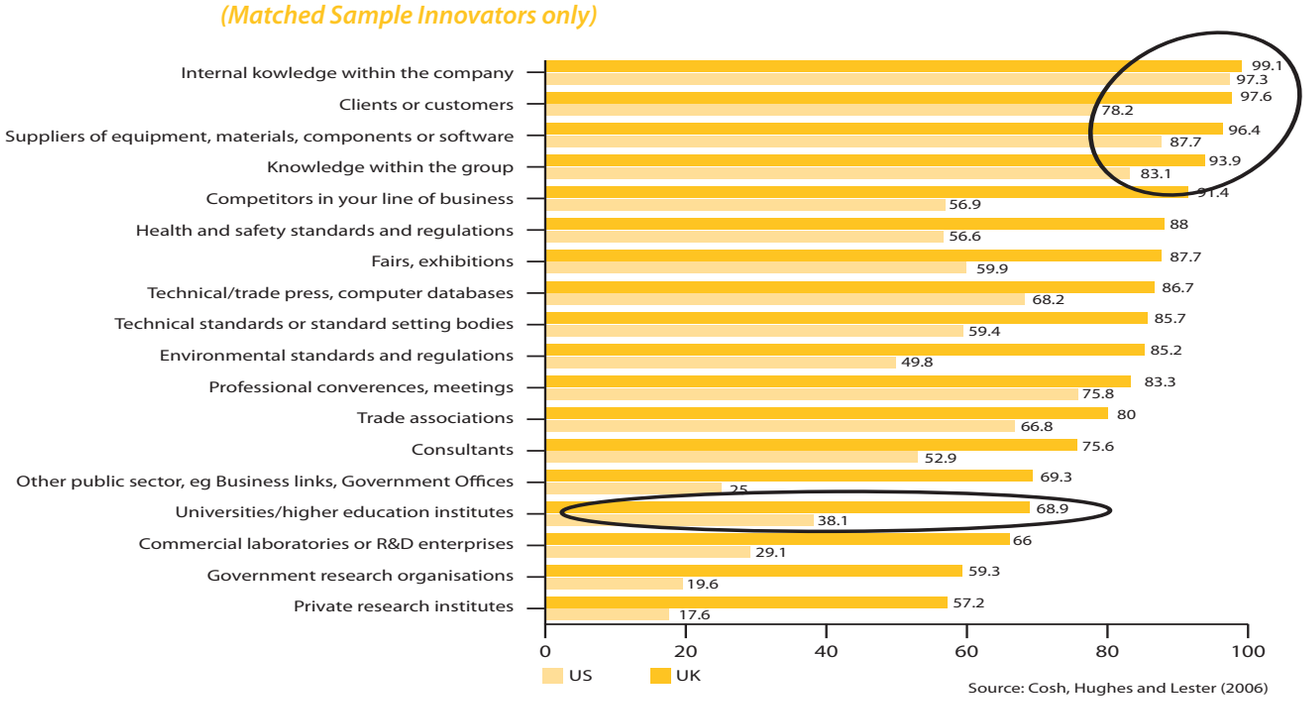
University-business knowledge exchange: a UK-US comparison

We discuss here the findings from the only study to date (Cosh et al, 2006) which allows direct comparison with the United States and is often cited as an exemplar to which the UK might aspire[9]. This study is based on the UK-US Innovation Benchmarking (IB) Survey, conducted by the Centre for Business Research (CBR) of the University of Cambridge and the Industrial Performance Center (IPC) of MIT. It includes responses from over 3500 UK and US 'innovative' firms of all sizes in manufacturing and business services. In the results reported here we focus on innovative companies only and within that group on 1,149 US companies and 1,149 UK companies matched by size and sector and focus on innovative companies only. This allows us to avoid potentially misleading results which may emerge from using grossed up data for both countries which are known to differ both in industrial sector composition, size distribution of firms and patterns of innovation frequency.

1.1 Universities - one of many components in the innovation ecosystem

If we measure the incidence of use of a source of knowledge for innovation in terms of the percentage of firms reporting use of that source it is clear that universities are low on the list in both the UK and the USA. Even so over 40 per cent of 'innovative' UK companies report using universities as a knowledge source and this proportion is far higher in the UK than the USA - contrary to much conventional wisdom. Figure A1.1 shows that in both countries internal business knowledge is the most frequent source of knowledge. This is followed by knowledge drawn from those company sources most likely to be intimately involved in innovation developments within a business namely its customers and suppliers. The IB and other studies show that smaller firms and service based firms are less likely than other to access university knowledge sources in both the UK and USA. Given those factors, rather less is known about forces operating at the individual firm level which predispose them towards the use of universities. Identifying these is an important task. Since our case discussions all involve industry university knowledge exchanges we attempt therefore to identify the characteristics of the business or innovation activity that led to the use of universities as a knowledge source.

Figure A1.1: Use of Sources of Knowledge for Innovation in the UK and the US: All Companies % (Matched Sample Innovators only)



Source: Cosh, Hughes and Lester (2006)

9 For a critical assessment of the lessons which might and might not be learned from the USA see Pavitt (2004) and Hughes (2008).

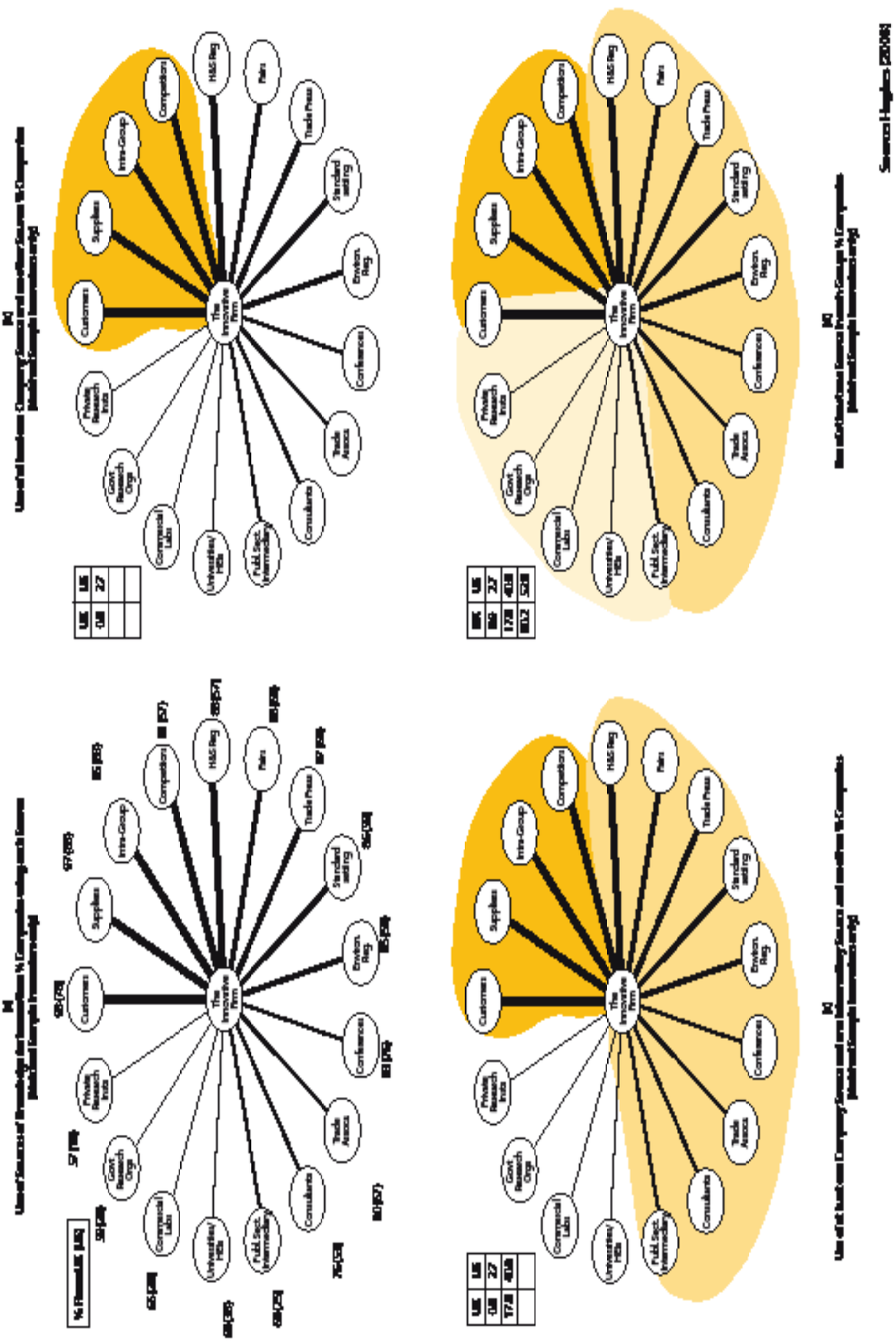


Figure A1.2: Combined Use of Sources of Knowledge for Innovation (Matched Sample of Innovators only)

1.2 Universities and the research base are often accessed in combination with other sources of knowledge

The sources of knowledge for innovation can be grouped into three broad categories corresponding to the business sector, intermediary institutions and a broader definition of the research base, wherein the latter we include universities, government and private research institutes and commercial laboratories. We can then identify how many firms rely solely on the business group how many rely on at lest one business source and one intermediary source and how many use at least one source from each group. This categorisation, as shown in Figures A1.2 (a-d), reveals an interesting picture in which few firms rely on corporate sources alone even though they are individually the most frequent set of sources used. What is clearly revealed when comparing the UK and the USA is that in the UK a much higher proportion report using sources in all three groups. This is shown in the box in the top left hand corner of figure A1.2 (d) which shows that over 80% of UK companies used all three source groups compared to only 52% of US companies. The use of multiple sources of knowledge raises important questions about the ways in which the knowledge flows from disparate sources can be effectively combined and acted upon in innovation related activities inside the firm. In our case studies we pay particular attention to problems which might arise in terms of boundary spanning between the domains of university and internal business sources of knowledge. We also look at the way in which potential university knowledge sources are identified and the processes and resources committed at the business end in translating the knowledge exchanged into forms suitable to meet the organisational commercial or technical objectives of the knowledge exchange

1.3 The importance of universities as a source of knowledge for innovation

This wider spread of use of university and other knowledge sources in the UK appears to be associated with a lower value placed upon them in the UK compared with the US. This is particularly apparent in relation to research base sources. Figure A1.3 reports the relative frequency of reporting a knowledge source as having high importance from a business point of view. The shorter the bar the lower the relative UK score compared to the US. The knowledge base is clearly the least valued in relative terms in the UK. Figure A1.4 shows that this effect is common across all industries including business services although the gap is lower in the latter. The IB study also shows that small firms, in particular, lag behind their US counterparts in the importance they attach to university-business linkages (Cosh et al, 2006), a finding which is echoed in other more qualitative investigations (Lambert, 2003; Brown and Ternouth, 2006). In focusing our case studies on examples of success we examine those factors which predispose businesses to place a high value on knowledge base interactions and to locate them in the wider knowledge source activities in which the case firms are involved.

Figure A1.3: Sources of Knowledge for Innovation regarded as Highly Important by Users of that Source: % UK Companies Relative to the US (Matched Sample Innovators only)

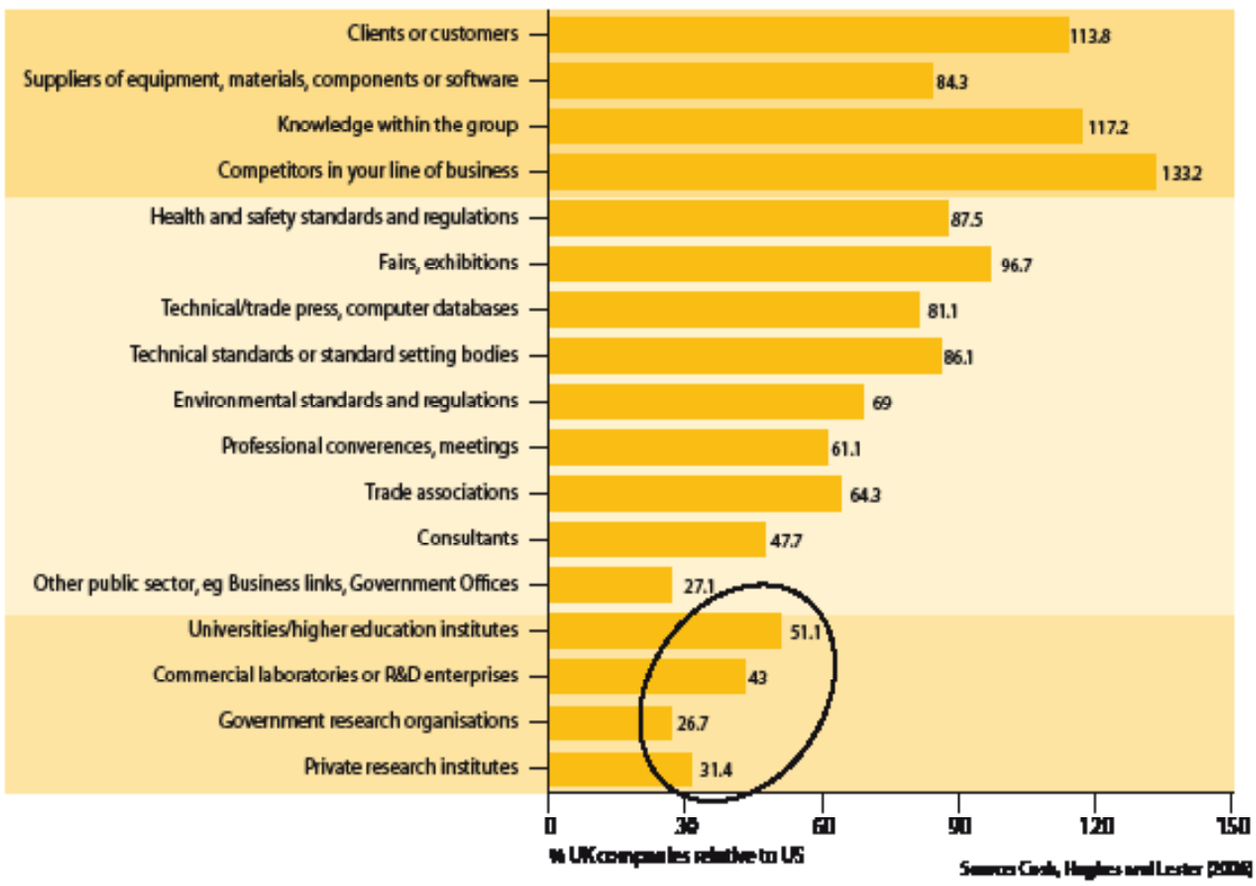
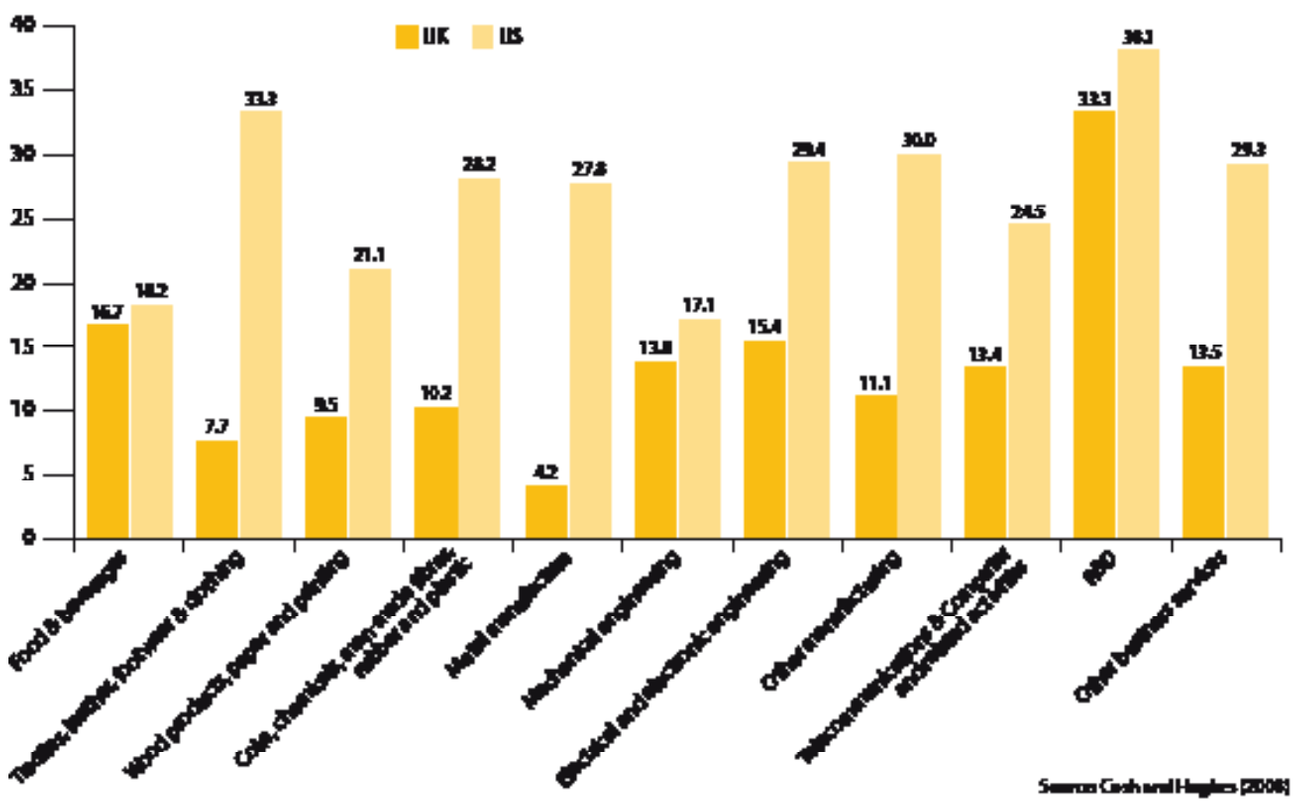


Figure A1.4: Users of Universities as a Source of Knowledge rating them as highly important (Matched Sample Innovators only)



1.4 The diversity of modes of university business knowledge exchange

The CBR data can also be used to analyse which modes of interaction characterise those university-industry links which do occur. This shows, as illustrated in Figure A1.5, a wide variety of modes through which knowledge exchange activity affects innovative performance in businesses (Cosh, Hughes and Lester, 2006). Such modes include not only those that are commonly cited in recent policy debates, such as spin-outs and patents, but also a wider range of interactions including informal contacts, publications, conferences, graduate recruitment, internships, joint research projects, problem solving and consulting by university staff, testing and standard-setting, participation in networks, access to public space for cross-sector engagement.

Figure A1.5: Types of University Industry Interaction Contributing to Innovation (% Companies) (Matched Sample Innovators only)

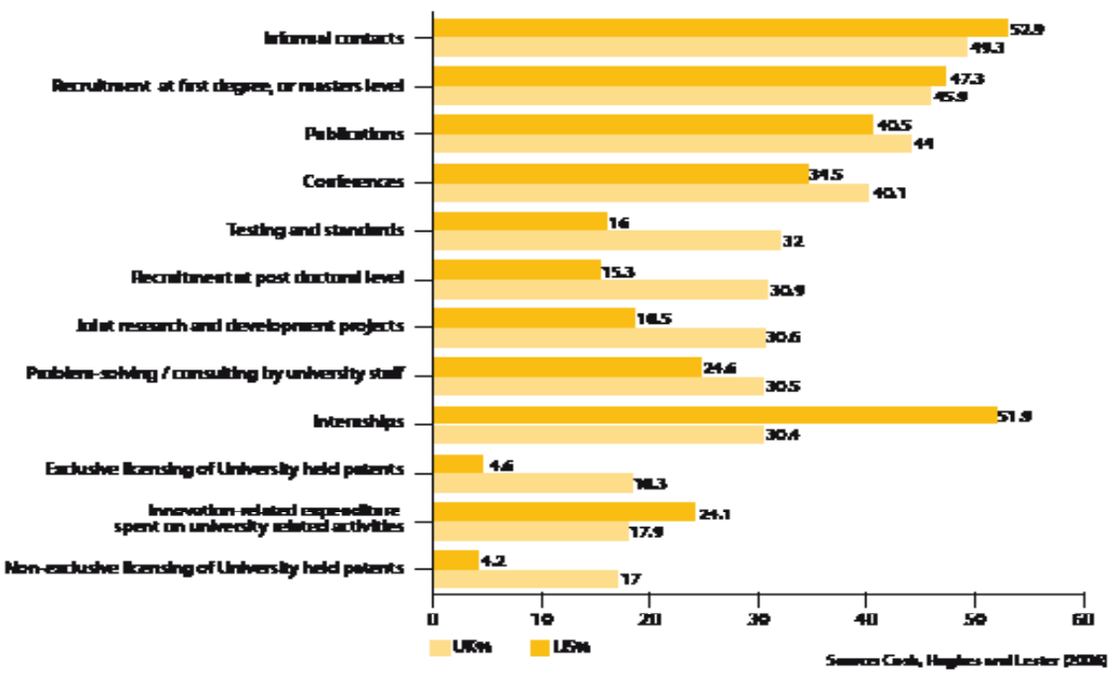
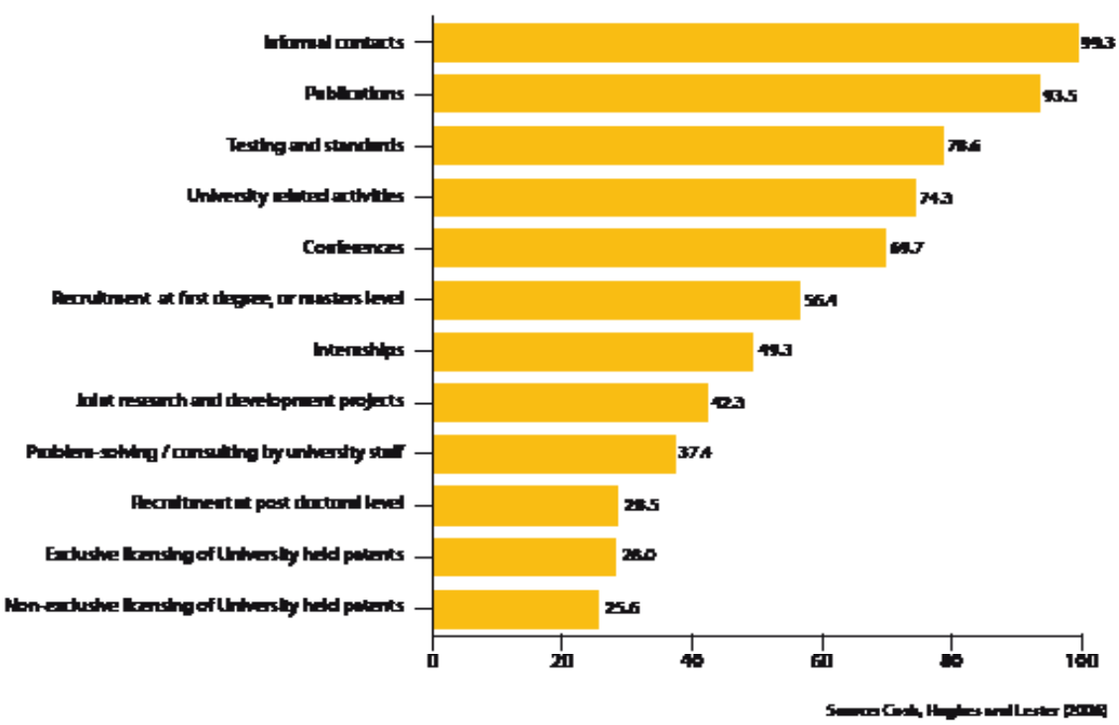


Figure A1.6: University Industry Interactions regarded as highly important for Innovation: % of UK Companies relative to US (Matched Sample Innovators only)



The results indicate a broadly similar pattern of university-business linkages in the UK and the US, with informal contacts being the most frequently cited followed by what may be regarded as conventional interactions involving recruiting graduates, using publications, and attending conferences. Licensing and patenting are among the least frequently cited interactions that contribute to innovative activity. Figure A1.6 shows that although UK and US firms are similar in the importance they attach to informal contacts and publications, in the UK they typically place less importance on graduate recruitment, joint publications problem-solving and licensing. The patterns, and the importance attached to particular modes of interaction may however, vary by industry, size and life cycle of the business, and the form of production process.

Moreover, if we look across the experience of other countries it is clear that the impact of various modes of interaction on business value added, and regional and national economic performance varies with the point in the value creation chain of the business and the location of its activities (Gambardello and Malerba, 1999; Adams and Smith, 2004; Malerba, 2005; Mowery and Sampat, 2005; Asheim and Gertler, 2005; Brown and Ternouth, 2006). A central task for our case studies is to identify factors determining the choice of mode, the extent to which multiple modes are followed. We also look at the factors affecting the success of different modes and ask how, if at all, businesses evaluate the success of the modes they use in terms of meeting their objectives.

Appendix 2

Conceptualising basic and applied research

It is often argued that there is a tension between the desire to carry out research in the quest for fundamental understanding and the desire to carry out research driven by specific considerations of actual or potential use. This broad distinction is embedded in conventional classificatory schema, such as the Frascati Manual, (OECD, 2002) for collecting and organising data on research efforts which as the following definitions show use considerations of use as a key factor separating basic research from applied research and experimental development.

- "Basic Research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, *without any particular application or use in view*" (our italics)

- "Experimental Development is systematic work, drawing on knowledge gained from research and practical experience that is directed to producing new materials, products or devices, to installing new processes, systems and services; or to improving substantially those already produced or installed."

- "Applied research is also original investigation undertaken in order to acquire new knowledge. It is … directed primarily towards a specific practical aim or objective."

Source: (OECD, 2002)

In framing our analysis of these issues we draw on the work of Stokes (1997). He argued on the basis of an examination of the process of scientific investigation in several disciplines, and in biology and medicine in particular, that the basic versus applied distinction was fundamentally inaccurate. In particular he showed that there was a dynamic iteration between considerations of use and fundamental understanding within the conduct of science itself and in addition to any specific request for mission driven or applied research made by business or government. His well known quadrant representation plots combinations of research motivated by consideration of use (Edison) or fundamental understanding (Bohr) or both (Pasteur).

In our version in Figure A2.1 we plot columns the relative heights of which indicate the balance of research and development resource commitments across quadrants. Depending on the sector or technology the relative heights of the vertical columns may vary cross quadrants. Thus in more mature technologies the Edison and Pasteur columns could dominate whereas in newly emerging research based areas the Bohr and Pasteur columns could be dominant. The arrows indicate that knowledge flows must, can, and do circle across the quadrant boundaries. The extent to which these boundary spanning flows involve university industry interactions is an empirical matter that we address in our case studies whilst recognising the iterative process by which technological knowledge fundamental understanding and applied research develop.

Figure A2.1 Spanning quadrant boundaries

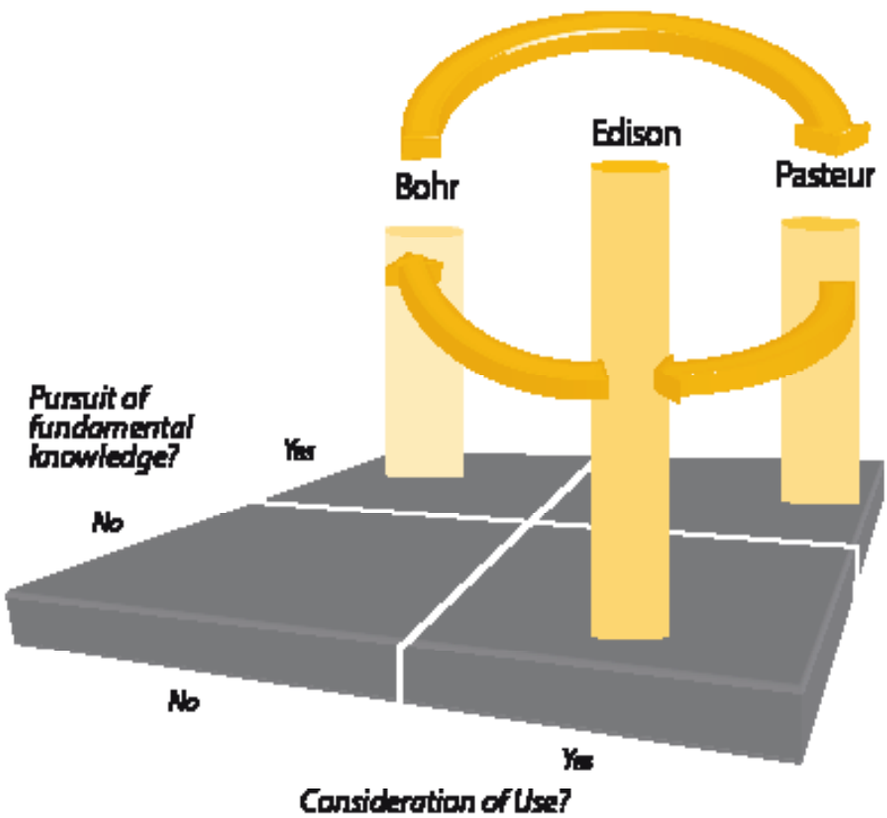
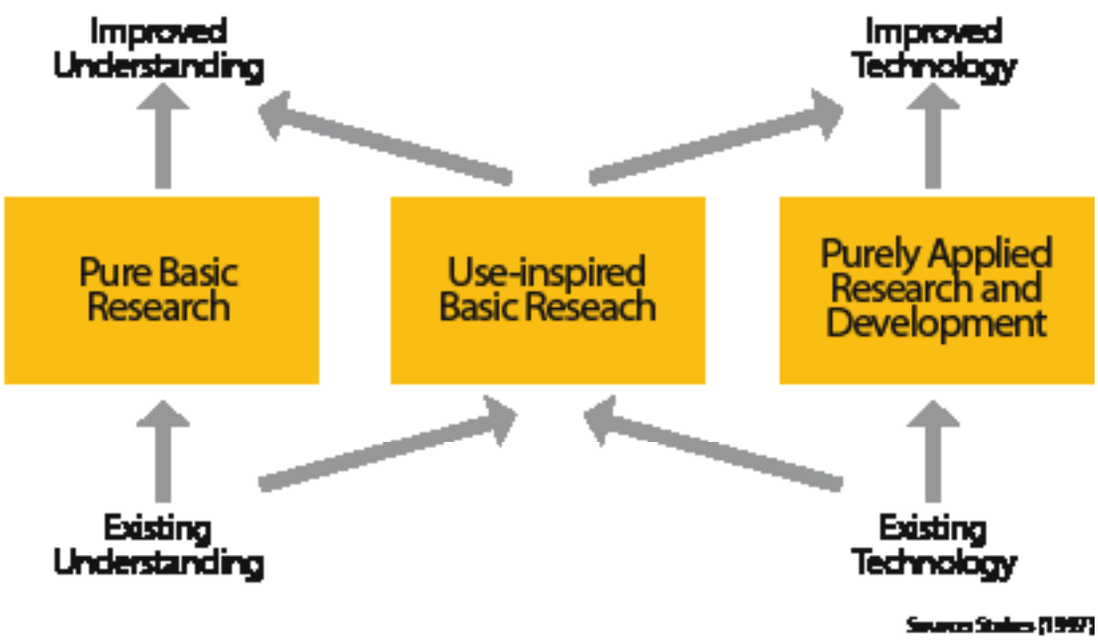


Figure A2.2 reproduces a version of Stokes's less often cited diagram which presents his dynamic view of this interplay. Seen in terms of this schematic diagram in each of our cases the stage at which the mode of interaction occurs will already have embedded in it a past pattern of development between basic and applied research and technological knowledge. It will itself contribute to further iterations. The cases may then be best understood in terms of episodes within a continuing process of knowledge development for the firms.

Figure A2.2 Stokes's Dynamic Model



Appendix 3

Proforma questionnaire for semi–structured interviews

About knowledge exchange activities:

1. Is the company involved in any form of knowledge exchange with HEIs (related to either humanities or sciences or both)?
2. In relation to various mechanisms of knowledge exchange which might be available to your company (see below), please comment on:

- actual and potential opportunities;
- motivations and objectives;
- the relative importance and choice of a particular instrument;
- measure of success used; and
- impact on the company's innovative activities and financial indicators.

Does geography matter? Is this list of mechanisms exhaustive?

Modes of Knowledge Exchange with HEIs:

People	Recruitment
	Personnel Exchanges and internships
	Studentships
Codified Knowledge	Publications
	Patents
	Prototypes
Problem Solving Contract Research	Joint R&D Projects
	Consortia
	Consulting by University Staff
	Testing, Standards, access to specialised equipment
	Non exclusive and/or exclusive licensing
Public Space	Meetings and Conferences
	Standard setting fora
	Entrepreneurship Centers
	Networks
	Joint Curriculum Development
	Committees
	Informal Contacts
	Invited Lectures
	Brainstorming Sessions
Other	Collaborations with University Spin Outs
	Contact with Intermediaries or Boundary Spanning Organisations

About Key Example Case - ideally to be volunteered by company based on e.g. perceived value

- How was the requirement to interact with a university identified? If the opportunity resulted from initial contact with a university, how did this occur (e.g. web search, existing contact, contact from university, networking events, conference)? What alternatives were considered?
- What were the origins of the knowledge transferred and how would it / they be classified? (See classification – draft attached)
- Was this part of a sequence of activities with the university or a single self-contained project?

- What internal justification in the company was needed to work with the university?
- How did the negotiations to set up the project proceed? How were the negotiations managed and, where there was a financial component (e.g. a research sponsorship, licence agreement) what was your perception of how the university approached this? What were the perceptions of value on each side and how were they assessed? Were there any issues arising in the negotiations and how were they resolved?
- What transactions need to occur to support and give legal effect to the project KT (e.g. IP licensing)?
- How did the project proceed, i.e. what was the nature of the interaction (e.g. academic working in a company, work done in university with results transferred via report)?
- By what mechanism did the knowledge transferred become embedded in the company?
- What was the nature of the embedding (e.g. certain key individuals with new skills and knowledge)?
- How did the company know that this had occurred?
- What did the company need to do subsequently to realise the potential value generated by the project?
- What was the nature of the impact upon the company value chain (i.e. direct contribution of technology to product development, manufacturing or logistics process, upskilling / increasing knowledge of staff, service development)? How easy is it to identify?
- What was the nature and scale of the outcome (e.g. increased sales, new market, faster to market, more efficient process) and how was it evaluated?
- Has this project affected the company's potential to collaborate with universities?

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